Empirical Investigation and Analysis of Various Factors Responsible for Sustainable Development of Electric Vehicles Manufacturing in India

THESIS

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by

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......dedicated

to my father

Late. Dr. Ashok Rastogi......

Birla Institute of Technology & Science, Pilani
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CERTIFICATE

This is to certify that the thesis entitled **"Empirical Investigation and Analysis of Various Factors Responsible for Sustainable Development of Electric Vehicles Manufacturing in India"** submitted by **Arpit Rastogi,** ID.No. **2016PHXF0108P** for award of Ph.D. degree of the Institute embodies original work done by him under my supervision.

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Abstract

The Continuous growth of Indian economy and living standards show that the transportation sector is important for improving the lives of people. However, with growth, responsibilities also come for meeting the associated challenges of fast depletion of conventional energy sources, rising energy cost, increasing oil import bill and the impact of mobility on the health and the environment. To mitigate these severe issues, the government of India is highly intended to develop an environmentally sustainable and economically viable solution i.e., electric vehicles (EVs) as an alternate solution and developed the plan for faster adoption and manufacturing of EVs. At present, very slow progress has been observed in the adoption and development of EVs in India. Studies in the past focused on one or more factors affecting the adoption of EVs. However, studies offering confirmatory evidences are lacking. Moreover, studies exploring factors responsible for sustainable development of EVs in the Indian context are very few. Therefore, there is a need to identify more responsible factors and their relationship and to develop the roadmap for achieving the targets. The present study developed a comprehensive framework through integrated DEMATEL-ISM approach, which evaluates the factors affecting the adoption and sustainable development of EVs manufacturing in India.

Present work, also demonstrated the findings by conducting the field study in capital of India, Delhi in which study analysed the social factors responsible for the growth of electric vehicles in India. A questionnaire has been developed for understanding the customer's perception towards EVs deployment. The results of the survey are analysed using structural equation model (SEM). The results of the study were based on three hypotheses. The findings showed that financial and the infrastructure factors have positive impact on rate of adoption of EVs in India, whereas the vehicle performance factors have a negative impact on EVs adoption, implying that the vehicle performance factors are the most imperative have a more passive mind-set towards the electric vehicles adoption.

Findings of the present study will be useful to the manufacturer, decision and policy makers to focus on the grey area so that they can expedite the growth of EVs in India.

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Symbol/Abbreviation	Description
AC	Academics
BEH	Behavioural
BEVs	Battery Electric Vehicles
CAGR	Compound Annual Growth Rate
CFFVs	Conventional Fossil Fueled Vehicles
CO_2	Carbon Dioxide
CUL	Cultural
DCAAI	Development Council for Automobile and Allied Industry
DEMATEL	Decision Making Trial and Evaluation Laboratory
DHI	Department of Heavy Industries
E-2Ws	Electric Two Wheelers
E-3Ws	Electric Three Wheelers
E-4Ws	Electric Four Wheeler and Passenger Cars
E-Bus	Electric Buses
ECO	Economic
EE	Environment Experts
EESL	Energy Efficiency Services Limited
ENG	Engineering
ENV	Environmental
EVs	Electric Vehicles
FAME-India	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India
GDP	Gross Domestic Product
GEO	Geographical
GEP	Geo-political
GoI	Government of India
HEVs	Hybrid Electric Vehicles
ICE	Internal Combustion Engine
IE	Industry Experts
IEA	International Energy Agency
INF	Infrastructural

Symbol/Abbreviation	Description
INV	Investors
ISM	Interpretive Structural Modeling
KMO	Kaiser-Meyer-Olkin
MCDM	Multi Criteria Decision Making
NAASQ	National Ambient Air Quality Standards
NBEM	National Board for Electric Mobility
NCR	National Capital Region
NEMMP 2020	National Electric Mobility Mission Plan 2020
NGOs	Non-Government Organizations
OEMs	Original Equipment Manufacturers
PHEVs	Plug-in Hybrid Electric Vehicles
POL	Political
R&D	Research and Development
RII	Relative Importance Index
SEM	Structural Equation Model
SEO	Socio-economic
SIAM	Society of Indian Automobile Manufacturers
SOC	Social
SOT	Socio-technical
SPSS	Statistical Package for the Social Sciences
SSIM	Structual Self Interaction Matrix
TEC	Technological
V2G	Vehicle-to-Grid
xEVs	Electric and Hybrid Vehicles

This chapter provides an overview, research motivation, objectives of the study, methodology, significance of the study and thesis organization.

1.1 Introduction

Today, India is rapidly rising in the transportation sector. As a result, urban traffic congestion, health and air quality worsen in the cities. The transport sector contributed around 27% of CO_2 emission as the dominant vehicle technology is based on fossil fuel (Davis et al., 2010). To tackle these challenges, The Government of India (GOI) has developed the National Electric Mobility Mission Plan-2020 (NEMMP-2020) with the aspiration of replacement of fossil fuel based vehicles with faster deployment of electric vehicles (EVs) on Indian roads (Saxena et al., 2014). The pace of the investments and R&D in this sector is now gaining momentum. Many researchers addressed the issues such as demand incentives, power infrastructure, charging infrastructure and battery technology for EVs. In addition, some studies are focusing on technical and infrastructural factors essential for deployment of EVs successfully in major cities. But, they have ignored the urban and rural population in their studies. Therefore, there is a need to consider the urban and rural population along with various geographical, economic, environmental, social, political and legal factors as well into account for the design, development, validation and to expedite the sustainable growth of EVs in India (Adepetu & Keshav, 2017).

Governments all across the world, including the China, United States, Norway, Japan, France, Germany, Sweden, and the Netherlands are pushing these evolving alternative technology vehicles. Efforts are being made around the world to promote the use of EVs through various forms of incentives, infrastructure development, and public awareness. Figenbaum, (2017) has given a multi-level perspective framework and explained the dynamics of policy framework for Norway which has achieved more than 20% market share of EVs (Berkeley et al., 2017). Lai et al., (2015) have prepared a model depicting the impact of specs, prices and incentives on sales of different personal and business EVs in Macau. Peters et al., (2018) have analysed eight different motivations for adoption of EVs by the people of Netherlands with the help of hypothesis testing. She et al., (2017) identified barriers to widespread adoption of EVs in China and have ranked them through descriptive statistics. Finally, they have used hypothesis testing to understand the customer's perception towards the barriers. Today, China accounts for more than 50% of the total EV sales (International Energy Agency, 2021). S. Yang et al., (2018) used factor analysis for finding out the customer behaviour for the EVs and on the basis of the results; suggestions were given for cultivation of the EVs market in China. Palmer et al., (2018) performed the assessment of total cost of ownership of conventional, hybrid, plug-in hybrid and the battery EVs in three different countries i.e. USA, UK and Japan and the variation has been analysed from 1997 to 2015 with respect to the market share. Regression analysis was used for establishing connection between adoption rates and the government policies in these countries (Chen et al., 2020).

Findings witnessed a fundamental shift in how governments around the world tackle energy-related environmental challenges in recent years (Jensen et al., 2013). As energy accounts for two-thirds of total greenhouse gas emissions resulting in 80% of total CO_2 generation and India is ranked third in per capita CO_2 emissions from fossil fuel combustion worldwide, promoting sustainable development and combating climate change have become integral aspects of energy planning, analysis, and policy making (Nejat et al., 2015). To reduce the emissions and mitigate climate change, the GOI has developed NEMMP-2020 for faster adoption and manufacturing alternative fuel technology vehicles i.e. hybrid EVs. Based on the study and stakeholders' recommendations, the GOI has taken this initiative on a national mission mode with an objective upbringing the growth of EVs in India (Department of Heavy Industry, 2013). Therefore, many practitioners, suppliers and manufacturers came forward and started focusing on demand incentives, power infrastructure, charging infrastructure and battery technology for EVs (Digalwar & Giridhar, 2015). Some studies recommended installing charging stations in top six cities of India, where the pollution level is very high. The studies also suggested amending existing electricity rules so that the challenges faced by private sector companies in installing charging stations may be removed. As per the studies, the concept of shared mobility and EVs in captive fleets are to be promoted (Srikanth, 2018). Very few studies are available which focuses on identification of sustainability factors for deployment of EVs in India. Also, these studies are mainly focused on metropolitan and major cities while the urban and rural areas of India where issues and challenges are entirely different, are ignored in the existing studies.

The present research work will focus on the identification and analysis of sustainability factors for manufacturing and successful deployment of EVs including urban and rural areas of India.

1.2 **Overview of EVs Industry**

The automotive industry is one of the largest industries globally and because of its deep forward and backward linkages with rest of the industry; it has a strong multiplier effect and is one of the major drivers for economic growth of the country. With the gradual liberalization of the automobile sector in India since 1991, the number of manufacturing facilities has grown progressively (Kumaraswamy et al., 2012). The Indian automotive industry produces a wide variety of vehicles: passenger cars, light, medium and heavy commercial vehicles, multi-utility vehicles such as jeeps, two wheelers that include scooters, motor- cycles and mopeds, three wheelers, tractors and other agricultural equipment. The Indian automobile industry is dominated by two wheelers, which account for 75% of the total vehicles sold in the country. In the passenger car segment, India has a small car market (Miglani, 2019)(SESEI E-Mobility, 2018).

In view of the huge potential of the automotive sector, the GOI jointly with Department of Heavy Industry under Ministry of Heavy Industries and Public Enterprises launched NEMMP-2020. For meeting ambitious targets Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME-India). This scheme was launched under NEMMP-2020, unveiled in 2013.

The scheme aimed to encourage progressive induction of reliable, affordable and efficient electric and hybrid vehicles (xEVs). The First Phase of the scheme was initially approved for a period of two years, commencing from 1st April, 2015. The Scheme has been extended from time to time, with the last extension allowed for a period up to 31st March 2019 (Office Memorandum, 2019).

Later in 2019, the GOI approved Phase-II of FAME-India Scheme with an outlay of Rs. 10,000 Crore for a period of 3 years commencing from 1st April 2019. Out of total budgetary support, about 86% of fund has been allocated for demand incentive so as to create demand for EVs in the country. This phase aims to generate demand by way of supporting 7000 electric buses (e-bus), 55000 electric four wheeler and passenger cars (e-4Ws), 5,00,000 electric three wheelers (e-3Ws), and 10,00,000 electric two wheelers (e-2Ws). However, depending upon off-take of different category of xEVs, these numbers may vary as the provision has been made for inter as well as intra segment wise fungibility. In addition, creation of charging infrastructure will also be supported under the scheme (FAME II Policy Document, 2019).

As per international energy agency (IEA) report, world energy outlook published in 2009, fossil fuel based transportation is the second largest source of CO_2 emissions globally. From 2006 to 2030, the global energy consumption is likely to rise by 53% and about three quarters of the projected increase in oil demand will come from transportation (Outlook, 2009). Therefore, the Government will need to focus on this sector and partner with industry for investing in sustainable mobility solutions for the future.

1.3 **Research Motivation**

The automobile industry has been undergoing a revolution for nearly a century. The rise in the price of fossil fuels, as well as the impact of their emissions on the environment has prompted a shift in individual mobility habits (Maev et al., 2021). Alternative vehicle technologies, such as full electric mobility have become popular in last decade. Whenever a new technology is launched, it certainly encounters new obstacles. It is therefore important to understand its impact on stakeholders. China, UK and USA have already established strategic plans for electric mobility, focusing potential consumers and their preferences.

Early adopters have already begun to accept EVs and governments of various countries are also investing to adopt them into their fleets, but they are still not the first choice of consumer at large. There is a need to understand various factors responsible for social acceptability and sustainability of EVs manufacturing. To bridge this gap, the present study identifies the various factors responsible for sustainable development 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 GOI could benefit in its goal to achieve its ambitious target projected in the FAME-India scheme.

1.4 **Objectives of the Study**

The aim of the present study is “Empirical Investigation and Analysis of Various Factors Responsible for Sustainable Development of Electric Vehicles Manufacturing in India”.

The objectives of this study are:

- To identify the factors responsible for the sustainable development of EVs manufacturing in India.
- To develop an inter-relationship between the identified factors to understand the cause and effect of each factor.
- To propose a framework of the reliable and valid factors for the sustainable development of EVs manufacturing in India.

1.5 **Methodology**

To achieve the objectives of the proposed research, the following activities are carried out:

- A thorough assessment of literature on status of EVs in India and across the world is done to identify various factors responsible for adoption of EVs and their sustainable manufacturing in India.
- A questionnaire is constructed containing no. of variables affecting the adoption and sustainable manufacturing of EVs in India, which is then pre-tested and validated by a panel of experts before being distributed.
- Finally, the effectiveness of identified factors and variables is analyzed by conducting a survey, in which a total of 902 responses are collected.
- The responses collected from the survey are assessed through descriptive analysis followed by an importance index analysis of identified factors as well as variables under each factor.
- The shortlisted factors are then categorized as casual and effect factors using decision making trial and evaluation laboratory (DEMATEL).
- The reliability and validity analysis of the results obtained from descriptive analysis and importance index analysis is performed using cronbach’s alpha method and conformity factor analysis.

- An inter-relationship among the factors is established using DEMATEL-MCDM technique and the inter-relationship among the factors, suggested an ISM model, which provides a roadmap for sustainable development of EVs manufacturing in India.

The above methodology is extensively discussed in the subsequence chapters of the thesis.

1.6 **Significance of the Study**

This study aims to develop and validate the factors affecting the sustainable development of EVs manufacturing in India that could be used by original equipment manufacturers (OEMs) and service providers in the EVs industry. Based on a thorough synthesis of the literature on EVs, twelve factors affecting sustainable manufacturing of EVs and corresponding 80 variables have been developed. The validated set of factors and their variables affecting the sustainable development of EVs manufacturing may be useful for OEMs, service providers and new players keen on enter the EVs market to assess the potential areas of development in the EVs industry. Insights gained from this evaluation may be helpful for EV engineers in incorporating customers' purchase intention into the engineering design. The validated results are in the Indian context; however, the instrument developed can be used in the global context as well.

1.7 **Organization of the Thesis**

To achieve the above set objectives, the thesis covers a total of seven chapters as shown in **Figure 1-1**. Chapter 1 presents, introduction of topic, objectives of the study, methodology adopted for the proposed research work and its significance. Chapter 2 contains, identification of 12 factors affecting the adoption of EVs and sustainable development of their manufacturing through literature review of the contribution given by other researchers. Chapter 3 presents, theoretical justification of identified factors and generation of 80 variables thereafter. Chapter 4 discusses the research methodology including questionnaire design, data administration process and descriptive analysis. Chapter 5 presents, reliability and validity assessment for the validation of factors through Interpretive Structural Modelling (ISM). A framework of factors is also proposed in this chapter. Chapter 6 presents a case study to find out the impact of social factors on adoption of EVs. Finally, chapter 7 concludes the research clearly stating its limitation and future scope.

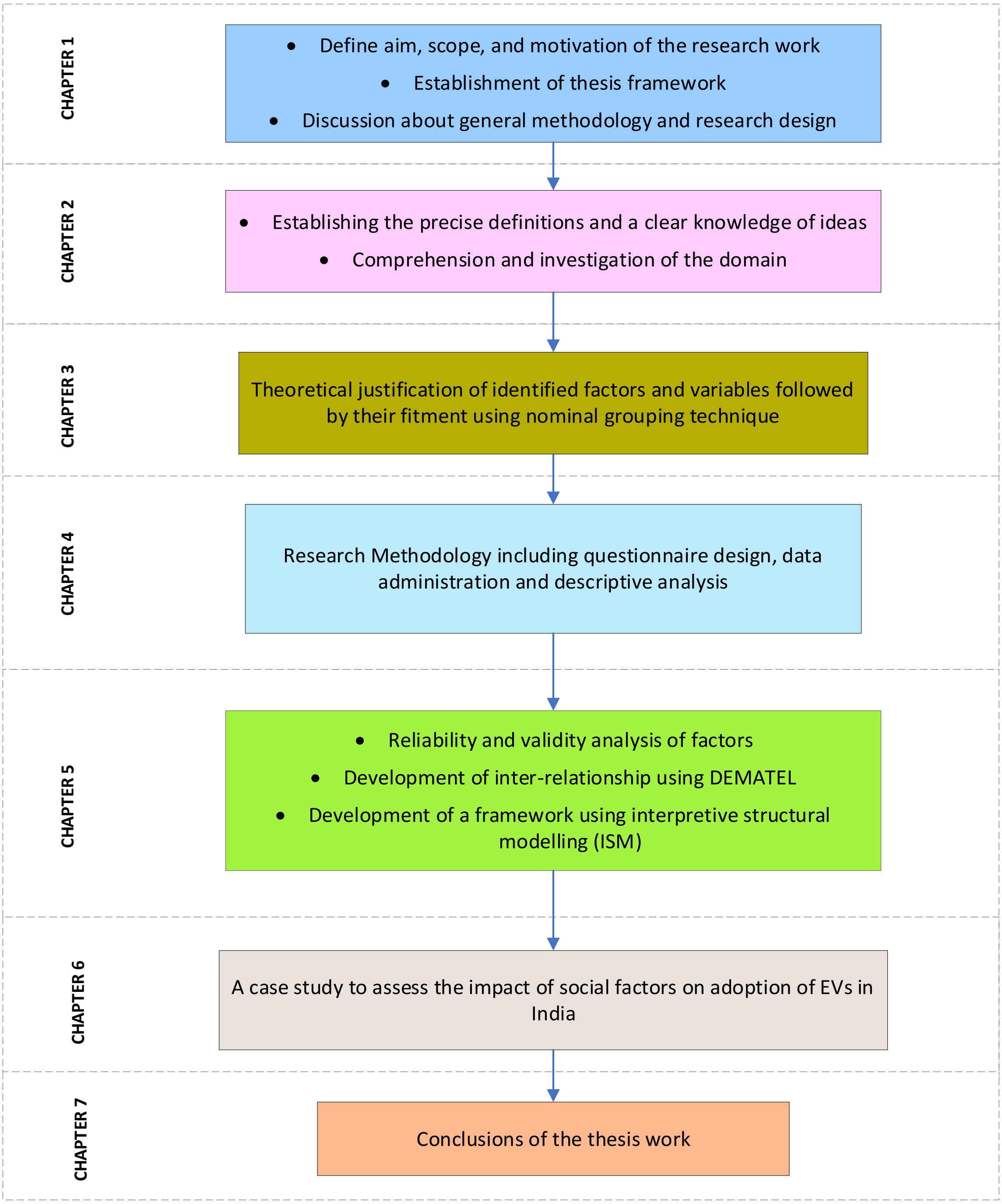

Figure 1-1 Organization of thesis

Chapter 2 **LITERATURE REVIEW**

This chapter presents a meta-analysis of literature relevant to the study and thereby identification and assessment of factors influencing the adoption and sustainable development of EVs manufacturing. Talking about various government policies, the chapter also presents a comparison of current status of EVs from Indian and global perspectives.

2.1 **Review Methodology**

The most crucial task in any literature review is finding the relevant material - defining proper search criteria, looking for potential research publications, and analysing them to see if they fall within the scope of study. After that, distribution metrics based on subject, publication year, region of study, and technique used etc. can be examined (Snyder, 2019).

Articles can be found in online scholarly databases, which are an excellent and efficient source of information. Emerald Insight, Inderscience, Taylor and Francis, ScienceDirect, Scopus, Google Scholars, Sage, and Springer databases are few examples of such databases. To discover the articles, relevant to our study, the present work employed a two-step technique as shown in **Figure 2-1**. The first step was to use above mentioned search engines to find research publications. The current study focuses on studies published after 2010, with keywords such as EVs, EV charging stations, social factors, descriptive statistics, structural equation model, content validation, reliability analysis, factor analysis, DEMATEL, and ISM, resulting in the identification of 2700 research studies. After dismissing 2200 studies because of their titles, a total of 500 studies were chosen for further investigation. Post examining their abstracts, 250 research publications were neglected and remaining 250 research publications were selected for further processing.

The second step was to go through the 250 research publications for identification of factors that influence the adoption of EVs and their manufacturing. The emphasis was on research studies that demonstrated the rationale for buyers' willingness to accept EVs. In addition, 20 research publications that did not focus on influencing factors were excluded, while 10 others were excluded owing to a lack of descriptive statistics on customer behaviour. 5 more research publications were rejected because studies on EVs' sales, EVs' market share, and EVs' social impact could not accurately reflect the customer perception. Further omitting 5 more research publications due to irrelevant text, shrined our database to a total of 210 papers in the final list as shown in Figure 2-1.

Figure 2-1 Review methodology

2.2 Meta-analysis of the literature

In this section of the study, a simple meta-analysis is performed to provide descriptive information on research publications considered for study. Present study analyzed 210 articles to identify factors, methodology used and validation technique used by several researchers. The research publications were further categorized on the basis of types of article, publication outlet, publication year, country, data analysis methodology and factors.

2.2.1 **Distribution of articles based on its types and publication outlet**

Figure 2-2 shows that 85% of the publications are research articles, 10% are presented at conference proceedings and 5% are review articles.

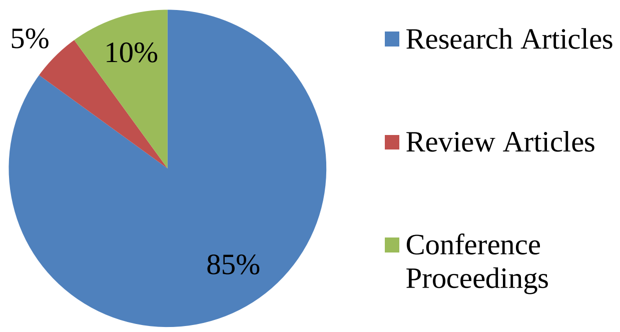

Figure 2-2 Distribution based on type of article

Figure 2-3 shows that transportation sector receives the greatest number of articles (42%), followed by energy sector (22%), and environmental science sector (15%), as shown in**Figure 2-3**. Other subject matters, broadly considered in review and their contributions are business management sector (10%), social science sector (6%), economy sector (3%) and decision science sector (2%) respectively.

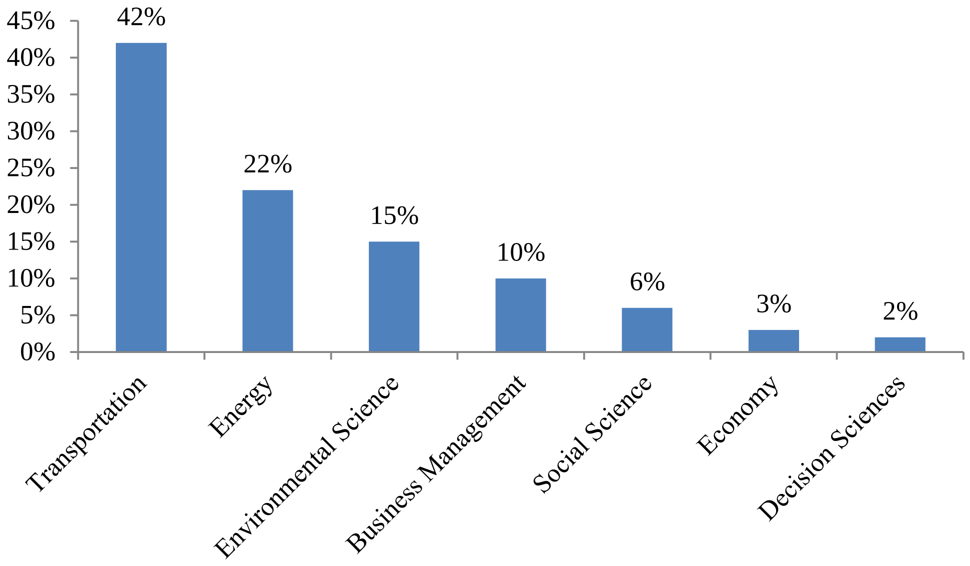

Figure 2-3 Subject wise distribution of articles

2.2.2 **Distribution of articles based on publication year**

Figure 2-4 shows a yearly distribution of articles published from 2011 to 2019. As previously stated, the percentage of articles published each year appears to be increasing. During the years 2011–2013, only a few academics focused on the factors influencing the adoption of EVs. From 2014 to 2015, there was a gradual growth. However, in 2016–2019, this field experienced a significant growth which is nearly, double to that of prior years. It is clear that this upward trend will aid in the global adoption of EVs.

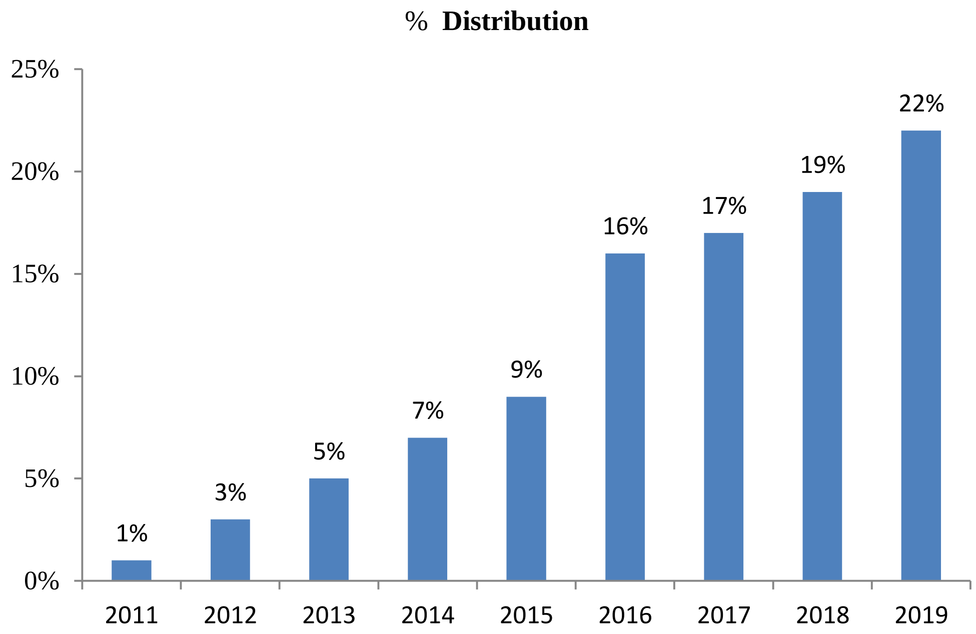

Figure 2-4 Distribution of articles based on publishing year

2.2.3 **Distribution of articles based on country of study**

Researchers from a various country have contributed to the study of factors influencing the adoption of EVs. China has the highest percentage of articles (19%) followed by the United States (17%), Germany (7%), United Kingdom (7%), and Netherlands (7%). Researchers from Sweden (6%), Norway (6%), and Denmark, Malaysia, Korea, Italy (4% each), and several others, have also submitted their findings on the issue as indicated in Figure 2-5.

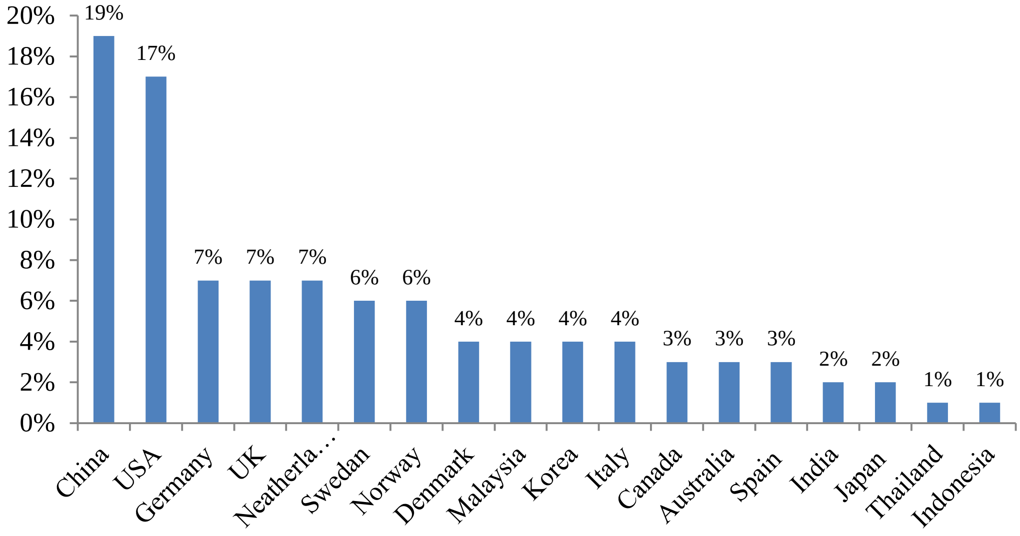

Figure 2-5 Distribution of articles based on country of study

2.2.4 **Distribution of articles based on data analysis methodology**

Regression analysis (42), structural equation model (39), factor analysis (29), descriptive statistics (25), Statistical Package for the Social Sciences (SPSS) (17), fuzzy techniques (17), interpretive structure modeling (14) were found to be employed in selected research articles, according to the meta-analysis as shown in Figure 2-6. MCDM techniques (12), hypothesis testing (8), path analysis (4) and DEMATEL (3) were also found to be effective in predicting customer willingness to adopt EVs.

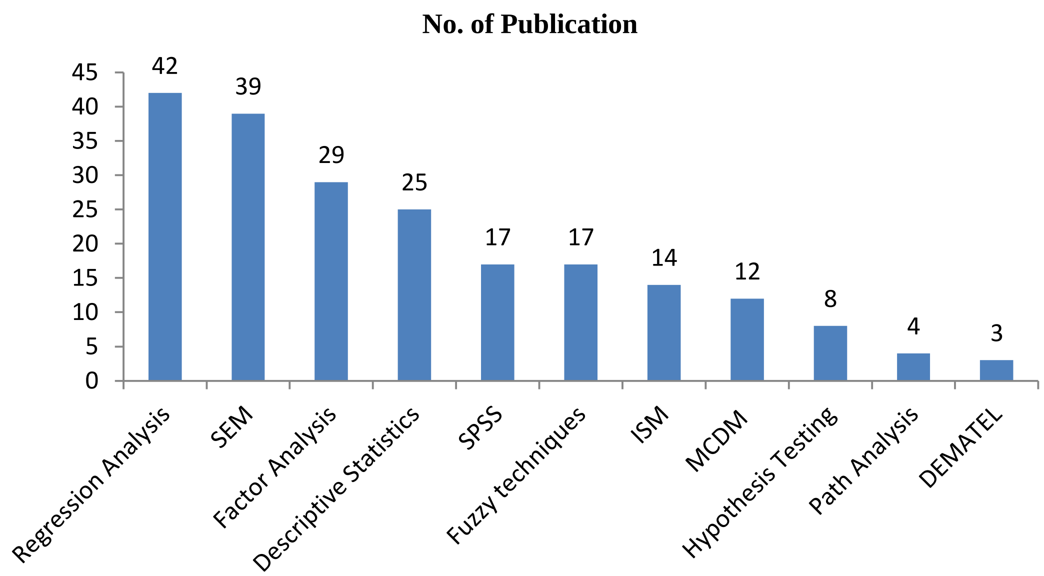

Figure 2-6 Distribution of articles based on data analysis methodology

2.2.5 **Distribution of articles based on factors affecting adoption of EVs**

According to a meta-analysis of research articles, the environmental factors (37) are the most frequently studied factors followed by social (35), technological factor (33), economic (32), infrastructural (29), political (22), behavioral (20), cultural (11), socio-technical (10), geographical (9), geo-political (5), socio-cultural (5) as shown in Figure 2-7.

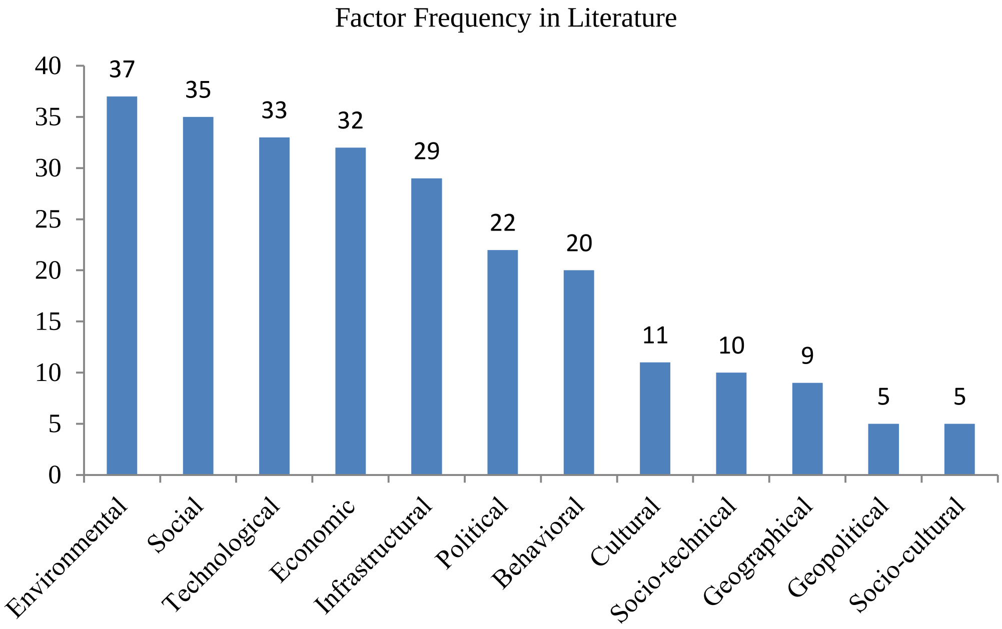

Figure 2-7 Distribution of articles based on factors affecting adoption of EVs

This study conducted a comprehensive literature review of 210 research publications on various aspects that influence the adoption of EVs. In contrast to previous similar review studies, such as Daramy-Williams et al., (2019) analyzed 75 research articles, Gnann, Stephens, et al., (2018) analyzed 40 research articles, and Adnan et al., (2017) analyzed 48 research articles only, our study provides more thorough information with a larger number of articles compared to the past studies. The findings revealed 12 major factors responsible for adoption of EVs and their interrelationships.

Further a total of 80 decision variables were also identified. The identified factors were broad and did not apply to an individual, as a result the variables and their inter-relationships are more logically drawn in relevance with the adoption of EVs in this study.

2.3 **Contribution of various studies on EVs**

Various research papers and articles are referred to find different elements for the sustainability assessment of EVs Manufacturing. According to the literature review, despite the on-going efforts and research performed around the world, there are several impediments to the commercial acceptance of EVs. The societal aspects that influence adoption of EVs are still a problem that needs to be addressed (Malmgren, 2016). She et al., (2017) conducted a similar study in a Chinese city and discovered that instate of people recognizing the relevance of EVs and wish them to be pushed, they still have limited interest in adopting them and have a wait and watch like attitude due to several concerns viz. primarily safety, dependability, and range. The Chinese people believe that the policies should be expanded and more subsidies should be provided to enhance the adoption rate. ISM was used by Digalwar & Giridhar, (2015) to prioritize the barriers to EVs, and they discovered that awareness and government commitment are the barriers with the highest driving force and hence must be addressed first. Other constraints, such as industry expansion, supplier and customer management and battery technology are highly dependent on the other barriers and will be overcome automatically if the other barriers are resolved. Westin et al., (2018) studied EVs adoption in Sweden and discovered that most people accept EVs because they are socially active, while some are motivated by environmental concerns and personal conventions. Both attitudes and adoption encourage customers to engage in pro-environmental activity and allow them to brag about their choice. Their findings show that social impact is very important in the adoption of eco-innovations. Axsen et al., (2013) investigated consumer views in the United Kingdom that how social influence can alter these beliefs. They worked on societal elements that are divided into three categories: diffusion, translation and reflexivity, with translation receiving the highest rating, followed by reflexivity and diffusion. Park et al., (2018) investigated social aspects and discovered that EVs drivers are quite satisfied with their driving experience. However, the cost of maintenance and purchase is a significant barrier for them so the deployments plans must take into account both user experiences and economic factors. Zheng et al., (2018) investigated how to make production decisions and government subsidies that maximize societal welfare. The report finds that government policies should consider both customers and manufacturers.

The literature review summarizes the factors or indicators which are recently being used in the previous studies. The study also analysed the importance and effectiveness of indicators on the performance of EV adoption and satisfaction. The recent literature is summarized in the following section.

Financial incentives and other socio-economic factors influence the adoption of EVs, according to Sierzchula et al., (2014). Financial incentives and infrastructure were shown to be the most important motivators of EVs uptake in a study of 30 countries. Income and education were not significant socio-demographic variables. D. Kim et al., (2015) studied the feasibility and success rate of EVs sharing programs by understanding the users' attitude towards car ownership. Participants' social and economic viewpoints were the most crucial factors influencing their attitudes, according to their research. Furthermore, sentiments differed based on personal variables including gender, age and income. Holland et al., (2016) looked at the short-term environmental benefits of electric mobility by comparing the pollution caused by gasoline vehicles against charging EVs. The results from the study showcased that ignoring local pollution leads to over-estimation of the environmental benefits of EVs. The results suggested that a full life cycle assessment on the environmental effects of EVs needs to be conducted.

Haustein & Jensen, (2018) compared the conventional and EVs users based on an expanded theory of planned behaviour to understand the factors affecting EVs adoption in Denmark and Sweden. They studied the socio-demographic profiles of the users to understand the usage pattern. According to their findings, battery EVs owners are mostly people who are well-educated, earn a lot of money and own multiple cars. Lin & Wu, (2018) studied the first-tier cities in China to understand the purchase intention of EVs. Their study focused on demographic and attitudinal factors. The demographic factors under consideration were gender, income level, age, marital status, education level, and geography whereas the attitudinal factors were network externality, performance, price acceptability, government subsidies, usage cost, charging infrastructure and concerns about smog. The study analysed the factors and provided suggestions for the effective growth of EVs.

Chu et al., (2019) investigated the psychological and behavioural aspects that influence the adoption and enjoyment of EVs in China. The major factors that they considered were environmental concern, consumer innovation, self-assessed knowledge of EVs, image related to EV usage, range satisfaction, and user satisfaction. Results of their study show that environmental concern is the most important determinant in EV adoption in China. The role of policies in overcoming hurdles to electric car uptake in the EU was investigated by Statharas et al., (2019). The results show the policy dilemmas that exist between adopting stringent standards and infrastructure to promote technology and market development and its adverse effect on cost. In Denmark, Finland, Iceland, Norway, and Sweden, (Chen et al., 2020) looked at the socio-demographic, technical, economic, and behavioural aspects that influence electric car adoption. Fuel economy, financial savings, and environmental values were the best indicators of the successful deployment of EVs in the region, according to their findings.

Mukherjee & Ryan, (2020) studied the factors affecting the early adoption of battery EVs in Ireland. According to their findings, adults with a university degree and long-distance commuters are favourable predictors of adoption, but young people aged 19 to 34 are negative predictors. Adopters are mostly clustered in Ireland's largest urban hubs, according to the spatial econometric study. (Zhuge & Shao, 2019) focused on the economic factors affecting the adoption of EVs in Beijing, namely upfront cost and usage-related cost and analysed the Beijing EVs market from the year 2016 to 2020 using a simulation model based on what-if scenarios. The results suggest that doubling the subsidies on EVs would make them price competitive. Results also show that electricity and petrol price had little influence on the adoption of EVs at the macro level.

2.3.1 **Status of EVs in India**

Increasing level of air pollution in Indian cities has been a cause of concern for policy makers. More than 25 Indian cities are within the 100 most polluted cities in the World. The problem of growing air pollution in cities is due to a variety of sources however transport sector makes significant contribution. Therefore, it is important to minimize the emissions from transport sector (Agency, 2019). In India, e-3Ws have been partly successful, however not much diffusion of EVs has happened within e-2Ws, e-4Ws and city bus fleets. Techno-economic assessments however show that e-2Ws are now gradually becoming commercially viable and e-4Ws can be a major technology option by 2030, if government provides incentives and charging infrastructure (Das & Deb, 2020). The government is keen on promoting EVs and the Minister of Power has even put an ambitious goal of becoming 100% electric by 2030. The other ministries, particularly Minister of Road Transport and Highways, made a strong statement at Society of Indian Automobile Manufacturers (SIAM) annual convention that has excited the automotive industry (Shearer et al., 2017).

Under the NEMMP-2020, a plan was set up to ensure saving on transportation fuel in coming years through initiation of NEMMP-2020. The plan called for achieving 6-7 million electric/hybrid vehicles in India by the year 2020 along with milestones for indigenization of technology, thereby ensuring India's global leadership in electric mobility segment (Anumita Roychowdhury, 2021). A total cumulative outlay of about Rs. 14,000 Crore has been planned during the span of the scheme, including contribution from the Industry.

In addition, the NEMMP-2020 also called for-

- Demand side incentives to facilitate adoption of hybrid/ EVs which was later accelerated through FAME-India scheme.
- Promoting R&D in technologies such as battery technology, power electronics, motors, systems integration, battery management system, testing infrastructure through participation of industry, academia and all other stakeholders to promote indigenization and achieving technology breakthrough for cost reduction.
- Promoting charging infrastructure to instill consumer confidence thereby creating necessary infrastructure.
- Providing supply side incentives.
- Encouraging retro-fitment of on-road vehicles with hybrid kit.

In order to create a sustainable ecosystem for adoption of Hybrid/Electric cars and their Manufacturing, Indian government identified four areas where necessary financial push are being provided by the government through initiation of FAME-India scheme. These four areas are technology development, charging infrastructure, pilot projects and demand creation (Ernst and Young LLP, 2019). A total outlay of 795 crores has been disbursed among the four identified areas for the period 2015-2017. Such funds are available to users/ stakeholders in smart cities notified by Indian Government under the smart city mission, north eastern states, state capitals, cities having more than million population, and Metros of NCR Delhi, Ahmedabad, Chennai, Bangalore, Kolkata, Greater Mumbai and Hyderabad (Smart Cities, 2015). Department of Heavy Industries (DHI) under Ministry of Heavy Industries & Public Enterprises, the GOI had been entrusted with the responsibility for successful implementation of this scheme and allocation of funds between different focus areas (PIB, 2019), with National Board for Electric Mobility (NBEM) and Development Council for Automobile and Allied Industry (DCAAI) overseeing the scheme. Several Pilot projects such as development of public charging infrastructure, development of new battery technologies, testing infrastructure for certification of EVs, sponsoring electric buses for various cities etc. have been initiated under the scheme through an implementation and sanctioning committee (Aijaz, 2021).

Table 2-1 Phase wise execution of electric mobility

Phase I (2017-2019)	**Phase II (2020-2024)**	**Phase III (2025-2032)**
➢ Implementing phase for Solutions which are already economic and scalable and cultivating solutions for phase II which are nearly economic. ➢ Lighthouse (test) cases to be taken up	➢ Implementing solutions cultivated in Phase I ➢ Ground work by private and public sector for future and complete mobility ➢ Lighthouse (test) cases to be taken up	➢ All spectrum of mobility implemented based on learning from previous phases and lighthouse cases
Focus: on Projects and States	**Focus:** on States and region	**Focus:** on entire nation as whole
Major Activities		
➢ Compile and share data ➢ Refine existing policies and incentives and suggest new policies ➢ Create Infra to support EV ➢ Mobility oriented development and Modal Integration	➢ Develop more policies and create shift from Government led to market led development ➢ Integrate Modes and region ➢ Increase domestic supply and improve supply chain management	➢ Phase out subsidy

Indian think tank, Niti Aayog along with Rocky Mountain Institute, USA has come up with a mobility transformation concept in May 2017, wherein India intends to leapfrog from private ownership and fuel based mobility to a new mobility paradigm which is shared, connected and electric (NITI Aayog, 2019). The roadmap of such transformation from ownership based approach to user ship based approach is proposed through a three phase activities of system integration. Further such transformation is expected to be achieved in three phases spread over a period of 15years from 2017 to 2032 as shown in Table 2-1.

The central government on its part is leaving no chance in underscoring its intention to move to EVs. As a number of government departments such as Ministry of Power, Ministry of New and Renewable Energy, Ministry of Road Transport and Highways, Ministry of Heavy Industries and Public Enterprises etc. are responsible for anchoring the transition from conventional to electric mobility. The GOI has shifted the EVs programme from the Department of Heavy Industries (DHI) to government's premier think tank Niti Aayog. This move is expected to help synchronize efforts of the different departments of the government to move the nation towards electric mobility by 2030 (Juyal et al., 2018).

Therefore, to fulfill their commitments, the GOI is highly intended for the development of EVs (EVs), hybrid EVs (HEV), and plug-in hybrid EVs (PHEV) in India. The government launched a prolonged strategy, targeting for both the manufacturers and as well as the buyers, these are briefly discussed in the following points (Niti Aayog, 2021).

- Initially, the GOI sanctioned an amount of $140 million for the development of the EV market in India with the combined aims of (i) subsidizing the EVs to attract buyers, and (ii) motivating the domestic manufacturer by importing heavy taxes on imported components.

- Secondly, on 14th December 2018, the GOI has released a document on the development of EV charging infrastructure that complied with the guidelines and instructions about the development and establishment of charging stations infrastructure at every 25 km distance along the highways or roads.

- Energy Efficiency Services Limited (EESL) procuring 10,000 no. of EVs for government departments with a substantial reduction in the cost of vehicles.

- NEMMP-2020: The program was launched by the GOI in 2012 with an aim to promote hybrid and EVs for the national fuel security as well as to increase the GDP share of automobile manufacturing industries from 22% to 25% by the year 2022.

- FAME-India Scheme: The scheme was launched as a part of the NEMMP-2020 to provide incentives for purchasing EVs which is being extended in phases viz, phase-I from 2015-19, and phase-II from 2019-22. The GOI, under FAME-India scheme has offered a subsidy of Rs.1800 to Rs.29,000 for electric 2-wheelers, and Rs.1.38 lac for electric 4-wheelers.

- GO Electric Campaign: The scheme was launched at the starting of the year 2021, to promote environment-friendly, economically viable, and indigenous electric mobility vehicles and cooking appliances.

The EV market in India has gained significant momentum after the implementation of FAME-India scheme. The total EV sales in 2018 hit 365,920 Units and expected to grow at a CAGR of 36% till 2026. The EV battery market in India is estimated to be US$ 520 Million in 2018 and forecasted to grow at a CAGR of 30% till 2026. The total MWh addition in 2018 hit 4.75 GWh and expected to grow till 28.0 GWh by 2026. (IESA, 2020)

2.3.2 **Status of EVs in other countries**

After a decade of strong expansion, the worldwide electric car stock reached ten million units in 2020, a 43% increase over 2019 and a 1% stock share. In 2020, two-thirds of new electric car registrations and two-thirds of the stock were battery EVs (BEVs). China had the largest fleet, with 4.5 million EVs; however, Europe had the largest annual rise, reaching 3.2 million in 2020 (Fredriksson et al., 2018).

The economic consequences of the Covid-19 pandemic had a profound impact on the global market for all types of automobiles. New car registrations fell by roughly a third in the first half of 2020 compared to the previous year. Stronger activity in the second half somewhat countered this, resulting in a 16% year-over-year reduction. Despite the fact that conventional and overall new automobile registrations are declining, global electric car sales share increased by 70% to a record 4.6% in 2020 (IEA, 2020).

In 2020, around 3 million new electric automobiles will be registered. With 1.4 million new registrations, Europe took the lead for the first time. China came in second with 1.2 million registrations, followed by the United States with 295000 new EVs. EVs registrations grew in 2020 due to a variety of factors.

In particular, on a total cost of ownership basis, electric cars are increasingly becoming more competitive in several countries. Several governments granted or extended fiscal incentives to help electric car buyers weather the market downturn.

China

The epidemic had a smaller influence on China's entire car market than it had on other regions. The total number of new car registrations fell by around 9%.

In the first half of 2020, new electric car registrations were lower than the general car market. This tendency shifted in the second half of the year, when China managed to contain the pandemic. The outcome was a 5.7% sales share, up from 4.8% in 2019. Around 80% of new EVs registered were BEVs (Rommel & Sagebiel, 2021).

Incentives for the electric car market in China have been subdued as a result of key regulatory decisions. Purchase subsidies were set to expire at the end of 2020, but after hints that they would be phased out more gradually before to the epidemic, they were instead slashed by 10% and extended to 2022 by April 2020, in the thick of the pandemic (Zhan & Chen, 2018). Several cities loosened car license restrictions in response to the pandemic's economic concerns, letting more internal combustion engine vehicles to be registered in order to help local car companies (J. C. Tu & Yang, 2019).

United States of America

In 2020, the US car market plummeted by 23%, however electric car registrations fell by less than the overall market. In 2020, 295 000 new electric cars were registered, down from 327 000 in 2019, with around 78% of them being BEVs (Vergis & Chen, 2015). Their market share has increased to 2%. Due to the federal tax credits for Tesla and General Motors, which account for the majority of electric car registrations, reaching their limit in 2020, federal incentives dropped (Stokes & Breetz, 2018).

Europe

In 2020, the European vehicle market had a shrunk by 22%. Nonetheless, new EVs registrations more than doubled to 1.4 million, representing a 10% market share (Morton et al., 2017). Germany registered 395 000 new electric cars in the major market, whereas France registered 185000 new electric cars (Dik et al., 2022). The number of registrations in the United Kingdom more than doubled, reaching 176000. In Norway, electric automobiles have a record high sales share of 75%, up almost a third from 2019. EVs sales exceeded 50% in Iceland, 30% in Sweden, and 25% in the Netherlands (Lévay et al., 2017).

Despite the economic downturn, there has been a boom in electric car registrations in Europe. This is due to two regulatory actions. First, the European Union's CO_2 emissions limits, which limit the average carbon dioxide (CO_2) emissions per kilometer driven for new cars, were set to expire in 2020 (International Council on Clean Transportation, 2016). Second, as part of stimulus packages to combat the pandemic's effects, numerous European government extended EV subsidy programs (Lévay et al., 2017).

BEV registrations accounted for 54% of electric car registrations in Europe in 2020, continuing to outnumber plug-in hybrid EVs registrations (PHEVs) (Hall et al., 2020). However, the number of BEVs registered doubled from the previous year, while the number of PHEVs tripled. The Netherlands (82% of all electric car registrations), Norway (73%), and the United Kingdom all had a high percentage of BEVs (62%). The yearly distribution of global EVs stock for China, USA and Europe can be seen from Figure 2-8.

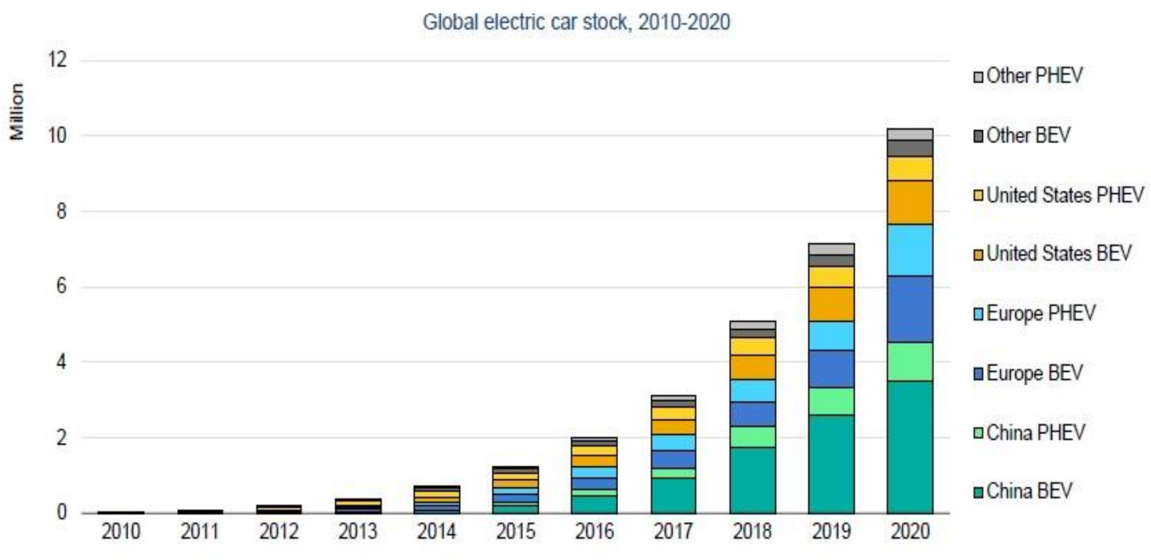

Figure 2-8 Yearly distribution of global EVs stock (Source:IEA)

Other Nations

Other countries' electric car markets remained stable in 2020. In Canada, for example, the new automobile market shrank by 21%, but new electric car registrations remained relatively steady at 51 000, compared to the previous year.

New Zealand is an outlier in this regard. Despite its strong epidemic response, it saw a 22% drop in new electric car registrations in 2020, which corresponded to a 21% fall in the car market. The drop appears to be mostly due to very low EVs registrations in April 2020, when New Zealand was on lockdown (Giroud & Ivarsson, 2020).

Table 2-2 Comparisons on status of EVs in India with EVs rich countries

FACTORS	CHINA	USA	JAPAN	NORWAY	INDIA
Carbon Footprint (t) per year per capita	7.7	16.1	9.9	8.28	1.9
No. of EVs	33,00,000	23,20,000	4,60,000	490,000	1,34,853
Charging Points	167000	48000	40000	8623	450
Renewable Energy	12% Hydroelectricity	15% Hydroelectricity	46%	99% Hydroelectricity	18.37 Hydroelectricity
Energy surplus	Export of 18.67 Twh	Export of 24 TWh		Export of 14.8 TWh	Surplus in 2017, the first time in 13 years.
Cost in Rs. per unit kWh	10	12	17.47	33	10
Policies	Rs. 1 lakh Subsidy directly to manufacturers, Preferential registration, Mandatory for companies to manufacture a certain threshold of EVs	$2,500 to $7,500 Tax incentives, Better electricity tariffs, $1.5 Billion in grants to U.S. based manufacturers, 50 % Tax credit for chargers, Access to HOV lanes	Clean energy vehicle introduction projects, Subsidies of upto $2100	Tax incentives, Free electricity, Free public charging, Exempt in Norway from all non-recurring vehicle fees, including purchase taxes, road toll exemptions, use of bus lanes for BEVs	Subsidies up to Rs. 150,000 for Car and Rs. 30,000 on 2-wheeler. GST of 12% instead of 25%
Market Share	1.37%	0.91%	0.59%	28.76%	0.0012%
No. of Manufacturers	41	37		32	11
No. of Models Available	117	52		47	12
Price Range	$16789-$142321	$28,000-$110,700.		$7438-$110700	$12627-$56386
Median Income (PPP Dollars)	$16,600	$59,500	$42,700	$124,900	$7,200
Distance Range of the Models Available	50km-539km	80km-539km		43km-539km	80km-120km
Import Tax	25%	22%	24%	25%	125%

Another outlier is Japan, where the overall new car market shrank by 11% in 2020 compared to 2019, while electric car registrations fell by 25%. Since 2017, when it peaked at 54 000 registrations and a 1% market share, the electric car market in Japan has declined in absolute and relative terms every year. There were 29,000 registrations in 2020, with a 0.6% sales share (Campbell et al., 2021).

From the literature review an attempt has been made to compile and compare the initiatives taken by various countries for accelerated adoption of EVs. **Table 2-2** presents a comparison on status of EVs in India with EVs rich countries on the basis of certain factors.

From the above discussion it is clear that, India has to go a long way to achieve its EVs objectives in terms of technology, infrastructure, financial support, etc.

2.4 **Research Gap**

Even though the GOI has built ambitious EVs adoption policies, still very slow progress has been observed in the adoption of EVs compared to their targets which shows that India is still in its nascent stage with respect to deployment of EVs (Yong & Park, 2017). Therefore, prior to formulating the policies, the GOI must understand the factors that motivate the customers to adopt EVs and satisfy their needs. Specifically, the policymakers must understand the importance of factors that had the capabilities to sustain the EVs manufacturing in India.

Researches in the past have focused on one or more factors affecting the adoption of EVs. However, a complete framework is yet to be established. There is a need to develop an exhaustive yet comprehensive framework that can be used to analyse the state of adoption of EVs in India and at the same time can be a reference for conducting the study at any other nation. The literature review also shows that the role of identified factors to influence adoption of EVs varies from country to country.

The motive behind the study is to understand the reasons behind the slow adoption of EVs. To bridge the research gap and enlighten the path of decision-makers and policymakers, the study formulates the following objectives.

- To identify various factors which are responsible for the sustainable growth of EVs manufacturing in India.

- To develop an inter-relationship between the reliable and valid factors to understand the cause and effect of each factors.
- To propose a framework of the reliable and valid factors for the sustainable growth of EVs manufacturing in India.

2.5 **Summary**

This chapter contains a systematic literature review of 210 articles on adoption and sustainable manufacturing of EVs. In addition, the literature's descriptive, comprehensive, and content analysis have been offered. The study started with the meta-analysis of articles for their suitability to the topic followed by the contribution of various studies on EVs, status of EVs in Indian and global prospective, and ended up stating the study emphasis areas in terms of research gap.

The present chapter provides theoretical justification of factors. It also shows the significance of certain variables under each factor in the Indian context through content validation.

3.1 **Introduction**

Churchill, (1979) emphasized the need to check for reliability and validity of any proposed framework for its effective implementation. He formulated a paradigm that refines and validates any framework consisting of factors and corresponding variables. Therefore, following Churchill's paradigm involves the identification of factors through the literature search. Hence, a total of 210 research papers related to EVs were collected using the keywords of 'EVs' 'hybrid EVs' 'pug-in hybrid EVs' 'sustainable EV manufacturing' 'EV technology development' 'policies for EVs' 'EVs in India', etc. Afterward, the collected literature is filtered out based on the relevancy, article language, and repentance. Finally, 40 research articles are selected based on the requirement of the study. These 40 research papers were considered for the content validation of identified factors as shown in **Table 3-1**.

Table 3-1 Content validation of identified factors

S. No.	Author	Technological	Social	Cultural	Economic	Political	Geographical	Environmental	Geo-political	Socio-technical	Socio-cultural	Behavioural	Infrastructural
1	(Afroz et al., 2015)	√	√	√	√		√	√		√	√	√	√
2	(Neves et al., 2019)	√	√		√			√					√
3	(Anfinsen et al., 2019)	√	√	√	√		√	√		√			√
4	(Axsen et al., 2013)	√	√		√			√				√	
5	(Biresselioglu et al., 2018)	√	√					√					√
6	(Coffman et al., 2017)	√	√		√			√					√
7	(Degirmenci & Breitner, 2017)		√	√	√			√		√	√	√	√
8	(Digalwar & Giridhar, 2015)	√	√		√			√					√
9	(Du et al., 2018)	√	√		√			√		√		√	
10	(Feng & Figliozzi, 2012)	√	√		√	√						√	
11	(Hanke et al., 2014)	√	√	√	√	√	√	√	√	√	√		

S. No.	Author	Technological	Social	Cultural	Economic	Political	Geographical	Environmental	Geo-political	Socio-technical	Socio-cultural	Behavioural	Infrastructural
12	(Helveston et al., 2015)		√				√					√	
13	(Holland et al., 2016)	√	√			√		√	√			√	
14	(Hosseinpour et al., 2015)	√			√	√		√					√
15	(Junquera et al., 2016)	√	√	√	√		√	√		√	√		√
16	(Khazaei & Khazaei, 2016)				√			√				√	√
17	(M. K. Kim et al., 2018)	√	√		√			√				√	√
18	(Lai et al., 2015)		√	√	√	√	√	√				√	√
19	(Li et al., 2017)	√	√	√	√			√				√	√
20	(Liu et al., 2017)	√	√	√	√			√		√	√	√	√
21	(O. Egbue & Long, 2012c)		√		√	√		√	√	√			√
22	(O. N. Egbue & Long, 2012)	√	√	√	√	√		√	√	√		√	√
23	(Qian & Yin, 2017)	√	√	√	√	√	√	√				√	
24	(She et al., 2017)	√	√		√			√					√
25	(Sierzchula et al., 2014)				√	√		√					√
26	(Spena et al., 2016)	√	√		√	√		√					√
27	(Steinhilber et al., 2013)	√	√		√	√		√		√			√
28	(Thananusak et al., 2017)	√	√		√	√		√					√
29	(J. C. Tu & Yang, 2019)	√	√	√		√		√				√	
30	(Ulrich, 2005)	√						√					√
31	(Vergis & Chen, 2015)	√	√		√		√	√					√
32	(S. Wang et al., 2017)	√	√		√	√		√				√	√
33	(W. Yang et al., 2015)	√	√			√							√
34	(Westin et al., 2018)	√	√		√	√	√	√	√			√	√
35	(White & Sintov, 2017)	√	√		√	√		√					
36	(Y. Wu & Zhang, 2017)	√				√		√					√
37	(J. Wu et al., 2019)	√	√			√		√				√	
38	(Yong & Park, 2017)	√	√		√	√		√					√
39	(Zheng et al., 2018)		√		√	√		√				√	
40	(Zhuge & Shao, 2019)	√	√		√	√		√				√	√

A panel of 10 experts was formed to finalize the factors and identify the variables within each factor using the nominal grouping technique. The experts belonged to one of the following categories: academicians researching in the field of EVs, renewable energy or sustainability; industrial experts with more than 10 years of experience in the field of EVs; policymakers working for the GOI. A total of 12 factors were identified from research papers namely *Technological, Social, Cultural, Economic, Political, Geographical, Environmental, Geo-political, Socio-technical, Socio-cultural, Behavioural, and Infrastructural*, as shown in **Figure 3-1**.

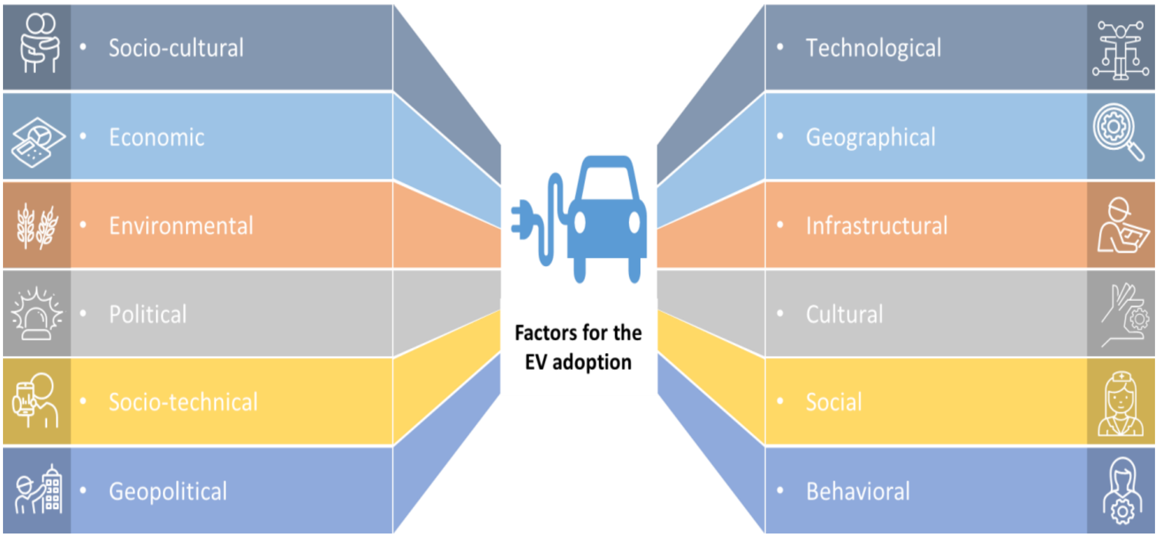

Figure 3-1 Factors considered in the EV studies

The identified list of factors was distributed among the panel of experts for brainstorming and to identify variables that can represent these factors. The experts were separately asked to submit appropriate variables under each factor. The responses from all the experts were combined and redundant variables were omitted. The experts were then called for a group meeting to create the initial set of variables using the nominal grouping technique. The variables were written down in self-adhesive notes and were assigned to one of the identified factors by making an affinity diagram, as shown in Figure 3-2.

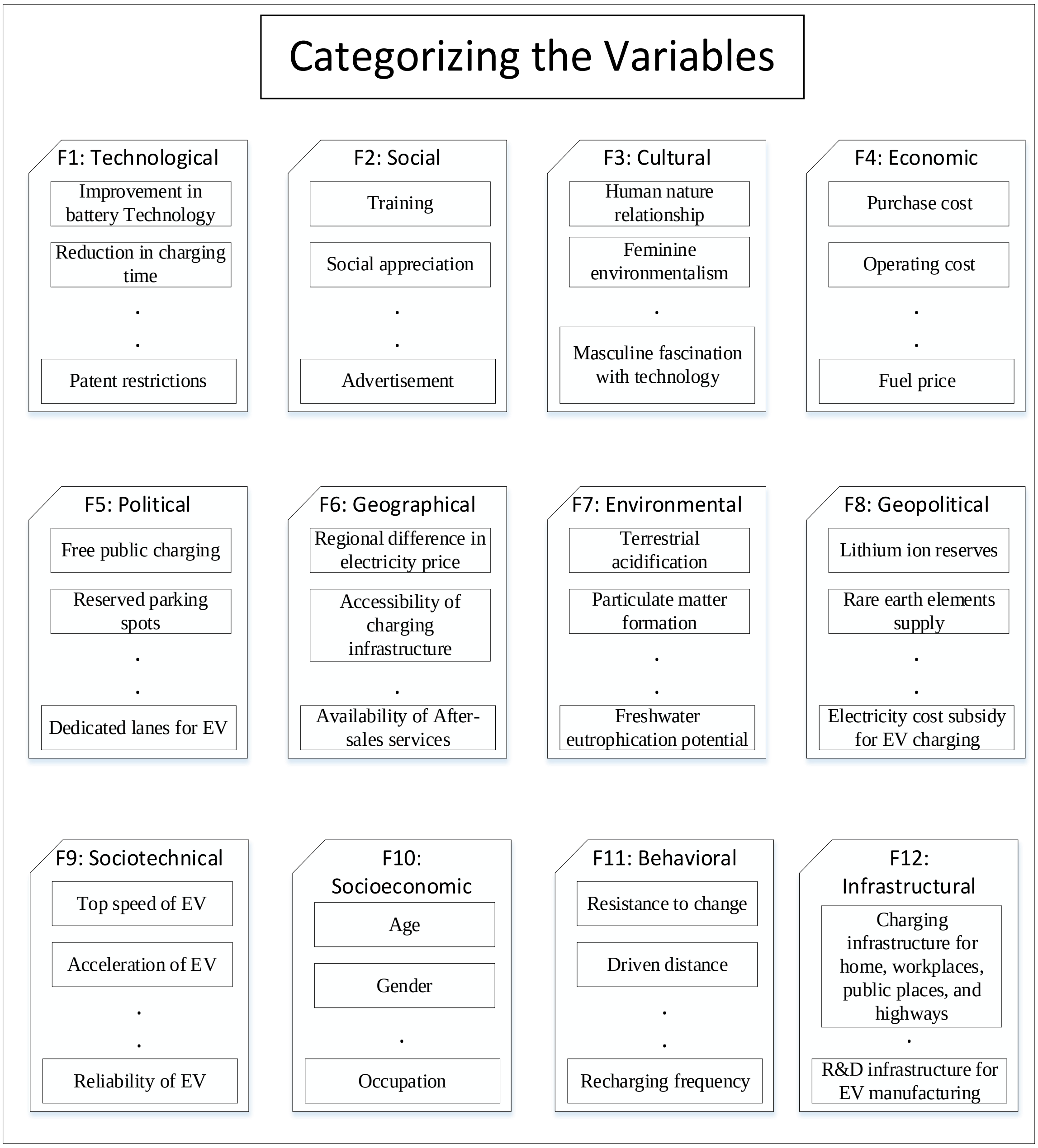

Figure 3-2 Affinity diagram

Finally, the panel of experts grouped these identified 80 variables under 12 major factors using nominal grouping technique. The identified factors are discussed briefly in the following section.

Table 3-2 Identified factors with variables

Factor	Variables	Code
Technological	Improvement in battery technology	TEC1
	Reduction in charging time	TEC2
	Improvement in driving range of EV	TEC3
	Increase in battery life	TEC4
	Power grid capacity	TEC5
	Wireless vehicle charging technology	TEC6
	R&D related to EV technology	TEC7
	Vehicle to grid (V2G) technology	TEC8
	Patent restrictions	TEC9
Social	Training	SOC1
	Social appreciation	SOC2
	Brand endorsements	SOC3
	Awareness	SOC4
	Status in society	SOC5
	Advertisements	SOC6
Cultural	Human-nature relationship	CUL1
	Feminine environmentalism	CUL2
	Long-term orientation	CUL3
	Face consciousness	CUL4
	Recycling mentality	CUL5
	Masculine fascination with technology	CUL6
Economic	Purchase cost	ECO1
	Operating cost	ECO2
	Maintenance cost	ECO3
	Battery cost	ECO4
	Replacement cost	ECO5
	Fuel price	ECO6
Political	Free public charging	POL1
	Reserved parking spots	POL2
	Fossil fuel taxes	POL3
	Government subsidy for EV purchase	POL4
	Vehicle insurance	POL5
	Tax exemption	POL6
	Dedicated lanes for EV	POL7
Geographical	Regional difference in electricity price	GEO1
	Accessibility of charging infrastructure	GEO2
	Region of residence (Urban/sub-urban/rural)	GEO3
	Availability of Renewable energy resources	GEO4
	Availability of After-sales services	GEO5
Environmental	Terrestrial acidification	ENV1
	Particulate matter formation	ENV2

Factor	Variables	Code
	Photochemical oxidation formation	ENV3
	Human toxicity potential	ENV4
	Global warming	ENV5
	Freshwater eco-toxicity potential	ENV6
	Air pollution	ENV7
	Noise pollution	ENV8
	Greenhouse gas emission	ENV9
	Metal resource depletion	ENV10
	Terrestrial eco-toxicity potential	ENV11
	Freshwater eutrophication potential	ENV12
Geo-political	Lithium ion reserves	GEP1
	Rare earth elements supply	GEP2
	Energy security	GEP3
	Climate policy	GEP4
	Electricity cost subsidy for EV charging	GEP5
Socio-technical	Top speed of EV	SOT1
	Acceleration of EV	SOT2
	Comfort of EV	SOT3
	Power of EV	SOT4
	Safety of EV	SOT5
	Aesthetic appearance of EV	SOT6
	Fuel economy	SOT7
	Seating and luggage capacity	SOT8
	Reliability of EV	SOT9
Socio-cultural	Age	SEO1
	Gender	SEO2
	Education	SEO3
	Income	SEO4
	Occupation	SEO5
Behavioural	Resistance to change	BEH1
	Driven distance	BEH2
	Parking time	BEH3
	Driving time	BEH4
	Number of trips driven per day	BEH5
	Recharging frequency	BEH6
Infrastructural	Charging infrastructure for home, workplaces, public places, and highways	INF1
	Maintenance, service & repair infrastructure	INF2
	Reliable electricity infrastructure	INF3
	R&D infrastructure for EV manufacturing	INF4

3.2 **Detailed Description of Identified Factors**

In the coming section, we will discuss the 12 identified factors in detail separately.

3.2.1 **Technological**

Technological factors are those factors which are either directly or indirectly related to electric mobility technology. These factors broadly lie in the categories of battery technology, electrical grid technology, charging technology or even materials technology (Peters et al., 2018; Usman et al., 2020).

Improvements in battery technology involve improving cycle ability (number of times a battery can be charged while maintaining its efficiency), energy density (amount of energy that can be stored in a unit volume), battery life, operating temperature range while reducing charging time and battery cost as well. It also includes solving issues of overheating and fire accidents.

The electricity demand of EVs can cause strain on the existing power grid. Existing power grids need to be strengthened to meet the peak demand. Vehicle-to-grid (V2G) technology is one such technology wherein the energy stored in the battery could be discharged back to the grid to cover the peak demand (Habib et al., 2018).

Wireless vehicle charging technology has captured the interest of many EVs companies. Wireless charging follows inductive charging wherein electricity is transferred to the battery through the air gap when the vehicle is aligned with the charging coils. The breakthrough in this technology can be achieved when vehicles can be charged viably on the go, eliminating the need for stopping for charging (Wilberforce et al., 2017) (Machura & Li, 2019).

Advancements in materials technology can lead to new high-performance batteries. Lithium-ion batteries, solid-state batteries, aluminium-ion batteries, lithium-sulphur batteries, and metal-air batteries are examples of emerging battery technologies. Each was developed as a result of R&D activities to improve cycle ability, energy density, battery life, operating temperature range and so on. The content validation of the technological factor and its variables are depicted in Table 3-3.

Table 3-3 Technological factors

		1	2	3	4	5	6	7	8	9
S.No.	**Author**	**TEC 1**	**TEC 2**	**TEC 3**	**TEC 4**	**TEC 5**	**TEC 6**	**TEC 7**	**TEC 8**	**TEC 9**
A1	(Afroz et al., 2015)					Y			Y	
A2	(Axsen et al., 2013)		Y	Y	Y	Y				
A3	(Barth et al., 2016)			Y		Y				
A4	(Bennett et al., 2016)		Y	Y	Y	Y				
A5	(Bigerna & Micheli, 2018)	Y	Y	Y		Y				
A6	(Biresselioglu et al., 2018)		Y	Y		Y			Y	
A7	(Coffman et al., 2017)		Y	Y		Y		Y		
A8	(Degirmenci & Breitner, 2017)		Y	Y			Y	Y		
A9	(Diamond, 2009)					Y				
A10	(Digalwar & Giridhar, 2015)	Y	Y		Y		Y	Y		
A11	(Du et al., 2018)					Y				
A12	(Eppstein et al., 2011)			Y						
A13	(Faria et al., 2013)	Y		Y						
A14	(Feng & Figliozzi, 2012)			Y						
A15	(Feng & Figliozzi, 2013)					Y				
A16	(Figenbaum et al., 2014)	Y	Y	Y	Y	Y				
A17	(Franke et al., 2018)		Y	Y		Y				
A18	(Franke et al., 2012)		Y	Y		Y				
A19	(Gnann, Funke, et al., 2018)	Y		Y	Y	Y				
A20	(Habib et al., 2018)	Y	Y	Y	Y					
A21	(Hagman et al., 2016)							Y		
A22	(Hahnel et al., 2014)		Y	Y						
A23	(L. Han et al., 2017)			Y						
A24	(Hanke et al., 2014)	Y		Y	Y	Y	Y	Y		
A26	(Helveston et al., 2015)					Y				
A27	(Hosseinpour et al., 2015)		Y	Y	Y	Y			Y	
A28	(Javid & Nejat, 2017)					Y				
A29	(Juan et al., 2016)	Y	Y	Y	Y	Y				
A30	(Junquera et al., 2016)		Y	Y	Y					
A31	(Kaplan et al., 2016)					Y				
A32	(Karplus et al., 2010)			Y						
A33	(Khan & Kar, 2009)						Y	Y		
A34	(Khazaei & Khazaei, 2016)			Y		Y				
A35	(S. Kim et al., 2017)		Y	Y		Y				
A36	(M.-K. Kim et al., 2018)			Y		Y				
A37	(Krupa et al., 2014)			Y						
A38	(Lai et al., 2015)			Y		Y				
A40	(Li et al., 2017)	Y	Y	Y		Y				
A41	(Lin & Tan, 2017)					Y				
A42	(Lin & Wu, 2018)		Y			Y				
A43	(Liu et al., 2017)					Y				
A44	(McLeay et al., 2018)			Y						
A45	(Mersky et al., 2016)					Y				
A47	(Moons & De Pelsmacker, 2012)	Y	Y	Y	Y	Y				
A48	(Nanaki & Koroneos, 2016)	Y		Y	Y	Y				
A49	(Neaimeh et al., 2017)		Y			Y				
A50	(Neves et al., 2019)	Y		Y		Y				Y

		1	2	3	4	5	6	7	8	9
S.No.	**Author**	**TEC 1**	**TEC 2**	**TEC 3**	**TEC 4**	**TEC 5**	**TEC 6**	**TEC 7**	**TEC 8**	**TEC 9**
A52	(Okada et al., 2019)					Y				
A53	(Priessner et al., 2018)			Y		Y				
A54	(Rezvani et al., 2015)		Y	Y		Y				
A57	(Sang & Bekhet, 2015)	Y	Y	Y	Y	Y				
A59	(She et al., 2017)	Y	Y	Y	Y	Y				
A60	(Sierzchula et al., 2014)					Y				
A62	(Spena et al., 2016)			Y		Y		Y		
A63	(Steinhilber et al., 2013)					Y	Y			Y
A65	(Thananusak et al., 2017)	Y	Y	Y	Y	Y				
A66	(J.-C. Tu & Yang, 2019)	Y	Y	Y		Y				
A67	(Vergis & Chen, 2015)					Y				
A68	(N. Wang & Liu, 2015)					Y				
A69	(N. Wang et al., 2018)	Y	Y	Y	Y	Y				
A71	(S. Wang et al., 2017)					Y				
A72	(Westin et al., 2018)		Y	Y		Y				
A73	(White & Sintov, 2017)			Y		Y				
A74	(Y. Wu & Zhang, 2017)	Y		Y	Y					
A77	(Yong & Park, 2017)		Y	Y						
A79	(Zhuge & Shao, 2019)	Y	Y	Y	Y	Y				

3.2.2 **Social**

Social factors are factors which are related to the entire or part of society that affects their purchase or adoption intention of EVs. Being a relatively newer mode of transportation, acceptance by society is expected to be a slow process(Liao et al., 2017; Park et al., 2018). Identification of social enablers, barriers and corresponding actions are essential for accelerating the adoption rate of EVs.

Customers need proper orientation and training for the usage and maintenance of EVs. Auto-expos and test-drives can help the customer get familiarized with EVs technology. Advertisements and brand endorsements are drivers of customer perception on e-mobility. India, the second-largest advertisement market in Asia after China, has huge potential to drive the customer perception on e-mobility. A significant portion of the Indian population follows celebrities, both domestic and international. Brand endorsements by celebrities can thus motivate customers to switch to electric mobility(Park et al., 2018).

Occasional awareness programs emphasizing the energy security, scarcity of fossil fuels with its harmful effects and the relative advantages of EVs in all aspects can create a sense of responsibility among the society. Appreciation in society for ownership of a cleaner fuel vehicle can also motivate individuals. It enhances the status of individuals in society. The content validation of the social factor and its variables are shown in Table 3-4.

Table 3-4 Social factors

		10	11	12	13	14	15
S.No.	**Author**	**SOC1**	**SOC2**	**SOC3**	**SOC4**	**SOC5**	**SOC6**
A1	(Afroz et al., 2015)		Y			Y	
A2	(Axsen et al., 2013)				Y		
A5	(Bigerna & Micheli, 2018)				Y		
A7	(Coffman et al., 2017)				Y		
A8	(Degirmenci & Breitner, 2017)				Y	Y	Y
A10	(Digalwar & Giridhar, 2015)	Y			Y		
A11	(Du et al., 2018)				Y		
A12	(Eppstein et al., 2011)						Y
A16	(Figenbaum et al., 2014)		Y		Y	Y	Y
A18	(Franke et al., 2012)				Y		
A19	(Gnann, Funke, et al., 2018)						Y
A22	(Hahnel et al., 2014)		Y			Y	
A23	(L. Han et al., 2017)		Y			Y	
A24	(Hanke et al., 2014)	Y					
A26	(Helveston et al., 2015)			Y			
A30	(Junquera et al., 2016)			Y			
A31	(Kaplan et al., 2016)				Y		
A33	(Khan & Kar, 2009)	Y			Y		
A34	(Khazaei & Khazaei, 2016)		Y			Y	
A37	(Krupa et al., 2014)		Y			Y	Y
A38	(Lai et al., 2015)				Y		
A40	(Li et al., 2017)		Y			Y	
A41	(Lin & Tan, 2017)				Y		
A43	(Liu et al., 2017)		Y	Y		Y	Y
A44	(McLeay et al., 2018)		Y			Y	
A47	(Moons & De Pelsmacker, 2012)				Y		Y
A55	(Saarenpää et al., 2013)		Y			Y	Y
A57	(Sang & Bekhet, 2015)		Y			Y	
A62	(Spena et al., 2016)			Y			
A66	(J.-C. Tu & Yang, 2019)		Y		Y	Y	Y
A67	(Vergis & Chen, 2015)				Y		
A68	(N. Wang & Liu, 2015)						Y
A69	(N. Wang et al., 2018)		Y			Y	Y
A72	(Westin et al., 2018)		Y			Y	
A73	(White & Sintov, 2017)		Y			Y	
A79	(Zhuge & Shao, 2019)		Y			Y	

3.2.3 **Cultural**

Cultural values affect customer’s decision-making process in switching to cleaner vehicle technology. Temperament or mentality has an intrinsic value among human beings(Anfinsen et al., 2019). Nature's relationship with humans can be described in three modes: supremacy over nature, harmony with nature, and submission to nature. Consumers who believe in coexisting in harmony with nature usually prefer to opt for more environment friendly options and may prefer EVs over internal combustion engine (ICE) vehicles.

Long-term orientation is that cultural value that inculcates a mentality to consider the past, present and future while making purchase decisions. Consumers with long-term orientation are more inclined towards sustainability and hence are in favour of the cleaner technology.

Consumer’s face consciousness, i.e., a concern of gaining or losing face in the society over choices made by the individual also promotes e-mobility. Consumers who are highly conscious in that aspect usually manage to maintain the public image and make environment-friendly and socially beneficial choices (Qian & Yin, 2017).

Feminine environmentalism and masculine fascination with technology are two cultural aspects of customers’ general outlook towards electric mobility. Women prefer EVs due to environmentalism, while men see the superior technological advancements associated with them. Both these factors are drivers for the growth of EVs. The recycling mentality of customers promote battery recycling thereby reducing the dependency on raw materials for battery and further affects the adoption rate positively (Anfinsen et al., 2019). Table 3-5 shows the content validation of the cultural factor and its variables.

Table 3-5 Cultural factors

		16	17	18	19	20	21
S. No.	**Author**	**CUL1**	**CUL2**	**CUL3**	**CUL4**	**CUL5**	**CUL6**
A1	(Afroz et al., 2015)	Y		Y	Y	Y	Y
A6	(Biresselioglu et al., 2018)					Y	
A8	(Degirmenci & Breitner, 2017)	Y	Y	Y			
A11	(Du et al., 2018)					Y	
A13	(Faria et al., 2013)					Y	
A24	(Hanke et al., 2014)	Y	Y	Y	Y	Y	Y

		16	17	18	19	20	21
S. No.	**Author**	**CUL1**	**CUL2**	**CUL3**	**CUL4**	**CUL5**	**CUL6**
A30	(Junquera et al., 2016)		Y				
A37	(Krupa et al., 2014)					Y	
A40	(Li et al., 2017)			Y		Y	
A44	(McLeay et al., 2018)					Y	
A48	(Nanaki & Koroneos, 2016)					Y	
A51	(Noori & Tatari, 2016)					Y	
A52	(Okada et al., 2019)		Y			Y	
A54	(Rezvani et al., 2015)			Y	Y		
A70	(N. Wang et al., 2017)					Y	

3.2.4 **Economic**

EVs come with economic benefits to their users in the long run although it appears to be an expensive investment to be made. When compared to an ICE vehicle, the cost of purchasing EVs is higher. Examples of Tata Nexon EV and Hyundai Elantra GLS can be taken for comparison. Both models have a power of 127BHP. Tata Nexon EV has priced at Rs. 14,00,000/- whereas the purchase price of Hyundai Elantra GLS is approximately Rs. 8,50,000/-. The high purchase cost of an EV can be attributed to the high cost of the battery. At present, battery contributes to about 30% of the total purchase cost of an EV. Moreover, if a battery has to be replaced during the lifetime of an EV, it makes a significant increase in the total cost of ownership (Bauer, 2018). Operating and maintenance costs associated with EVs are quite less compared to that of an ICE vehicle. The low cost of electricity brings down the operating cost of an EVs (Hinz et al., 2015). The number of parts in EVs is quite low compared to that in an ICE vehicle, making the maintenance cost of EVs low. Table 3-6 shows the content validation of the economic factor and its variables.

Table 3-6 Economic factors

		22	23	24	25	26	27
S. No.	**Author**	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**ECO5**	**ECO6**
A2	(Axsen et al., 2013)	Y	Y				
A3	(Barth et al., 2016)	Y		Y			
A4	(Bennett et al., 2016)	Y	Y			Y	
A5	(Bigerna & Micheli, 2018)	Y		Y			Y
A6	(Biresselioglu et al., 2018)	Y		Y			
A7	(Coffman et al., 2017)	Y			Y		Y
A8	(Degirmenci & Breitner, 2017)	Y	Y	Y	Y		Y

		22	23	24	25	26	27
S. No.	**Author**	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**ECO5**	**ECO6**
A9	(Diamond, 2009)						Y
A12	(Eppstein et al., 2011)	Y					Y
A13	(Faria et al., 2013)		Y	Y			Y
A14	(Feng & Figliozzi, 2012)	Y	Y	Y			Y
A15	(Feng & Figliozzi, 2013)	Y	Y	Y			Y
A16	(Figenbaum et al., 2014)						Y
A17	(Franke et al., 2018)	Y	Y	Y	Y	Y	Y
A19	(Gnann, Funke, et al., 2018)	Y	Y	Y	Y		Y
A20	(Habib et al., 2018)				Y	Y	
A21	(Hagman et al., 2016)	Y	Y	Y		Y	
A22	(Hahnel et al., 2014)	Y	Y				Y
A23	(L. Han et al., 2017)	Y					
A24	(Hanke et al., 2014)				Y	Y	Y
A26	(Helveston et al., 2015)	Y	Y	Y			Y
A27	(Hosseinpour et al., 2015)	Y	Y	Y			Y
A28	(Javid & Nejat, 2017)						Y
A30	(Junquera et al., 2016)	Y	Y	Y	Y		
A32	(Karplus et al., 2010)	Y	Y	Y	Y		Y
A33	(Khan & Kar, 2009)	Y	Y	Y	Y	Y	
A35	(S. Kim et al., 2017)	Y					Y
A36	(M.-K. Kim et al., 2018)	Y	Y	Y	Y	Y	
A37	(Krupa et al., 2014)	Y	Y	Y	Y	Y	Y
A38	(Lai et al., 2015)	Y	Y	Y			
A39	(Lévay et al., 2017)	Y	Y	Y	Y	Y	Y
A40	(Li et al., 2017)	Y	Y	Y	Y	Y	Y
A42	(Lin & Wu, 2018)	Y	Y	Y	Y	Y	
A43	(Liu et al., 2017)	Y	Y	Y			Y
A44	(McLeay et al., 2018)	Y	Y	Y			Y
A47	(Moons & De Pelsmacker, 2012)	Y	Y	Y	Y	Y	Y
A48	(Nanaki & Koroneos, 2016)				Y	Y	
A50	(Neves et al., 2019)				Y		Y
A51	(Noori & Tatari, 2016)	Y	Y	Y			Y
A53	(Priessner et al., 2018)	Y	Y				
A54	(Rezvani et al., 2015)	Y	Y	Y	Y	Y	Y
A56	(Sánchez-Braza et al., 2014)	Y	Y	Y	Y		
A57	(Sang & Bekhet, 2015)						Y
A58	(Sen et al., 2017)		Y	Y			
A59	(She et al., 2017)	Y	Y	Y	Y	Y	Y
A60	(Sierzchula et al., 2014)	Y	Y				Y
A61	(Soltani-Sobh et al., 2017)						Y
A62	(Spena et al., 2016)	Y	Y	Y	Y	Y	Y
A65	(Thananusak et al., 2017)	Y	Y	Y	Y	Y	Y

		22	23	24	25	26	27
S. No.	**Author**	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**ECO5**	**ECO6**
A67	(Vergis & Chen, 2015)						Y
A69	(N. Wang et al., 2018)	Y	Y	Y	Y	Y	
A73	(White & Sintov, 2017)	Y	Y	Y	Y	Y	Y
A76	(W. Yang et al., 2015)	Y	Y	Y	Y	Y	Y
A77	(Yong & Park, 2017)	Y					
A78	(Zheng et al., 2018)	Y	Y	Y	Y	Y	
A79	(Zhuge & Shao, 2019)	Y	Y	Y	Y	Y	Y

3.2.5 **Political**

Central and state government policies play a significant role in the adoption of electric mobility. The central government has provided incentives for EV purchase and imposed a hike in import tariffs to increase the in-house manufacturing capability of the nation (Wikström et al., 2016a). The policy has also earmarked Rs.14000 crores for the development of charging infrastructure throughout the nation. State governments have also come up with policies like road tax exemption for EVs to promote the growth of the EV market in India.

More policies can be implemented to ensure the sustainable growth of EVs manufacturing and sales in India. For EV users, free charging can be provided at public places. Imposing more taxes on fossil fuels may force customers to consider EV as an alternative. Reserved parking spots for EVs and other similar provisions can enhance the enthusiasm in individuals to consider EV as their next purchase choice (Langbroek et al., 2016). Content validation of political factor and its associated variables is given in Table 3-7. In the future, when the road infrastructure improves, policies like dedicated lanes for EVs can also be considered (Sánchez-Braza et al., 2014).

Table 3-7 Political factors

		28	29	30	31	32	33	34
S. No.	**Author**	**POL1**	**POL2**	**POL3**	**POL4**	**POL5**	**POL6**	**POL7**
A4	(Bennett et al., 2016)				Y			
A5	(Bigerna & Micheli, 2018)				Y			
A6	(Biresselioglu et al., 2018)				Y			
A7	(Coffman et al., 2017)				Y			
A8	(Degirmenci & Breitner, 2017)				Y			
A9	(Diamond, 2009)				Y		Y	
A10	(Digalwar & Giridhar, 2015)						Y	
A11	(Du et al., 2018)				Y		Y	

		28	29	30	31	32	33	34
S. No.	**Author**	**POL1**	**POL2**	**POL3**	**POL4**	**POL5**	**POL6**	**POL7**
A12	(Eppstein et al., 2011)				Y		Y	
A14	(Feng & Figliozzi, 2012)				Y		Y	Y
A15	(Feng & Figliozzi, 2013)				Y		Y	Y
A16	(Figenbaum et al., 2014)	Y	Y		Y		Y	Y
A17	(Franke et al., 2018)			Y	Y		Y	
A19	(Gnann, Funke, et al., 2018)				Y		Y	
A21	(Hagman et al., 2016)				Y		Y	
A23	(L. Han et al., 2017)		Y					Y
A24	(Hanke et al., 2014)	Y	Y		Y	Y	Y	Y
A26	(Helveston et al., 2015)				Y		Y	
A27	(Hosseinpour et al., 2015)			Y	Y		Y	
A31	(Kaplan et al., 2016)		Y					Y
A33	(Khan & Kar, 2009)	Y			Y		Y	
A35	(S. Kim et al., 2017)	Y	Y	Y	Y		Y	Y
A36	(M.-K. Kim et al., 2018)	Y			Y		Y	
A38	(Lai et al., 2015)				Y		Y	
A39	(Lévay et al., 2017)	Y	Y		Y		Y	Y
A40	(Li et al., 2017)	Y			Y		Y	
A42	(Lin & Wu, 2018)	Y			Y		Y	
A43	(Liu et al., 2017)					Y		
A45	(Mersky et al., 2016)	Y			Y		Y	
A46	(Mirhedayatian & Yan, 2018)	Y			Y		Y	
A49	(Neaimeh et al., 2017)	Y						
A51	(Noori & Tatari, 2016)				Y		Y	
A52	(Okada et al., 2019)				Y			
A54	(Rezvani et al., 2015)	Y			Y		Y	
A57	(Sang & Bekhet, 2015)				Y		Y	
A59	(She et al., 2017)	Y			Y		Y	
A60	(Sierzchula et al., 2014)				Y		Y	
A61	(Soltani-Sobh et al., 2017)				Y			
A62	(Spena et al., 2016)		Y		Y	Y	Y	Y
A63	(Steinhilber et al., 2013)				Y		Y	
A64	(Stokes & Breetz, 2018)	Y	Y	Y	Y	Y	Y	Y
A67	(Vergis & Chen, 2015)	Y			Y	Y	Y	
A68	(N. Wang & Liu, 2015)	Y	Y		Y		Y	Y
A69	(N. Wang et al., 2018)	Y	Y					Y
A70	(N. Wang et al., 2017)	Y			Y	Y	Y	
A71	(S. Wang et al., 2017)	Y			Y	Y	Y	
A72	(Westin et al., 2018)	Y			Y		Y	
A77	(Yong & Park, 2017)	Y	Y	Y	Y	Y	Y	Y
A78	(Zheng et al., 2018)	Y			Y		Y	
A79	(Zhuge & Shao, 2019)	Y	Y		Y	Y	Y	Y

3.2.6 **Geographical**

Variation in the adoption rate of EVs can also be due to geographical factors. Having public charging stations in the locality can reduce anxiety about the range of EVs and boost confidence in the customers (Usman et al., 2020). The nation has a long way to go in this direction. By 2030, 80 lakh public charging stations (both fast and slow) will be erected across India, according to EESL, the world's largest public-sector energy service firm.

After-sales services are as important as charging infrastructure in gaining the confidence of the customer. As EV technology is a comparatively new one, special training needs to be given to mechanics to handle the repair and maintenance of EVs (Dixit et al., 2018). Content validation of geographical factor and its associated variables is shown in Table 3-8.

All efforts towards electric mobility will be worthless if the electricity for the vehicles comes from a thermal source. Availability of renewable sources of electricity can smoothen the transition to a cleaner mode of transportation. Karnataka, Rajasthan, Tamil Nadu, Telangana, and Andhra Pradesh are the top states in India in solar installations. Other states and union territories must set goals towards tapping solar energy potential and increase their contribution towards sustainable sources of energy.

Table 3-8 Geographical factors

		35	36	37	38	39
S.No.	**Author**	**GEO1**	**GEO2**	**GEO3**	**GEO4**	**GEO5**
A1	(Afroz et al., 2015)		Y			
A2	(Axsen et al., 2013)		Y			
A3	(Barth et al., 2016)		Y			
A4	(Bennett et al., 2016)		Y			
A5	(Bigerna & Micheli, 2018)		Y			
A6	(Biresselioglu et al., 2018)		Y			
A7	(Coffman et al., 2017)		Y			
A8	(Degirmenci & Breitner, 2017)				Y	
A9	(Diamond, 2009)		Y			
A10	(Digalwar & Giridhar, 2015)					Y
A11	(Du et al., 2018)		Y			
A15	(Feng & Figliozzi, 2013)		Y			
A16	(Figenbaum et al., 2014)	Y	Y	Y	Y	
A17	(Franke et al., 2018)		Y		Y	
A18	(Franke et al., 2012)		Y			

		35	36	37	38	39
S.No.	**Author**	**GEO1**	**GEO2**	**GEO3**	**GEO4**	**GEO5**
A19	(Gnann, Funke, et al., 2018)		Y			
A20	(Habib et al., 2018)				Y	
A21	(Hagman et al., 2016)				Y	
A24	(Hanke et al., 2014)	Y	Y			Y
A26	(Helveston et al., 2015)		Y		Y	
A27	(Hosseinpour et al., 2015)		Y			
A28	(Javid & Nejat, 2017)		Y			
A29	(Juan et al., 2016)		Y			
A31	(Kaplan et al., 2016)		Y			
A33	(Khan & Kar, 2009)	Y				Y
A34	(Khazaei & Khazaei, 2016)		Y			Y
A35	(S. Kim et al., 2017)	Y	Y			
A36	(M.-K. Kim et al., 2018)	Y	Y			
A37	(Krupa et al., 2014)			Y		Y
A38	(Lai et al., 2015)		Y			
A39	(Lévay et al., 2017)	Y				
A40	(Li et al., 2017)	Y	Y			
A41	(Lin & Tan, 2017)		Y			
A42	(Lin & Wu, 2018)	Y	Y	Y		
A43	(Liu et al., 2017)		Y			Y
A45	(Mersky et al., 2016)	Y	Y			
A47	(Moons & De Pelsmacker, 2012)		Y			Y
A48	(Nanaki & Koroneos, 2016)		Y		Y	
A49	(Neaimeh et al., 2017)	Y	Y		Y	
A50	(Neves et al., 2019)		Y		Y	
A52	(Okada et al., 2019)		Y		Y	
A53	(Priessner et al., 2018)		Y			
A54	(Rezvani et al., 2015)	Y	Y			
A55	(Saarenpää et al., 2013)			Y		
A56	(Sánchez-Braza et al., 2014)			Y		
A57	(Sang & Bekhet, 2015)	Y	Y			
A59	(She et al., 2017)	Y	Y			Y
A60	(Sierzchula et al., 2014)	Y	Y			
A61	(Soltani-Sobh et al., 2017)			Y		
A62	(Spena et al., 2016)		Y	Y		Y
A63	(Steinhilber et al., 2013)	Y	Y			
A64	(Stokes & Breetz, 2018)	Y			Y	
A65	(Thananusak et al., 2017)		Y			
A66	(J.-C. Tu & Yang, 2019)		Y	Y		
A67	(Vergis & Chen, 2015)	Y	Y			
A68	(N. Wang & Liu, 2015)	Y	Y			Y
A69	(N. Wang et al., 2018)		Y			Y

		35	36	37	38	39
S.No.	**Author**	**GEO1**	**GEO2**	**GEO3**	**GEO4**	**GEO5**
A70	(N. Wang et al., 2017)	Y		Y		
A71	(S. Wang et al., 2017)	Y	Y			
A72	(Westin et al., 2018)	Y	Y	Y		
A73	(White & Sintov, 2017)		Y			
A76	(W. Yang et al., 2015)	Y			Y	
A77	(Yong & Park, 2017)	Y				
A78	(Zheng et al., 2018)	Y				
A79	(Zhuge & Shao, 2019)	Y	Y	Y		

3.2.7 **Environmental**

Environmental factors are the harmful environmental phenomena, arising out of human exploitation of resources without considering its nourishment. The most common are air pollution and global warming caused by greenhouse gas emissions from incomplete combustion of fossil fuel. The transportation industry accounts for a large share of world emissions (Dhar & Shukla, 2015; Moriarty & Wang, 2017).

Hawkins et al., (2013) explain other environmental factors that have an impact on the transition to electric mobility. They compared the effects produced by the EVs and internal combustion vehicles during their life cycle and arrived at the following conclusions: terrestrial acidification potential and particulate matter formation from both types of vehicles are similar, although the root causes may differ. Photochemical oxidation formation potential is higher for internal combustion engine vehicles during their usage phase as compared with EVs. Human toxicity potential is a major barrier towards EV adoption as the human toxicity potential is quite high during battery manufacturing for EVs. The situation is same for freshwater, terrestrial eco-toxicity and eutrophication potential. The metal resource depletion potential of EVs is significantly higher than that of an ICE vehicle due to their reliance on metals of differing scarcities. Hence the environmental domain of factors needs to be analysed in-depth to understand the net environmental benefits of electric mobility as shown in Table 3-9.

Table 3-9 Environmental factors

		40	41	42	43	44	45	46	47	48	49	50	51
S.No.	**Author**	**ENV 1**	**ENV 2**	**ENV 3**	**ENV 4**	**ENV 5**	**ENV 6**	**ENV 7**	**ENV 8**	**ENV 9**	**ENV 10**	**ENV 11**	**ENV 12**
A2	(Axsen et al., 2013)								Y	Y			
A4	(Bennett et al., 2016)								Y	Y			
A5	(Bigerna & Micheli, 2018)								Y				
A6	(Biresselioglu et al., 2018)							Y		Y			
A8	(Degirmenci & Breitner, 2017)							Y		Y			
A11	(Du et al., 2018)									Y			
A13	(Faria et al., 2013)									Y			
A15	(Feng & Figliozzi, 2013)							Y	Y	Y			
A16	(Figenbaum et al., 2014)							Y	Y	Y			
A20	(Habib et al., 2018)								Y	Y			
A21	(Hagman et al., 2016)									Y			
A22	(Hahnel et al., 2014)									Y			
A23	(L. Han et al., 2017)									Y			
A24	(Hanke et al., 2014)								Y				
A25	(Hawkins et al., 2013)	Y	Y	Y	Y	Y	Y				Y	Y	Y
A26	(Helveston et al., 2015)									Y			
A29	(Juan et al., 2016)							Y	Y	Y			
A31	(Kaplan et al., 2016)							Y	Y	Y			
A32	(Karplus et al., 2010)									Y			
A33	(Khan & Kar, 2009)							Y		Y			
A34	(Khazaei & Khazaei, 2016)							Y					
A36	(M. K. Kim et al., 2018)							Y		Y			
A40	(Li et al., 2017)							Y	Y	Y			
A41	(Lin & Tan, 2017)							Y					
A43	(Liu et al., 2017)							Y	Y	Y			
A44	(McLeay et al., 2018)							Y	Y	Y			
A47	(Moons & De Pelsmacker, 2012)							Y	Y	Y			
A48	(Nanaki & Koroneos, 2016)							Y	Y	Y			
A50	(Neves et al., 2019)									Y			
A51	(Noori & Tatari, 2016)							Y	Y	Y			

		40	41	42	43	44	45	46	47	48	49	50	51
S.No.	**Author**	**ENV 1**	**ENV 2**	**ENV 3**	**ENV 4**	**ENV 5**	**ENV 6**	**ENV 7**	**ENV 8**	**ENV 9**	**ENV 10**	**ENV 11**	**ENV 12**
A52	(Okada et al., 2019)								Y	Y			
A53	(Priessner et al., 2018)								Y	Y			
A54	(Rezvani et al., 2015)							Y	Y	Y			
A56	(Sánchez-Braza et al., 2014)							Y	Y	Y			
A57	(Sang & Bekhet, 2015)									Y			
A58	(Sen et al., 2017)							Y	Y	Y			
A60	(Sierzchula et al., 2014)							Y	Y	Y			
A62	(Spena et al., 2016)								Y				
A65	(Thananusak et al., 2017)							Y	Y	Y			
A67	(Vergis & Chen, 2015)							Y	Y	Y			
A68	(N. Wang & Liu, 2015)								Y				
A69	(N. Wang et al., 2018)							Y	Y	Y			
A70	(N. Wang et al., 2017)							Y	Y	Y			
A73	(White & Sintov, 2017)							Y	Y	Y			
A74	(Y. Wu & Zhang, 2017)							Y		Y			
A75	(J. Wu et al., 2019)							Y	Y	Y			
A76	(W. Yang et al., 2015)									Y			
A77	(Yong & Park, 2017)							Y	Y	Y			
A78	(Zheng et al., 2018)							Y	Y	Y			
A79	(Zhuge & Shao, 2019)							Y	Y	Y			

3.2.8 **Geo-political**

Geo-political factors are those policies related factors which are influenced by the geographical location. China dominates the lithium-ion battery production as it has more lithium-ion reserves than other producing nations(O. Egbue & Long, 2012c). Similarly, China produces 95% of the world's rare-earth metals and enjoys its global monopoly.

As nations face scarcity of fossil fuels, it affects their energy security as well. The International Energy Agency defines energy security as the uninterrupted availability of energy sources at an affordable price. This forces the nations to better manage their resources and critically analyse their consumption. Based on the renewable energy potential, nations formulate energy policies and usage restrictions. The fossil fuel usage restriction in the transportation sector has led to the global acceptance of EVs as an alternate transportation choice.

On a global level, countries came together to fight global warming and signed the Paris agreement in 2015. The goal of climate policy was to keep global temperature rise below 2 degree Celsius in this century. Every nation who is part of the agreement was expected to take up national level initiatives to achieve this goal. Such climate policies suggest that the need of an hour can also be quite instrumental in promoting cleaner modes of transportation such as electric mobility. The variables belonging to geo-political factor are validated in Table 3-10.

Table 3-10 Geo-political factors

		52	53	54	55	56
S.No.	**Author**	**GEP1**	**GEP2**	**GEP3**	**GEP4**	**GEP5**
A5	(Bigerna & Micheli, 2018)			Y		
A6	(Biresselioglu et al., 2018)					Y
A7	(Coffman et al., 2017)			Y		
A8	(Degirmenci & Breitner, 2017)			Y		Y
A9	(Diamond, 2009)			Y		
A12	(Eppstein et al., 2011)			Y		
A13	(Faria et al., 2013)			Y		Y
A14	(Feng & Figliozzi, 2012)			Y		Y
A15	(Feng & Figliozzi, 2013)			Y		
A16	(Figenbaum et al., 2014)			Y	Y	Y
A17	(Franke et al., 2018)					Y
A19	(Gnann, Funke, et al., 2018)			Y		Y
A22	(Hahnel et al., 2014)					Y
A24	(Hanke et al., 2014)	Y	Y		Y	
A26	(Helveston et al., 2015)			Y		Y
A27	(Hosseinpour et al., 2015)					Y
A28	(Javid & Nejat, 2017)					Y
A32	(Karplus et al., 2010)				Y	Y
A33	(Khan & Kar, 2009)			Y		Y
A35	(S. Kim et al., 2017)					Y
A36	(M.-K. Kim et al., 2018)				Y	
A37	(Krupa et al., 2014)					Y
A38	(Lai et al., 2015)					Y
A39	(Lévay et al., 2017)				Y	Y
A40	(Li et al., 2017)					Y

		52	53	54	55	56
S.No.	**Author**	**GEP1**	**GEP2**	**GEP3**	**GEP4**	**GEP5**
A42	(Lin & Wu, 2018)					Y
A43	(Liu et al., 2017)	Y	Y		Y	Y
A44	(McLeay et al., 2018)			Y		Y
A46	(Mirhedayatian & Yan, 2018)				Y	
A47	(Moons & De Pelsmacker, 2012)					Y
A48	(Nanaki & Koroneos, 2016)					Y
A49	(Neaimeh et al., 2017)					Y
A50	(Neves et al., 2019)			Y		Y
A51	(Noori & Tatari, 2016)					Y
A54	(Rezvani et al., 2015)				Y	Y
A56	(Sánchez-Braza et al., 2014)				Y	
A57	(Sang & Bekhet, 2015)					Y
A59	(She et al., 2017)					Y
A60	(Sierzchula et al., 2014)			Y		Y
A61	(Soltani-Sobh et al., 2017)					Y
A62	(Spena et al., 2016)					Y
A63	(Steinhilber et al., 2013)				Y	Y
A64	(Stokes & Breetz, 2018)				Y	
A65	(Thananusak et al., 2017)					Y
A67	(Vergis & Chen, 2015)					Y
A68	(N. Wang & Liu, 2015)					Y
A73	(White & Sintov, 2017)					Y
A74	(Y. Wu & Zhang, 2017)				Y	
A76	(W. Yang et al., 2015)					Y
A77	(Yong & Park, 2017)				Y	
A79	(Zhuge & Shao, 2019)			Y	Y	Y

3.2.9 **Socio-technical**

Socio-technical factors are those factors which interrelate the social and technological aspects of society(O. Egbue & Long, 2012a). Potential customers consider several characteristics like top speed, acceleration, power, comfort, appearance, fuel economy, seating, luggage capacity and safety while they purchase a vehicle as shown in

Earlier EVs were considered inferior to an ICE vehicle. However, with technological advancements and research & development in motor design, like battery management systems and development of new materials, EVs are equivalent or even superior to ICE vehicles.

Table 3-11 Socio-technical factors

		57	58	59	60	61	62	63	64	65
SN	**Author**	**SOT 1**	**SOT 2**	**SOT 3**	**SOT 4**	**SOT 5**	**SOT 6**	**SOT 7**	**SOT 8**	**SOT 9**
A1	(Afroz et al., 2015)			Y						
A2	(Axsen et al., 2013)	Y	Y					Y		
A3	(Barth et al., 2016)				Y					
A4	(Bennett et al., 2016)	Y	Y	Y				Y	Y	
A5	(Bigerna & Micheli, 2018)							Y		
A6	(Biresselioglu et al., 2018)							Y		
A7	(Coffman et al., 2017)				Y					
A8	(Degirmenci & Breitner, 2017)	Y	Y							
A12	(Eppstein et al., 2011)			Y	Y			Y	Y	
A13	(Faria et al., 2013)	Y	Y							
A16	(Figenbaum et al., 2014)	Y	Y		Y			Y	Y	
A21	(Hagman et al., 2016)				Y					
A22	(Hahnel et al., 2014)	Y	Y		Y					
A23	(L. Han et al., 2017)			Y						
A24	(Hanke et al., 2014)	Y	Y	Y	Y	Y				Y
A26	(Helveston et al., 2015)	Y	Y							
A27	(Hosseinpour et al., 2015)					Y				Y
A29	(Juan et al., 2016)							Y		
A33	(Khan & Kar, 2009)					Y				Y
A34	(Khazaei & Khazaei, 2016)	Y	Y							
A35	(S. Kim et al., 2017)	Y	Y		Y				Y	
A36	(M.-K. Kim et al., 2018)	Y	Y	Y	Y	Y		Y		Y
A37	(Krupa et al., 2014)	Y	Y		Y			Y		
A38	(Lai et al., 2015)	Y	Y		Y	Y		Y		Y
A39	(Lévay et al., 2017)							Y		
A42	(Lin & Wu, 2018)	Y	Y		Y					
A44	(McLeay et al., 2018)						Y	Y		
A47	(Moons & De Pelsmacker, 2012)	Y	Y	Y	Y		Y		Y	
A49	(Neaimeh et al., 2017)							Y		
A50	(Neves et al., 2019)				Y					
A51	(Noori & Tatari, 2016)							Y		
A52	(Okada et al., 2019)	Y	Y		Y					
A54	(Rezvani et al., 2015)	Y	Y			Y	Y	Y		Y
A57	(Sang & Bekhet, 2015)	Y	Y		Y		Y	Y	Y	
A59	(She et al., 2017)	Y	Y		Y	Y		Y		Y
A60	(Sierzchula et al., 2014)							Y		
A62	(Spena et al., 2016)	Y	Y	Y	Y	Y	Y	Y	Y	Y
A65	(Thananusak et al., 2017)	Y	Y	Y	Y	Y	Y		Y	Y
A66	(J.-C. Tu & Yang, 2019)	Y	Y		Y	Y				Y
A68	(N. Wang & Liu, 2015)	Y	Y	Y	Y	Y				Y
A69	(N. Wang et al., 2018)	Y	Y		Y	Y				Y
A72	(Westin et al., 2018)	Y	Y		Y	Y				Y
A74	(Y. Wu & Zhang, 2017)				Y					
A76	(W. Yang et al., 2015)							Y		
A79	(Zhuge & Shao, 2019)	Y	Y		Y		Y	Y	Y	

3.2.10 **Socio-cultural**

Socio-cultural factors like age, gender, educational qualification, income and occupation etc also influence the purchase intention of customers. Youngsters and adults are more open to newer technologies and are early adopters of EVs (Mukherjee & Ryan, 2020). Customers with a high educational background are more likely to invest in sustainable cleaner technology than uneducated customers. Income is an obvious factor while making the choice of vehicle. Families with a stable and high income tend to opt EVs easily. The content validation of the socio-cultural factor and its variables are shown in Table 3-12.

Table 3-12 Socio-cultural factors

		66	67	68	69	70
S.No.	**Author**	**SEO1**	**SEO2**	**SEO3**	**SEO4**	**SEO5**
A1	(Afroz et al., 2015)				Y	
A4	(Bennett et al., 2016)				Y	
A7	(Coffman et al., 2017)			Y	Y	
A8	(Degirmenci & Breitner, 2017)			Y	Y	Y
A9	(Diamond, 2009)				Y	
A11	(Du et al., 2018)			Y	Y	Y
A12	(Eppstein et al., 2011)				Y	
A14	(Feng & Figliozzi, 2012)				Y	
A15	(Feng & Figliozzi, 2013)				Y	
A16	(Figenbaum et al., 2014)	Y	Y	Y	Y	Y
A22	(Hahnel et al., 2014)				Y	
A23	(L. Han et al., 2017)			Y	Y	Y
A28	(Javid & Nejat, 2017)			Y	Y	Y
A30	(Junquera et al., 2016)	Y	Y			
A31	(Kaplan et al., 2016)	Y	Y	Y		
A35	(S. Kim et al., 2017)			Y	Y	
A36	(M.-K. Kim et al., 2018)	Y	Y	Y	Y	Y
A37	(Krupa et al., 2014)	Y	Y	Y	Y	Y
A38	(Lai et al., 2015)	Y	Y	Y	Y	Y
A40	(Li et al., 2017)	Y	Y	Y	Y	Y
A41	(Lin & Tan, 2017)	Y	Y	Y	Y	Y
A42	(Lin & Wu, 2018)	Y	Y	Y	Y	Y
A44	(McLeay et al., 2018)	Y	Y	Y	Y	Y
A50	(Neves et al., 2019)			Y		Y
A52	(Okada et al., 2019)	Y	Y		Y	
A53	(Priessner et al., 2018)	Y	Y	Y	Y	Y

		66	67	68	69	70
S.No.	**Author**	**SEO1**	**SEO2**	**SEO3**	**SEO4**	**SEO5**
A55	(Saarenpää et al., 2013)	Y	Y	Y	Y	Y
A56	(Sánchez-Braza et al., 2014)	Y	Y	Y	Y	Y
A57	(Sang & Bekhet, 2015)	Y	Y	Y	Y	Y
A58	(Sen et al., 2017)	Y	Y	Y	Y	Y
A59	(She et al., 2017)	Y	Y	Y	Y	Y
A60	(Sierzchula et al., 2014)	Y	Y	Y	Y	Y
A61	(Soltani-Sobh et al., 2017)				Y	
A62	(Spena et al., 2016)	Y	Y	Y	Y	Y
A65	(Thananusak et al., 2017)	Y	Y	Y	Y	Y
A66	(J.-C. Tu & Yang, 2019)	Y	Y	Y	Y	Y
A67	(Vergis & Chen, 2015)			Y		
A68	(N. Wang & Liu, 2015)	Y	Y	Y	Y	Y
A69	(N. Wang et al., 2018)	Y	Y	Y	Y	Y
A70	(N. Wang et al., 2017)	Y	Y	Y	Y	Y
A71	(S. Wang et al., 2017)				Y	
A72	(Westin et al., 2018)	Y	Y	Y	Y	Y
A73	(White & Sintov, 2017)	Y	Y	Y	Y	Y
A75	(J. Wu et al., 2019)	Y	Y	Y	Y	Y
A79	(Zhuge & Shao, 2019)	Y	Y	Y	Y	Y

3.2.11 **Behavioural**

Behavioural factors are those which are part of an individual's lifestyle. An EVs does not mean anything to a person who relies more on public transport for a commute. Current EVs give a range of 300 km on a full charge. Low range models can serve individuals with less daily travel distance. Individual’s resistance to change can be a barrier for adoption of EV. Adopting EV technology implies major changes in lifestyle like vehicle usage patterns, recharging patterns, etc (Lai et al., 2015). The acceptance thus depends on factors like driving distance, parking time, driving time, recharging frequency, number of trips per day, etc. The content validation of the behavioural factor and its variables are shown in Table 3-13.

Table 3-13 Behavioural factors

		71	72	73	74	75	76
S. No.	**Author**	**BEH1**	**BEH2**	**BEH3**	**BEH4**	**BEH5**	**BEH6**
A2	(Axsen et al., 2013)		Y			Y	Y
A4	(Bennett et al., 2016)						Y
A5	(Bigerna & Micheli, 2018)						Y
A6	(Biresselioglu et al., 2018)						Y

		71	72	73	74	75	76
S. No.	**Author**	**BEH1**	**BEH2**	**BEH3**	**BEH4**	**BEH5**	**BEH6**
A7	(Coffman et al., 2017)						Y
A8	(Degirmenci & Breitner, 2017)						Y
A10	(Digalwar & Giridhar, 2015)						Y
A16	(Figenbaum et al., 2014)		Y		Y	Y	Y
A17	(Franke et al., 2018)						Y
A18	(Franke et al., 2012)						Y
A20	(Habib et al., 2018)						Y
A22	(Hahnel et al., 2014)						Y
A27	(Hosseinpour et al., 2015)	Y					Y
A29	(Juan et al., 2016)						Y
A30	(Junquera et al., 2016)				Y		Y
A31	(Kaplan et al., 2016)				Y		
A32	(Karplus et al., 2010)		Y			Y	
A34	(Khazaei & Khazaei, 2016)		Y			Y	
A35	(S. Kim et al., 2017)		Y			Y	Y
A36	(M.-K. Kim et al., 2018)		Y		Y	Y	
A37	(Krupa et al., 2014)		Y		Y	Y	
A38	(Lai et al., 2015)		Y		Y	Y	
A40	(Li et al., 2017)		Y		Y	Y	Y
A41	(Lin & Tan, 2017)				Y		
A42	(Lin & Wu, 2018)				Y		Y
A44	(McLeay et al., 2018)		Y		Y	Y	
A47	(Moons & De Pelsmacker, 2012)	Y					Y
A49	(Neaimeh et al., 2017)						Y
A50	(Neves et al., 2019)			Y			
A52	(Okada et al., 2019)				Y		
A53	(Priessner et al., 2018)		Y		Y	Y	
A54	(Rezvani et al., 2015)		Y			Y	Y
A55	(Saarenpää et al., 2013)				Y		
A56	(Sánchez-Braza et al., 2014)				Y		
A57	(Sang & Bekhet, 2015)		Y		Y	Y	Y
A58	(Sen et al., 2017)				Y		
A59	(She et al., 2017)		Y		Y	Y	Y
A60	(Sierzchula et al., 2014)				Y		
A62	(Spena et al., 2016)		Y		Y	Y	
A63	(Steinhilber et al., 2013)			Y			
A65	(Thananusak et al., 2017)		Y		Y	Y	Y
A66	(J.-C. Tu & Yang, 2019)		Y		Y	Y	Y
A68	(N. Wang & Liu, 2015)				Y		
A69	(N. Wang et al., 2018)		Y		Y	Y	Y
A70	(N. Wang et al., 2017)				Y		
A72	(Westin et al., 2018)		Y		Y	Y	Y

		71	72	73	74	75	76
S. No.	**Author**	**BEH1**	**BEH2**	**BEH3**	**BEH4**	**BEH5**	**BEH6**
A73	(White & Sintov, 2017)		Y		Y	Y	
A74	(Y. Wu & Zhang, 2017)		Y			Y	
A75	(J. Wu et al., 2019)				Y		
A77	(Yong & Park, 2017)		Y			Y	Y
A78	(Zheng et al., 2018)						
A79	(Zhuge & Shao, 2019)		Y		Y	Y	Y

3.2.12 **Infrastructural**

EVs and supporting infrastructure go hand-in-hand. Both are essential for the existence of one another. Supporting infrastructure consist of charging infrastructure, service and maintenance infrastructure, reliable electricity infrastructure and R&D infrastructure. Setting up charging stations at home, workplace, public places and highways is crucial for driving the fear of range of EVs away from the customers. Early adopters rely mainly on home charging; however, as more customers switch to electric mobility, it becomes essential to set up charging stations at public places and highways to cater the need of customers who travel a long distance(Jensen et al., 2014). Service and maintenance of EVs are entirely different from conventional vehicles, so dedicated service centres and repair workshops need to be set up with in accessibility of the customers(Morrissey et al., 2016a). Reliable electricity infrastructure to support the excess needs from EVs also needs to be met. To strengthen the EVs industry, R&D centres for EVs manufacturing should also be set up. Table 3-14 shows the content validation of the infrastructural factor and its variables.

Table 3-14 Infrastructural factors

		77	78	79	80
S.No.	**Author**	**INF1**	**INF2**	**INF3**	**INF4**
A1	(Afroz et al., 2015)	Y			
A2	(Axsen et al., 2013)	Y			
A3	(Barth et al., 2016)	Y			
A4	(Bennett et al., 2016)	Y			
A5	(Bigerna & Micheli, 2018)	Y			
A6	(Biresselioglu et al., 2018)	Y			
A7	(Coffman et al., 2017)	Y			
A8	(Degirmenci & Breitner, 2017)			Y	Y
A9	(Diamond, 2009)	Y			
A10	(Digalwar & Giridhar, 2015)		Y		Y
A11	(Du et al., 2018)	Y			

		77	78	79	80
S.No.	**Author**	**INF1**	**INF2**	**INF3**	**INF4**
A15	(Feng & Figliozzi, 2013)	Y			
A16	(Figenbaum et al., 2014)	Y		Y	
A17	(Franke et al., 2018)	Y		Y	
A18	(Franke et al., 2012)	Y			
A19	(Gnann, Funke, et al., 2018)	Y			
A20	(Habib et al., 2018)			Y	
A21	(Hagman et al., 2016)			Y	
A24	(Hanke et al., 2014)	Y	Y		Y
A26	(Helveston et al., 2015)	Y		Y	
A27	(Hosseinpour et al., 2015)	Y			
A28	(Javid & Nejat, 2017)	Y			
A29	(Juan et al., 2016)	Y			
A31	(Kaplan et al., 2016)	Y			
A33	(Khan & Kar, 2009)		Y		Y
A34	(Khazaei & Khazaei, 2016)	Y	Y		
A35	(S. Kim et al., 2017)	Y			
A36	(M.-K. Kim et al., 2018)	Y			
A37	(Krupa et al., 2014)		Y		
A38	(Lai et al., 2015)	Y			
A40	(Li et al., 2017)	Y			
A41	(Lin & Tan, 2017)	Y			
A42	(Lin & Wu, 2018)	Y			
A43	(Liu et al., 2017)	Y	Y		
A45	(Mersky et al., 2016)	Y			
A47	(Moons & De Pelsmacker, 2012)	Y	Y		
A48	(Nanaki & Koroneos, 2016)	Y		Y	
A49	(Neaimeh et al., 2017)	Y		Y	
A50	(Neves et al., 2019)	Y		Y	
A52	(Okada et al., 2019)	Y		Y	
A53	(Priessner et al., 2018)	Y			
A54	(Rezvani et al., 2015)	Y			
A57	(Sang & Bekhet, 2015)	Y			
A59	(She et al., 2017)	Y	Y		
A60	(Sierzchula et al., 2014)	Y			
A62	(Spena et al., 2016)	Y	Y		
A63	(Steinhilber et al., 2013)	Y			Y
A64	(Stokes & Breetz, 2018)			Y	
A65	(Thananusak et al., 2017)	Y			
A66	(J.-C. Tu & Yang, 2019)	Y			
A67	(Vergis & Chen, 2015)	Y			
A68	(N. Wang & Liu, 2015)	Y	Y		

		77	78	79	80
S.No.	**Author**	**INF1**	**INF2**	**INF3**	**INF4**
A69	(N. Wang et al., 2018)	Y	Y		
A71	(S. Wang et al., 2017)	Y			
A72	(Westin et al., 2018)	Y			
A73	(White & Sintov, 2017)	Y			
A76	(W. Yang et al., 2015)			Y	
A79	(Zhuge & Shao, 2019)	Y			

The literature available on the factors responsible for adoption of EVs indicates a need to:

- Develop and validate a comprehensive set of factors and their variables which take into account all the aspects of EVs manufacturing.
- Develop a framework which integrates all factors and which can be used for continuous improvement and sustainable growth of EVs manufacturing in India.

3.3 Summary

The present chapter theoretically justified factors identified by literature review, for adoption of EVs and their sustainable manufacturing in India. Experts from relevant background came together for brainstorming and finally categorized the 80 variables into 12 factors using nominal grouping technique. The affinity diagram of the same is also constructed in this chapter.

The present chapter compiles a detailed description of survey instrument and descriptive analysis of survey data. It also contains the computation of importance index analysis of identified factors with respect to demographic factors and importance index analysis of variables under each identified factor.

4.1 Introduction

A three-step method has been proposed for the realization of the research objectives.

In the first step, a rigorous literature survey for identification of the effective factors and variables has been performed in the previous section of study. The effectiveness of these factors and variables are analysed by conducting a survey in the present section.

In the second step, the identified factors are categorized as causal and effect factors using the decision-making trial and evaluation laboratory (DEMATEL) method. The results of DEMATEL are visually represented through causal diagram that showcases the driving power and overall relationship of factors, in the next section of the study.

In the third step, a multi-level hierarchical structure of the developed factors based on interdependencies is modelled using Interpretive Structural Modelling (ISM). The steps involved in each stage of research are summarized in Figure 4-1.

4.2 Survey Instrument

The questionnaire has been developed as a research tool with the goal of tapping the collective expertise of manufacturing industry specialists who genuinely care about it, as well as policy makers, suppliers, stakeholders and potential customers from metropolitan, urban, and rural areas of India, in order to determine the relative relevance of variables. A questionnaire was formulated using the identified criteria and associated variables. A covering letter was created with general information about the research work and instrument, such as the study's goal, the confidentiality of the responses, and a request to return the completed questionnaire. To aid data interpretation, the questionnaire was then separated into descriptive and statistical sections.

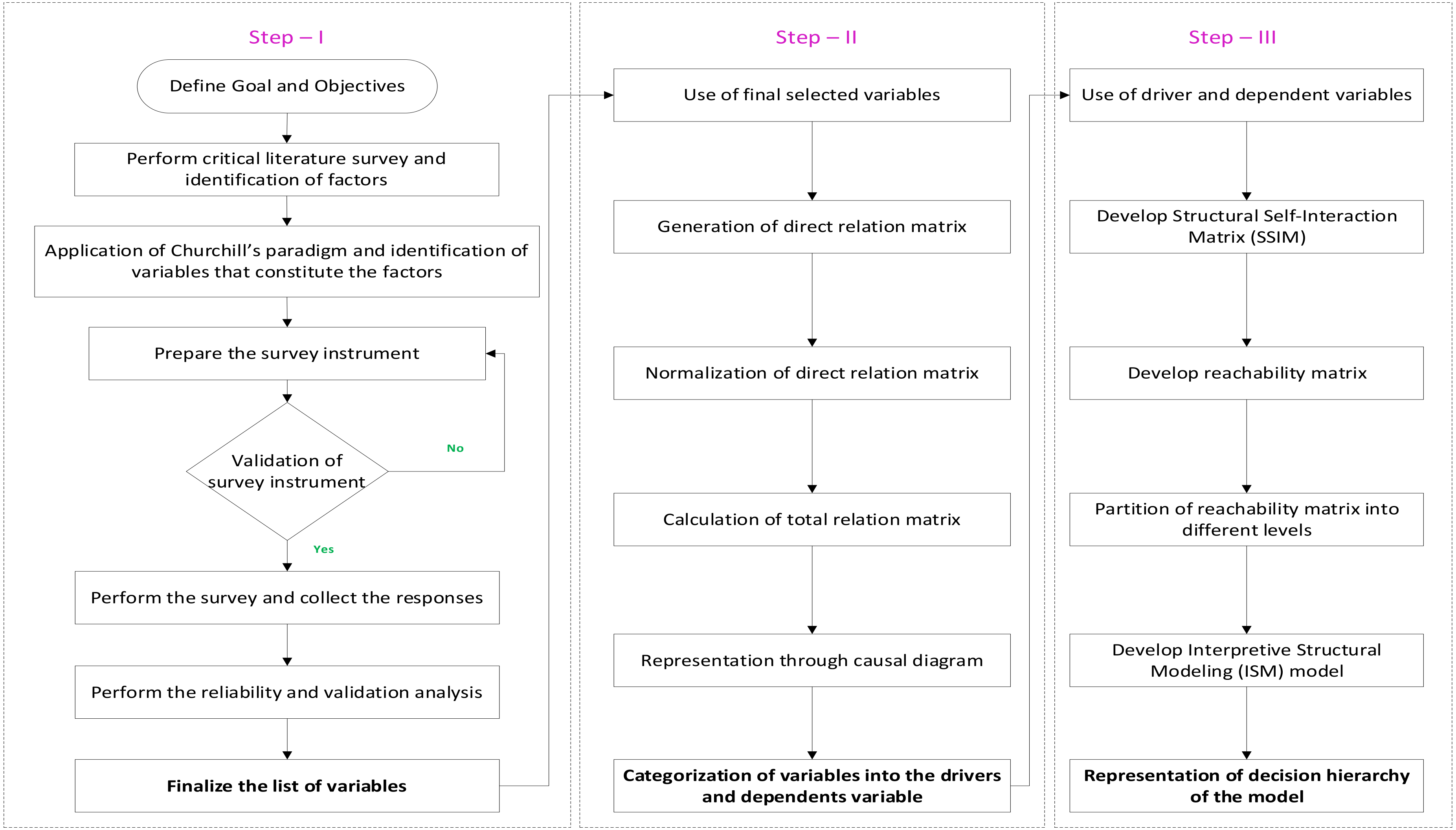

Figure 4-1 Research methodology of proposed work

The questions were examined for clarity and content from five academician and five industry experts to ensure the simplicity, relevancy and adequacy of the questions. To allow participants to reply to the survey items, a five-point Likert scale (1-5) was utilized, with 1 denoting extremely low, 2 denoting low, 3 denoting medium, 4 denoting moderate, and 5 denoting very high. Respondents were asked to rate the degree or extent of practice of each item using the five-point Likert scale and the corresponding performance measure.

Pre-testing took place in two stages. In the first stage, ten experts were given a draft of the questionnaire and asked them to critically examine the questions in terms of specificity and clarity of construction. Some questions were updated in response to feedback to increase their specificity and clarity.

The questionnaire was given to ten industrial professionals in the second pre-test. The professionals were asked to complete the amended questionnaire and note any ambiguity or other difficulty they had while answering the questions, as well as provide any recommendations they thought were suitable. The questionnaire was revised based on experts' feedback after the second pre-test, and the wording of some items was changed to make the final research instrument more effective. Appendix contains the completed questionnaire. A pre-test suggested that the questionnaire would take 15-20 minutes to complete.

4.2.1 **Survey**

Snowball sampling approach has been adopted for the collection of data. In this regard, initially, 100 participants were invited to participate in the study.

The survey was administered from August 2020 to February 2021. The questionnaires were mainly targeted to manufacturer, potential customers from cities, urban and rural areas, suppliers and existing users. The experts have been chosen from fields like Academics (AC), Non-Government Organizations (NGOs), Engineering (ENG), Industry Experts (IE), Environment Experts (EE), Investors (INV), and Others. The classes of expert "others" encompass the politicians, social workers, people from the general public, and authorities' employees. The objective of considering the experts from different fields was to cover their angle and suitable assessment of the various indicators (Saraswat & Digalwar, 2021). To obtain consent to participate in the survey, the sample group was contacted by phone or e-mail. Participants were contacted ahead of time to schedule visits to their offices/plants for the survey. The questionnaires' Google form links were sent via e-mail, and in some cases, the questionnaires were handed out to the responders in person. Mostly the survey was conducted by online platform due to current pandemic situation with the academicians and industry experts. Every interview is preceded by a brief introduction pertaining to the objectives of the study and its methodology and then respondent used to fill the questionnaire. Each of these interviews lasted one to one and half-hours. In some circumstances, experts were so busy that after being briefed on the survey, they pledged to return the questionnaire whenever it was convenient for them within a week or two. If these respondents did not return the questionnaires within the time frame they promised, they were contacted by phone or e-mail.

A total of 940 responses were collected out of which 38 were rejected due to incomplete responses. The ratings given by the remaining 902 responses were used to conduct importance index analysis, reliability analysis, and validity analysis to arrive at the final framework of factors and variables. The remaining 902 responses (leading to an acceptable response rate of 95.96%) were used for further analysis.

The greater response rate is mostly due to the use of snowball sampling in conjunction with a human contact strategy. Despite the fact that this strategy is time-consuming and impractical in many circumstances, it was successful in this investigation. The response rate was higher than the average for survey research in the manufacturing industry, and the sample size was sufficient for statistical analysis (Phogat & Gupta, 2019).

To determine the causes for not returning completed questionnaires, a non-response analysis was undertaken. Direct phone contact with a randomly selected subset of 15 non-respondents was employed to determine why they did not respond. The main cause for respondents' non-response was a lack of time to complete a questionnaire. This is the reason cited by all non-respondents. In terms of organizational demographics, non-respondents were no different than respondents. As a result, the actual responses received can be deemed to be the original sample's legitimate responses.

4.3 **Data Preparation**

Effective data preparation and management are required for proper data analysis. In choosing a database-management system, the length of the questionnaire, the expected number of completed surveys, and the data analysis tools to be used all had to be taken into account. Microsoft excel, a logical database-management application, was chosen for this task. In the database, survey responses were coded. Open-ended replies, both quantitative and qualitative, were recorded for future research. This also aided in the clarification of quantitative responses (Phogat & Gupta, 2019).

The survey data was broken down into three sections: descriptive analysis, importance index analysis, and statistical analysis. Counting the frequencies of demographic data, calculating the proportion, and presenting the results in tables is the descriptive statistic utilised. The objective of importance index analysis is to determine the numerical scores of each item. The goal of statistical analysis is to figure out how the variables are related and to validate the performance measures/factors. A thorough assessment of the descriptive characteristics of the organization and specialists, as well as statistical analysis of the factors, is required for a thorough analysis. The following sections cover descriptive analysis and importance index analysis, while the statistical analysis is covered in the next chapter.

4.4 **Descriptive Analysis**

The data was first investigated using Microsoft Excel to represent descriptive features. The study Firstly the calculated proportion and frequency count are presented in the results through tables and graphs using descriptive analysis. The descriptive data reflect the solicitation of respondents from different states.

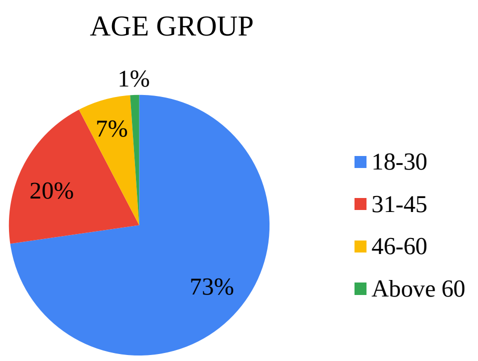

Figure 4-2 Data based on age group

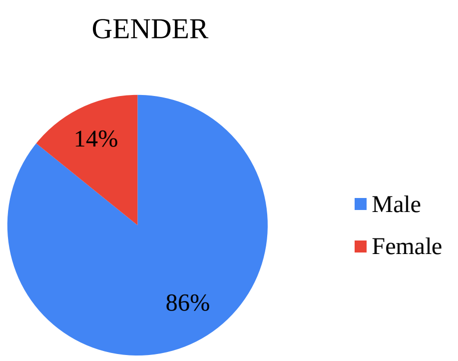

Figure 4-3 Gender based classification

Data has been first classified based on age group and then by gender. Out of total responses, 73% fall under the age group of 18-30 years followed by 20% under the age group of 31-45 years, 7% under the age group of 46-60 years and only 1% above 60 years age group as shown in Figure 4-2. The gender wise distribution was male (86%) and female (14%) as shown from Figure 4-3. Further the respondents were classified based on their academic qualifications. Under this classification, 55% respondents were having master's degree followed by 27% having undergraduate degree, 9% having doctorate degree as well as qualified till 10+2 standards each as shown in Figure 4-4.

As shown in Figure 4-4, the respondents were classified whether they are technically qualified or not, 85% respondents were technically qualified while rest 15% were not having technical qualifications.

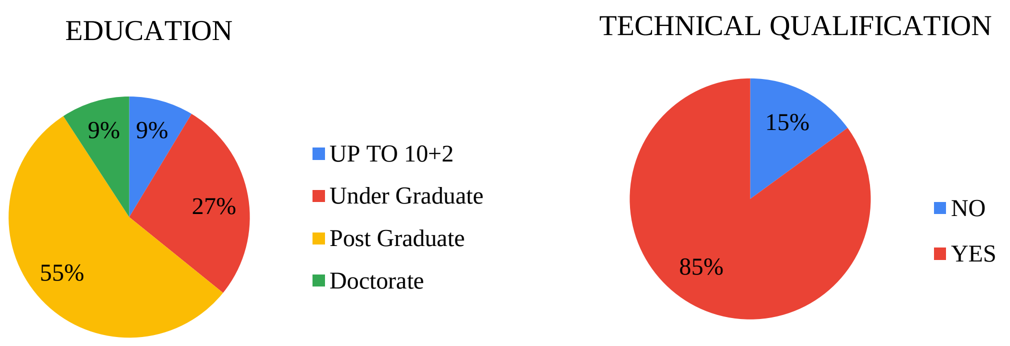

Figure 4-4 Data classification based on education and technical qualification

As shown from Figure 4-5, based on respondent's occupation, 60% respondents who participated in the survey were potential users followed by 34% service personals, 5% business professionals, and 1% was retired persons. This indicates that the survey was conducted in the right manner to get representation from all segments of society. Individuals have different pay scales based on their experience and expertise. Therefore while classifying based on monthly income as shown in Figure 4-5, 40% respondents fall in the category of monthly income less than Rs. 25000, followed by 21% in the range of Rs. 25000 - Rs. 50000, 17% in the range of Rs. 50000 - Rs. 75000, 7% in the range of Rs. 75000 - Rs. 100000 and 16% having monthly income more than Rs. 100000.

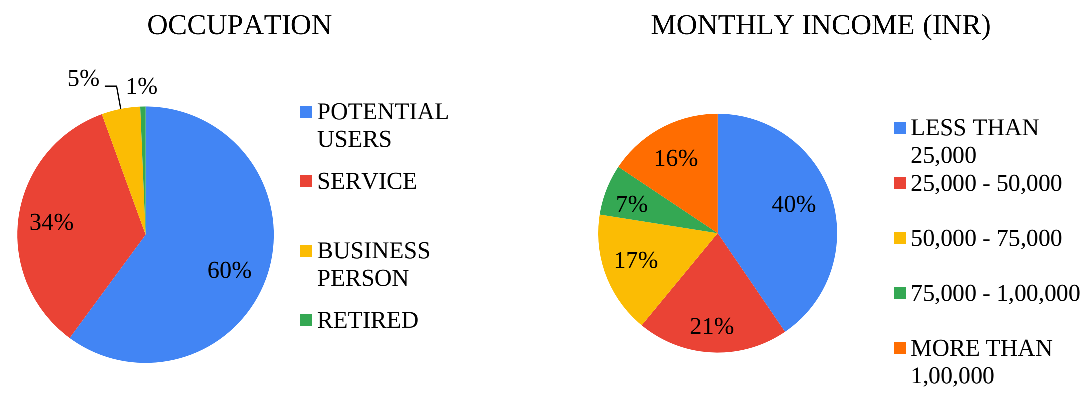

Figure 4-5 Data classification based on occupation and income

In further descriptive classification, the responses collected from the survey were categorized based on the city of residence of the respondents shown in Figure 4-6. India is a densely populated country that has four main divisions: Urban, Rural, Metropolitan, and National Capital Region (NCR). Out of total responses, 51% were collected from urban centres, followed by 21% from NCR, 15% from rural and 14% from metropolitan city. India is divided into five regions based on their geographical locations: the Eastern region, the North-eastern region, the Northern region, the Southern region, and the Western region. Bihar, Jharkhand, Odisha, Sikkim, and West Bengal make the Eastern region. In the north-eastern region, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, and Tripura are located. The northern states include Chandigarh, Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, Uttar Pradesh, and Uttarakhand. Andhra Pradesh, Karnataka, Kerala, Lakshadweep, Pondicherry, Tamil Nadu, and Telangana make up the southern region. Finally, the western states include Chhattisgarh, Dadar & Nagar Haveli, Daman & Diu, Goa, Gujarat, Madhya Pradesh, and Maharashtra. In terms of percentage share, the western and northern regions received the most responses 44% and 39% respectively. Similarly, the southern and eastern regions received 10% and 6% of the responses, respectively (Saraswat & Digalwar, 2021). We got only 1% responses from the north eastern region compared to the northern and western regions because of the Covid-19 pandemic, affecting our country when the survey was being conducted as shown in Figure 4-6.

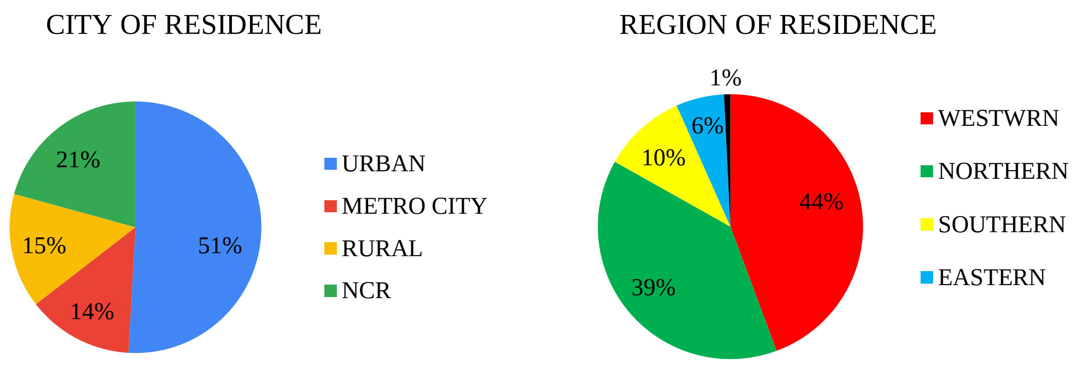

Figure 4-6 Data classified based on city of resident and region of residence

The behavioural factors were also considered as they vary person to person. Considering distance travelled per day as shown in Figure 4-7, the distance range of 0-25 km got the highest number of responses i.e. 66%, followed by 24% for the distance range of 25-50 km, 5% for the range of 50-75 km and 5% for more than 75 km distance travelled per day. This shows that the majority of the respondents are short to medium-distance travellers and approximately 90% travellers come from the first distance ranges. We also classified refuelling frequency into daily (18%), weekly (55%), twice a month (20%), and monthly (7%) responses respectively as shown in Figure 4-8.

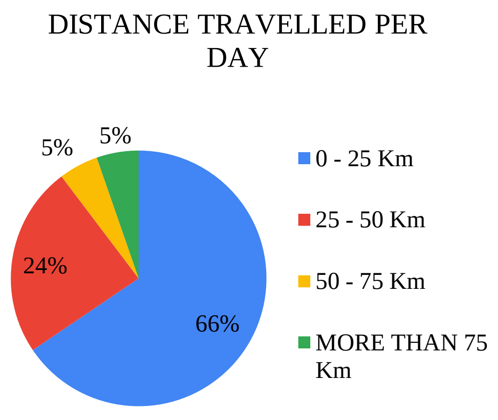

Figure 4-7 Distance travelled per day

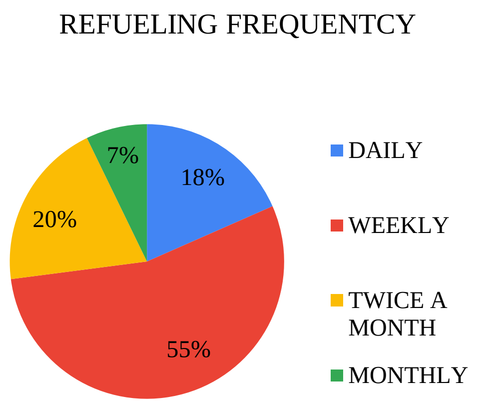

Figure 4-8 Refuelling frequency

When enquired about driving pattern, as shown in Figure 4-9, we find that many individuals used to prefer a steady driving with 73% responses followed by fast/ accelerated driving with 25% responses and racing mode with only 3% responses. People purchase vehicles, depending on their requirements and needs. This survey also focuses on the buying preference of customers, 46% respondents showed interest in 5-seater (economy sedan/ hatchback), while 2-wheelers, luxury cars, 7-seater compact SUVs, and commercial vehicles received 25%, 16%, 12% and only 0.33% responses respectively as shown in Figure 4-10.

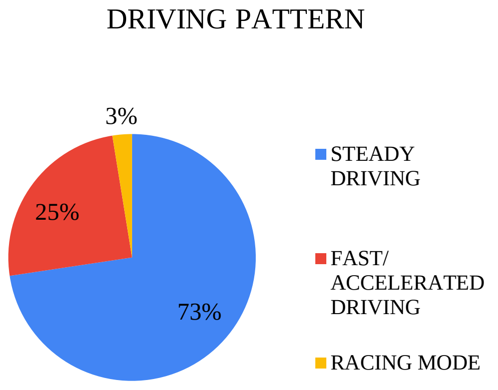

Figure 4-9 Driving pattern

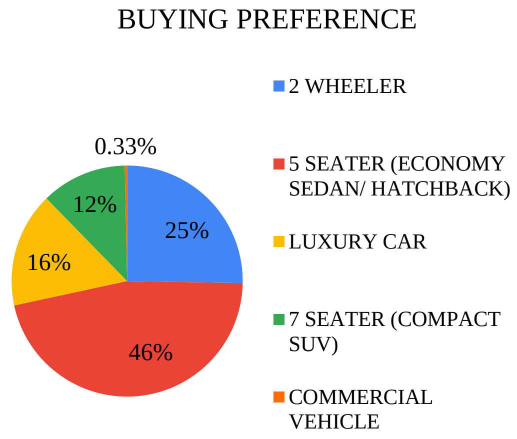

Figure 4-10 Buying preference of customers

4.5 Importance Index Analysis

The numerical ratings on the questionnaire represented the strength of opinion on the impact of each variable on the project's performance. The following formula is used to convert these into relative importance index (RII). These indices reflect the relative importance of the factors listed in the questionnaire.

$$\text{Relative Importance Index (RII)} = \sum W / AN$$

where, N = number of respondents, A = maximum weight given to single criterion (A = 5), and W = weight given to each factor by the respondent to the criterion ranging from 1 to 5.

The following section describes the importance index of factors from demographic and variables prospective.

4.5.1 Importance index analysis of identified factors

RII is first calculated for the 12 identified factors with respect to demographic factors as mentioned in survey questionnaire i.e. Age, Gender, Education, Technical qualifications, Occupation, Monthly income, City of residence, Region of residence, Distance travelled per day, refuelling frequency, driving pattern and Buying preference.

Age

The respondents were categorized by age into young adults (18-31 years), middle-aged adults (31-45 years), older adults (46-61 years), and elderly people (greater than 61 years). Surveying on age ranges to identify the age demographic of the respondents, will reveal if there is a strong correlation between age and the factors responsible for adoption and sustainable manufacturing of EVs in India. It is observed that young adults have given the highest importance to the "social factor" (0.873) followed by "environmental factor" (0.843), and "economic factor" (0.815), while the least importance is given to "geographical factor" (0.671). Middle-aged adults have also preferred the "social factor" (0.858) to be of highest importance, followed by "environmental factor" (0.818), "geo-political factor" (0.786) while "infrastructural factor" (0.579) was considered as the least important factor. Similarly, respondents in the old age group gave the highest preference to "political factor" (0.795) followed by "environmental factor" (0.789), social (0.742), and the least preference was given to "geographical" (0.605). Elderly people have chosen the highest and the lowest preference to the "behavioural factor" (0.938) and "socio-technical" (0.538) respectively as shown in Figure 4-11.

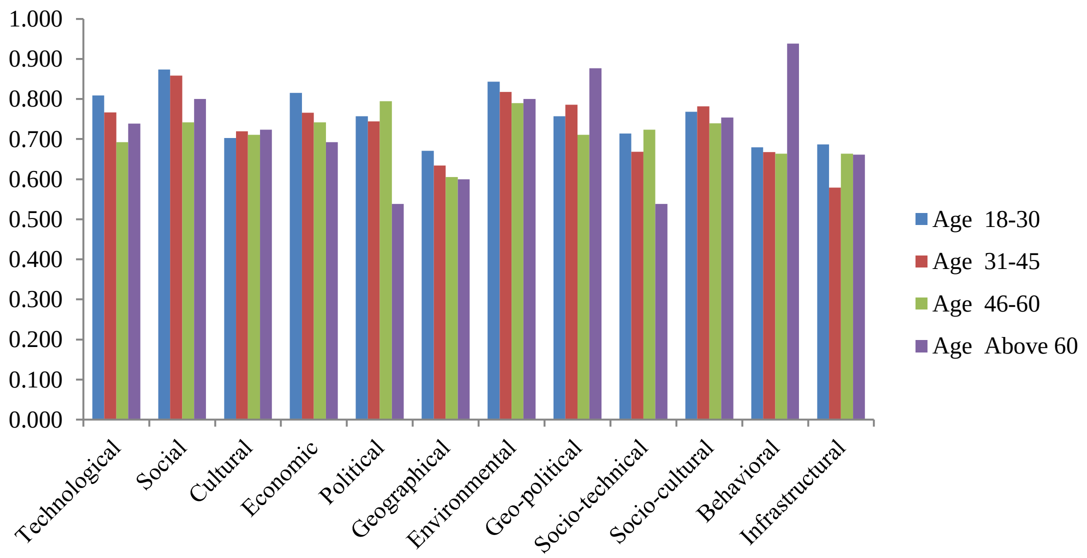

Figure 4-11 Relative importance index (Age)

Gender

Gender statistics are important for monitoring gender gaps by accepted variables that are relevant to men's and women's lives. In social research, gender is an important demographic trait to analyse. From Figure 4-12, it is observed that males have given the highest importance to the "social factor" (0.869) followed by "environmental factor" (0.840), while the least importance is given to "infrastructural factor" (0.661). Females responded in almost similar manner with "social factor" (0.809) and "environmental factor" (0.800) as the most important and second most important factor, while the least importance is given to "geographical factor" (0.628).

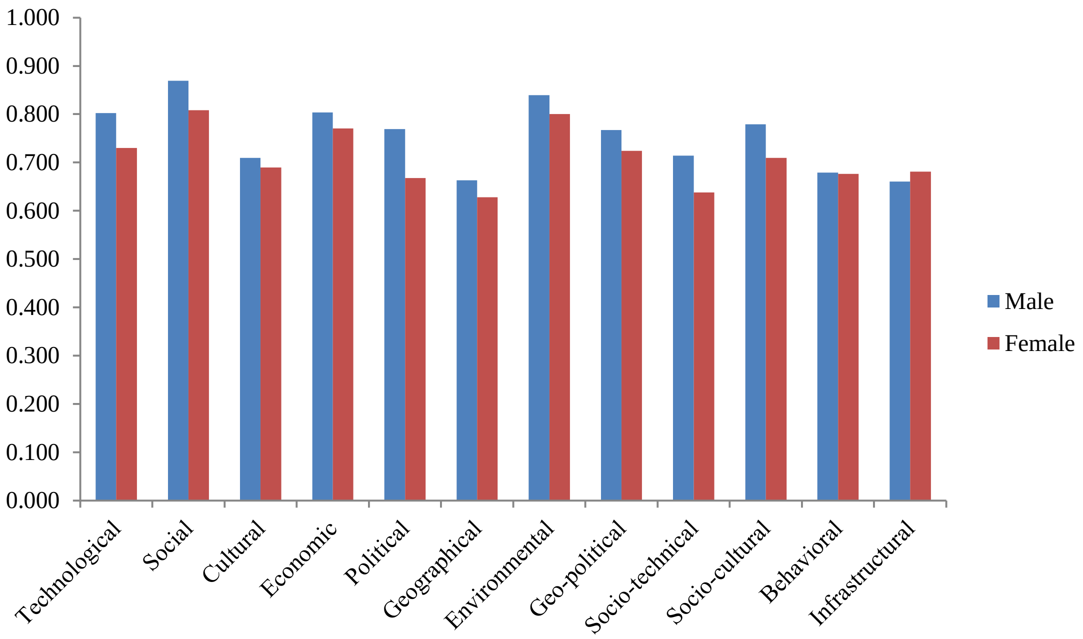

Figure 4-12 Relative importance index (Gender)

Education

In the educational category, as shown in Figure 4-13, the highest RII is given to "social factor" (0.770) and "technological factor" (0.736) by the respondents with a doctorate, while the least weightage is given to "geographical factor" (0.591). It is observed that post graduate respondents have given the highest and the least preference to "social factor" (0.865) and "infrastructural factor" (0.612) respectively. Under graduate, respondents preferred "social factor" (0.870) and "environmental" (0.843) as the most important considerations, while "behavioural factor" (0.673) was considered as the least important criterion. Similarly, respondents with qualifications up to 10+2 standard have also chosen "social factor" (0.897) and "environmental factor" (0.880) as the most important criterion, whereas “geographical factor” with RII of 0.627 got the least preference. In the educational category, the highest RII is given to “social factor” (0.870) which may be due to lack of awareness of EVs among people and social acceptance of EVs.

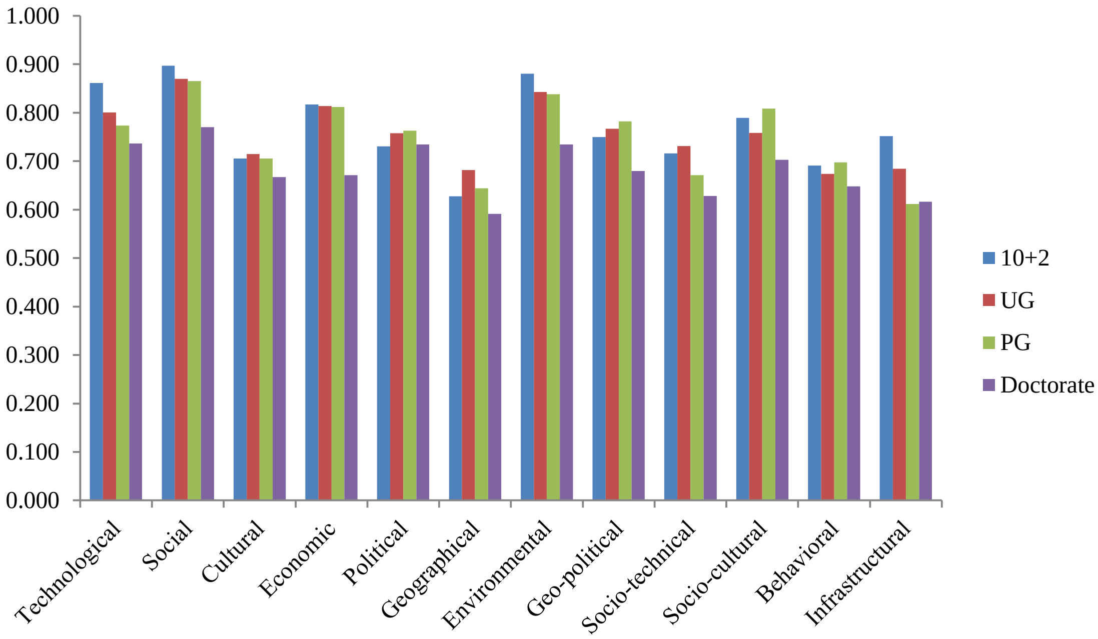

Figure 4-13 Relative importance index (Education)

Technical Qualification

Based on the technical qualifications, respondents with technical backgrounds also assigned highest priority to “social factor” followed by “environmental factor” with RII of 0.862 and 0.829 respectively, while the least priority was assigned to “geographical factor” with RII of 0.661. Those respondents without technical qualification have given the highest preference to “economic factor” (0.863) and “environmental factor” (0.862) while “geographical factor” with RII of 0.642 again stood on least priority as shown in Figure 4-14.

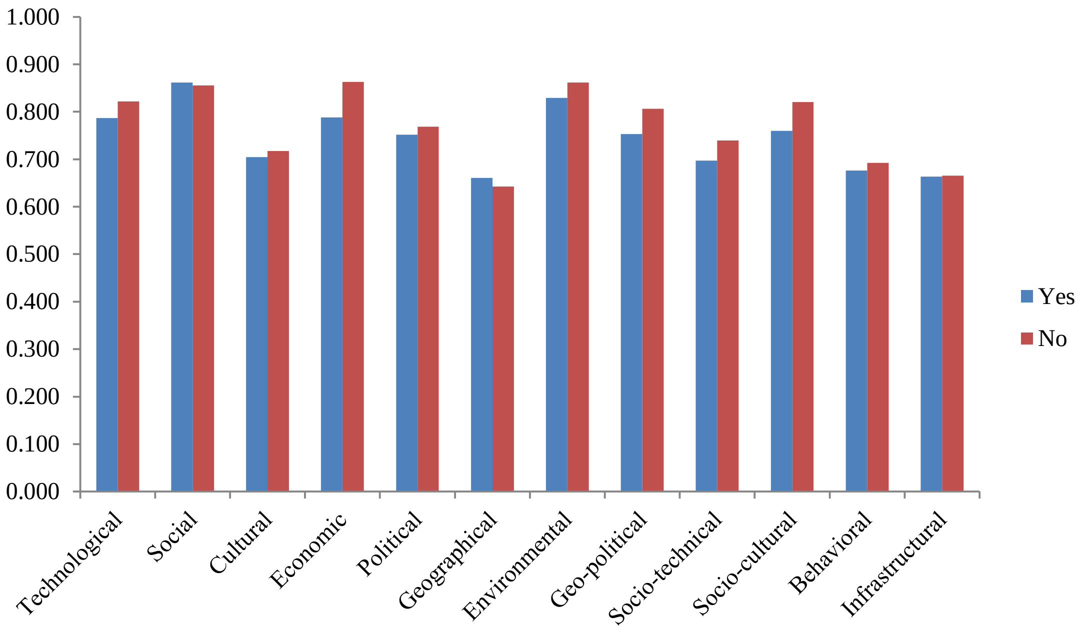

Figure 4-14 Relative importance index (Technical Qualification)

Occupation

On the basis of occupation, it is evident from the Figure 4-15 that business persons have a primary concern about the “environmental factor” (0.950) and “geo-political factor” (0.943). They considered “infrastructural factor” (0.782) and “geographical factor” (0.750) as the least essential indicators. The analysis also shows that potential users have highly favoured “social factor” (0.880) and “environmental factor” (0.853), and least favoured “infrastructural factor” (0.680) and “geographical factor” (0.669). It has been further observed that the respondents currently in service gave the highest weightage to “social factor” (0.822) and “environmental factor” (0.784), while the least weightage were given to “infrastructural factor” and “geographical factor” with RII of 0.617 and 0.626 respectively. The respondents who were retired, choose the highest and least priority for “behavioural factor” (0.911) and “socio-technical factor” (0.422) respectively.

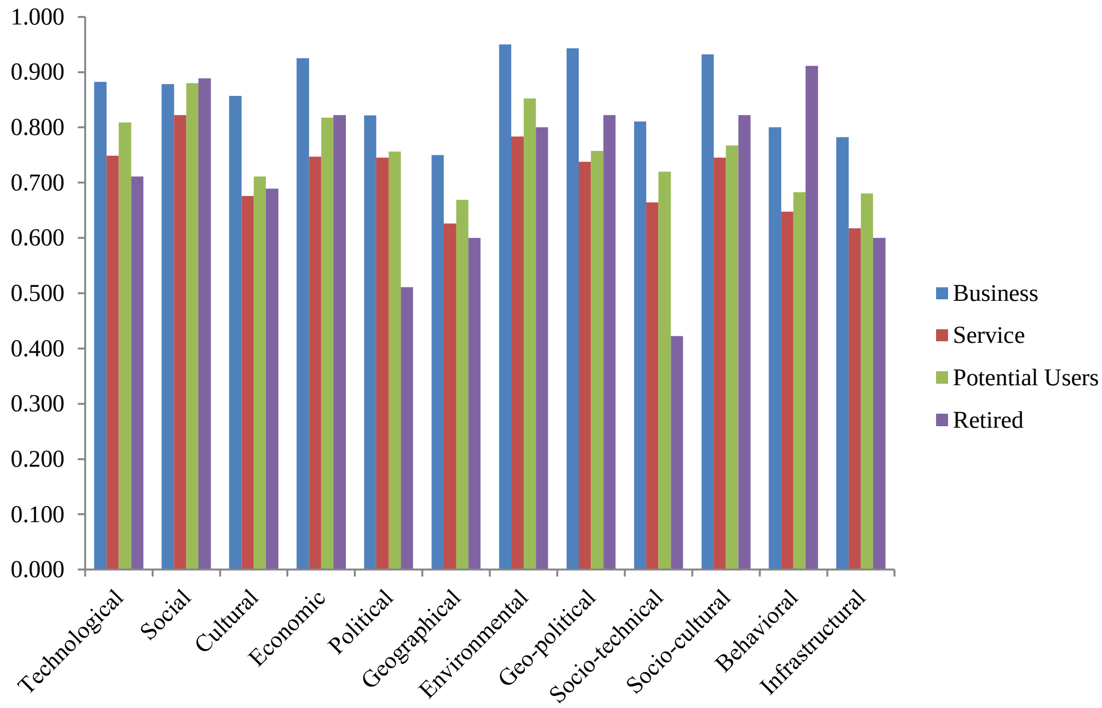

Figure 4-15 Relative importance index (Occupation)

Monthly Income

Based on monthly income, as shown in Figure 4-16 the respondents with a monthly income of less than Rs. 25,000 have given the highest weights to “social factor” (0.882) and “environmental factor” (0.850), while “infrastructural factor” (0.658) was considered as the least preference. Respondents from monthly income group of Rs. 25,000 - Rs. 50,000 preferred “environmental factor” (0.865) as the most important indicator followed by “social factor” (0.861) and “geographical factor” (0.664) as the least important indicator. Respondents with monthly income range Rs. 50,000 - Rs. 75,000 preferred similar pattern with “social factor” (0.872) as the most important criterion followed by “environmental factor” (0.819) and “infrastructural factor” (0.629) as the least important criterion. Respondents with monthly income range Rs. 75,000 - Rs. 1,00,000 have chosen the highest and least indicators as “social factor”(0.842) and “behavioural factor” (0.674) respectively. At last the respondents with a monthly income of more than Rs. 1,00,000 gave the highest preference to “social factor” (0.801) and the lowest preference to “geographical factor” (0.626).

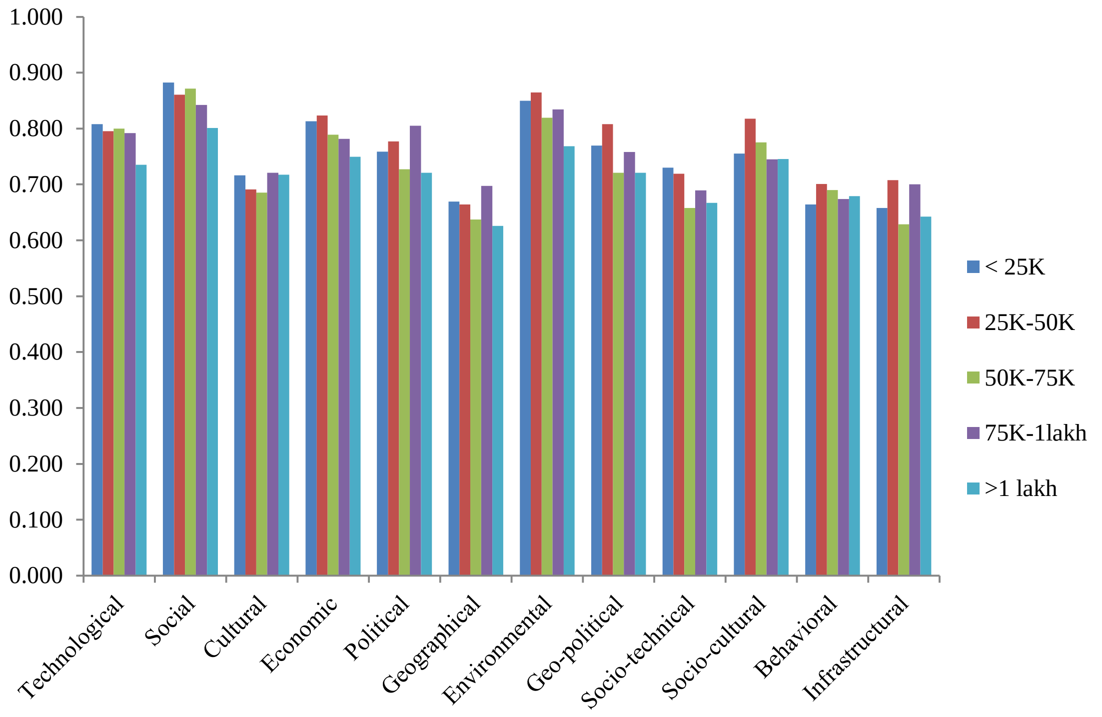

Figure 4-16 Relative importance index (Monthly Income)

City of Residence

While classifying on the basis of city of residence, it was seen that the respondents from metropolitan and urban cities have given the highest importance to "social factor" with RII of 0.830 and 0.880 respectively followed by "environmental factor" with RII of 0.809 and 0.837 respectively, while the least importance is given to "geographical factor" with RII of 0.631 and 0.640 respectively. Respondents from rural locations also assigned highest preference to "social factor" (0.869) and the least preference to "political factor" (0.740). People from NCR have chosen the highest and least indicator as "social factor" (0.824) and "infrastructural factor" (0.585). Overall, the highest preference was given to social as well as environmental factor, which shows that the respondents are concerned towards protection the environment by adopting a cleaner mode of transportation as shown in Figure 4-17.

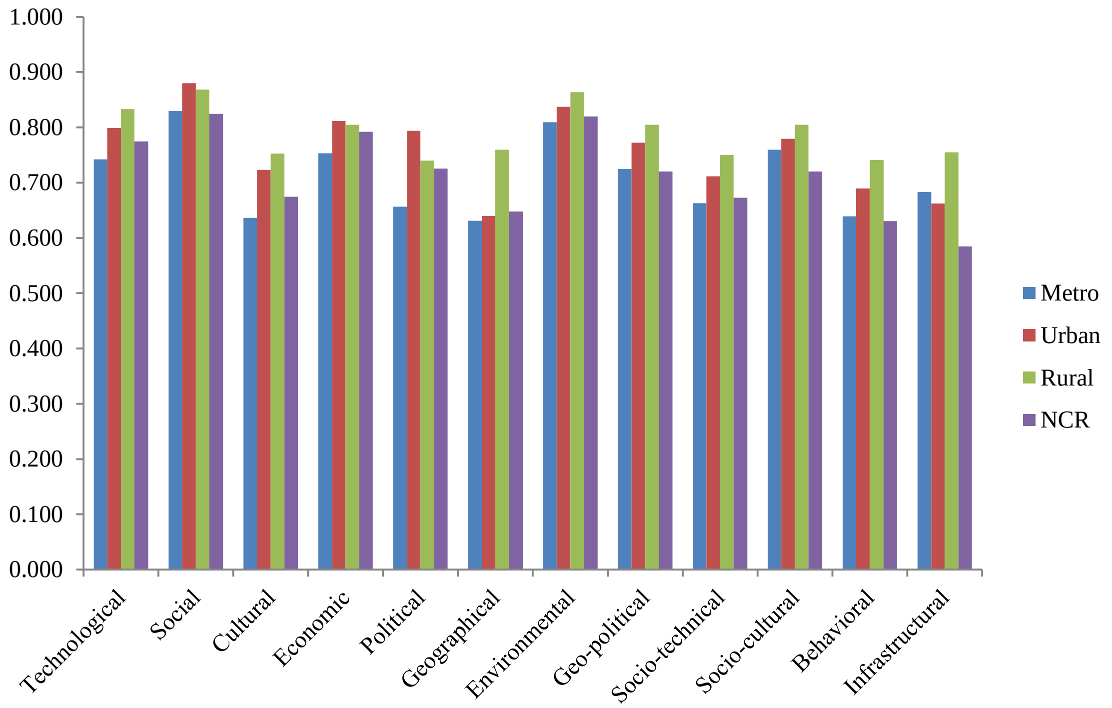

Figure 4-17 Relative importance index (City of residence)

Region of Residence

Based on the region of the residence, it was observed that respondents from the Northern region have given most importance to "social factor" (0.863) followed by "environmental factor" (0.841), while least importance was given to "infrastructural factor" (0.619) and "geographical factor" (0.652) as shown in Figure 4-18. Respondents from the Western region give similar priority with "social factor" (0.859) as most important factor followed by "environmental factor" (0.839), while the least importance was given to "geographical factor" (0.670). Respondents from both Eastern and Southern regions preferred the highest preference to "social factor" with RII of 0.864 and 0.867 while the least preference to "socio-technical factor" with RII of 0.536 and 0.422. At last, the respondent's from north-eastern region gave highest and lowest importance to "social factor" (0.863) and "infrastructural factor" (0.614).

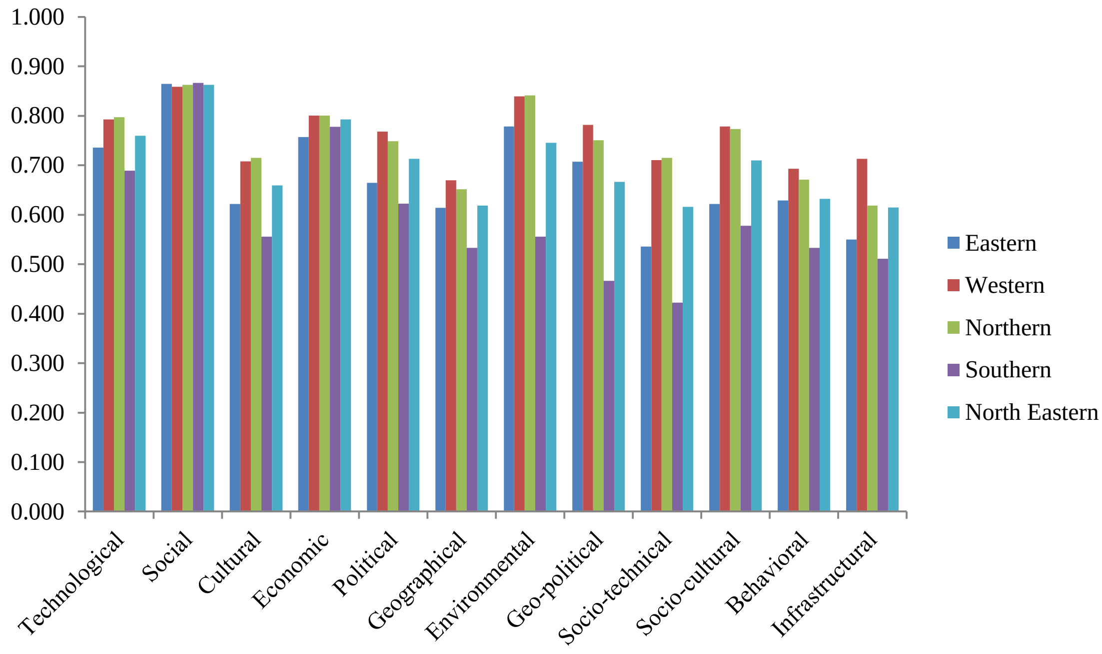

Figure 4-18 Relative importance index (Region of residence)

Distance Travelled per Day

On the basis of distance travelled per day, as shown in Figure 4-19, the highest weightage is given to "social factor" (0.862) followed by "environmental factor" (0.818) by the respondents whose daily travel is less than 25Km, while the least weightage is given to "geographical factor" (0.645). It is observed that respondents with travelling range of 25Km - 50Km have given the highest and the least preference to "environmental factor" (0.913) and "infrastructural factor" (0.667) respectively. Similarly, respondents with daily travelling between 50Km - 75Km preferred "technological factor" (0.757) and "environmental factor" (0.745) as the most important considerations, while "socio-technical" (0.566) is considered as the least important criterion. Finally, respondents who travel more than 75Km have chosen "environmental factor" (0.830) and "social factor" (0.815) as the most important criterion, whereas "economic factor" with RII of 0.556 got the least preference. In this category, the highest RII is given to "environmental factor" (0.913) which means that the daily commuters are environment conscious and willing to switch on a eco-friendly mode of transportation.

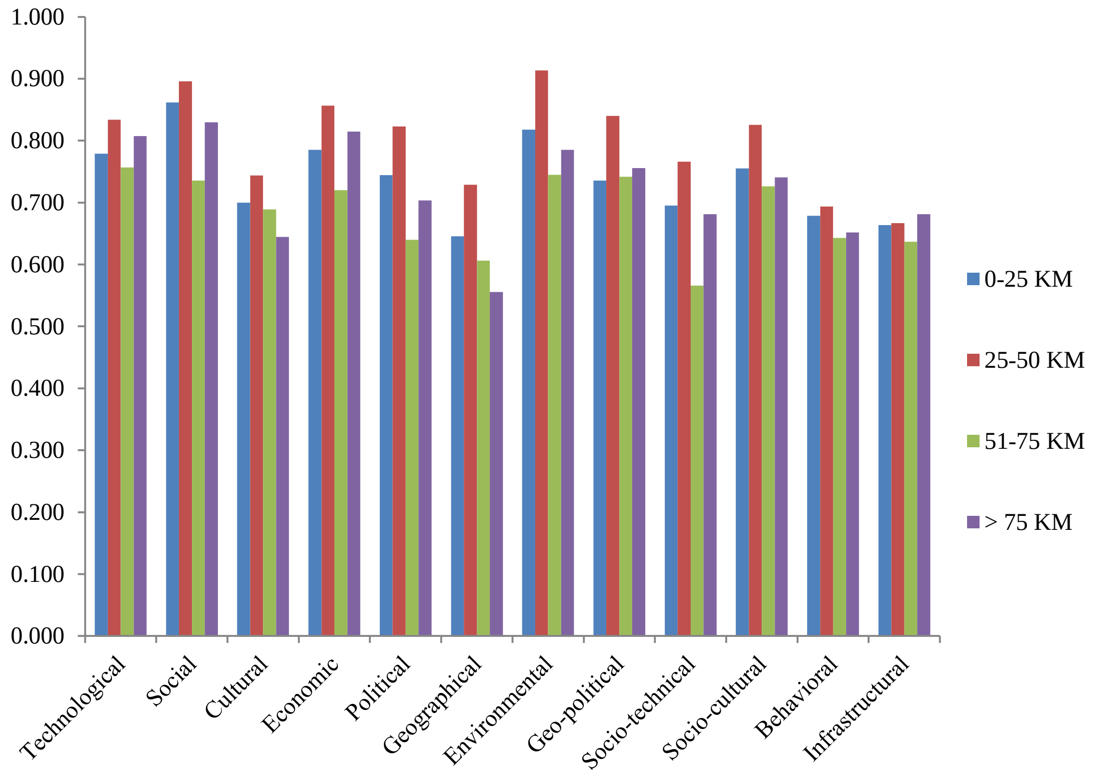

Figure 4-19 Relative importance index (Distance travelled per day)

Refuelling Frequency

While responding on refuelling frequency, the respondent's with a daily refuelling attitude shown primary concern about the "environmental factor" (0.892) and "cultural factor" (0.867). They considered "socio-technical factor" (0.629) as the least essential indicators. The analysis also shows that respondent's with a practice of weekly and twice a month refuelling have highly favoured "environmental factor "with RII of 0.852 and 0.861 respectively followed by "cultural factor" with RII of 0.820 and 0.857 respectively whereas the least RII of 0.653 and 0.676 respectively are assigned to "economic factor". It is further observed that the respondents having an attitude of once a month refuelling have given the highest weightage to "environmental factor" (0.857) and "cultural factor" (0.823), while the least weightage was given to "geographical factor" (0.634) as shown in Figure 4-20.

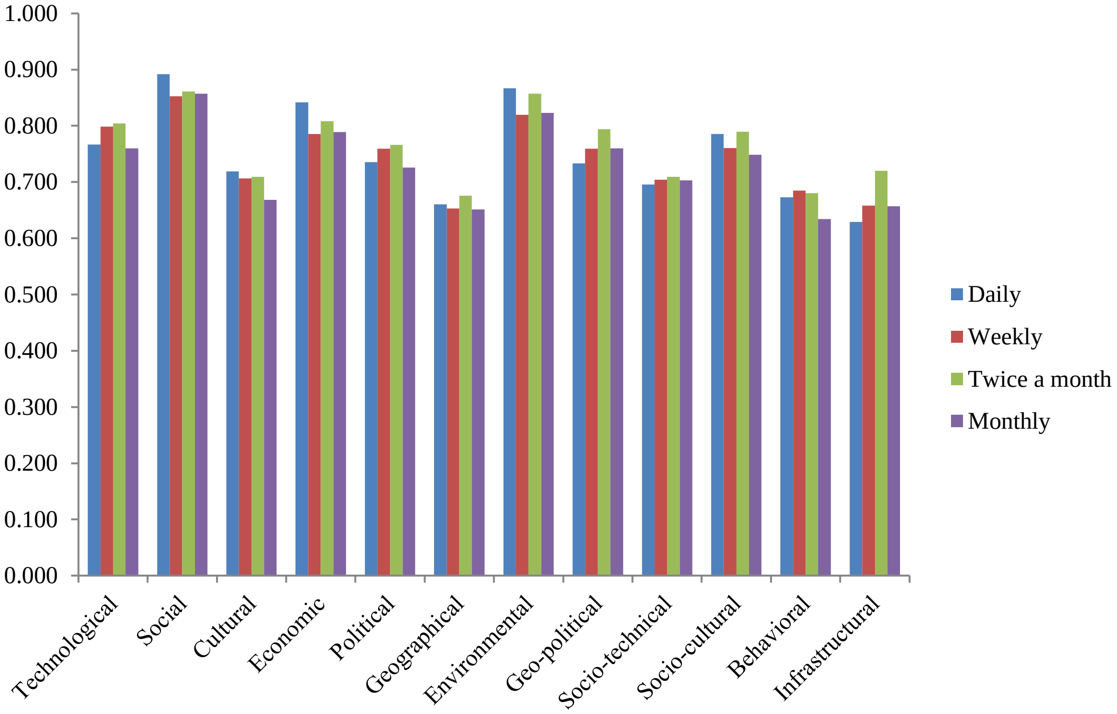

Figure 4-20 Relative importance index (Refuelling frequency)

Driving Pattern

On the basis of driving pattern, the respondents were categorized in three categories, viz. (i) steady driving, (ii) fast/ accelerated driving, and (iii) racing mode. The respondents belonging to steady driving pattern assigned the highest and lowest importance to “social factor” (0.861) and “infrastructural factor” (0.635) respectively. Respondents from fast/ accelerated driving category preferred the highest and the lowest preference to “environmental factor” (0.854) and “geographical factor” (0.678) respectively. On the other hand respondents who enjoy racing mode have chosen the highest and least importance for “technological factor” (0.954) and “geographical factor” (0.739). As shown in Figure 4-21, the highest importance was given to “technological factor” which shows that the choice of driving pattern is greatly affected by technology involved in the electric vehicles.

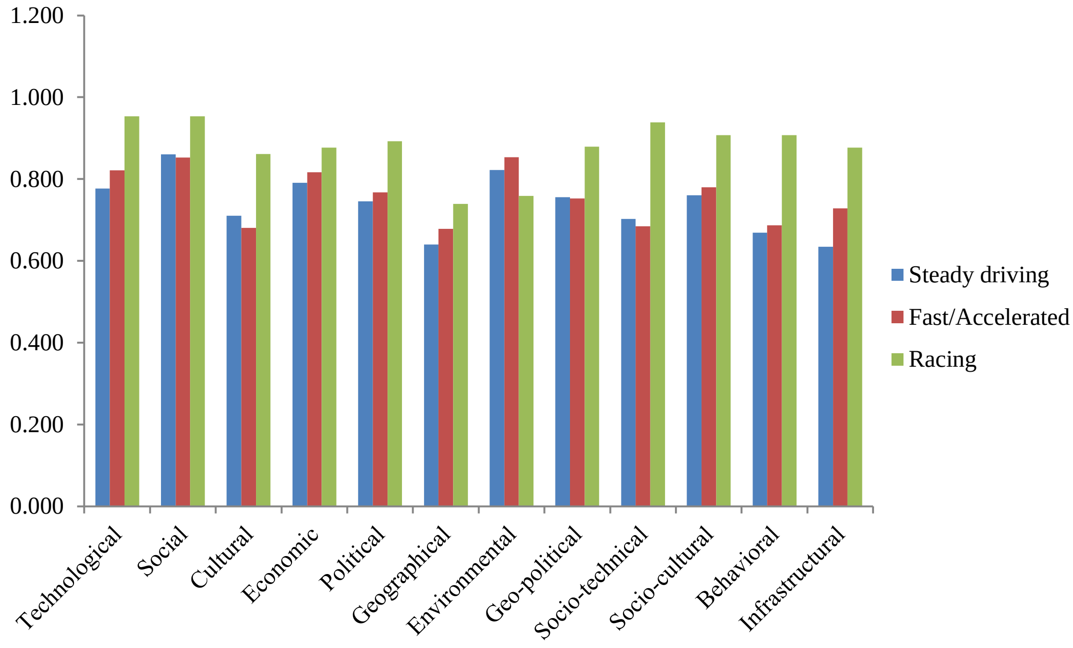

Figure 4-21 Relative importance index (Driving pattern)

Buying Preference

Respondents have their own choices and constraints in buying preferences. These buying preferences are broadly classified in five variants namely, viz. 2-wheeler, 5-seater (economy sedan/ hatchback), 7-seater (compact SUV), luxury car, and commercial vehicle. The respondents with a buying preference for 2-wheeler and 5-seater (economy sedan/ hatchback) have given the highest weightage to “social factor” with RII of 0.836 and 0.855 respectively, while the least weightage to “political factor” with RII of 0.658 and 0.647 respectively. Similarly respondents having liking in 7-seater (compact SUV) preferred “geo-political factor” (0.932) as the most important indicator followed by “social factor” (0.910) while “socio-technical factor” (0.688) was given the least importance. Further respondents with preference for luxury car assigned highest and lowest index to “social factor” (0.875) and “geographical factor” (0.682) respectively. Finally, respondents interested in commercial vehicles have chosen the highest and least priority for “technological factor” and “geo-political factor” with RII of (0.809) and (0.400) respectively.

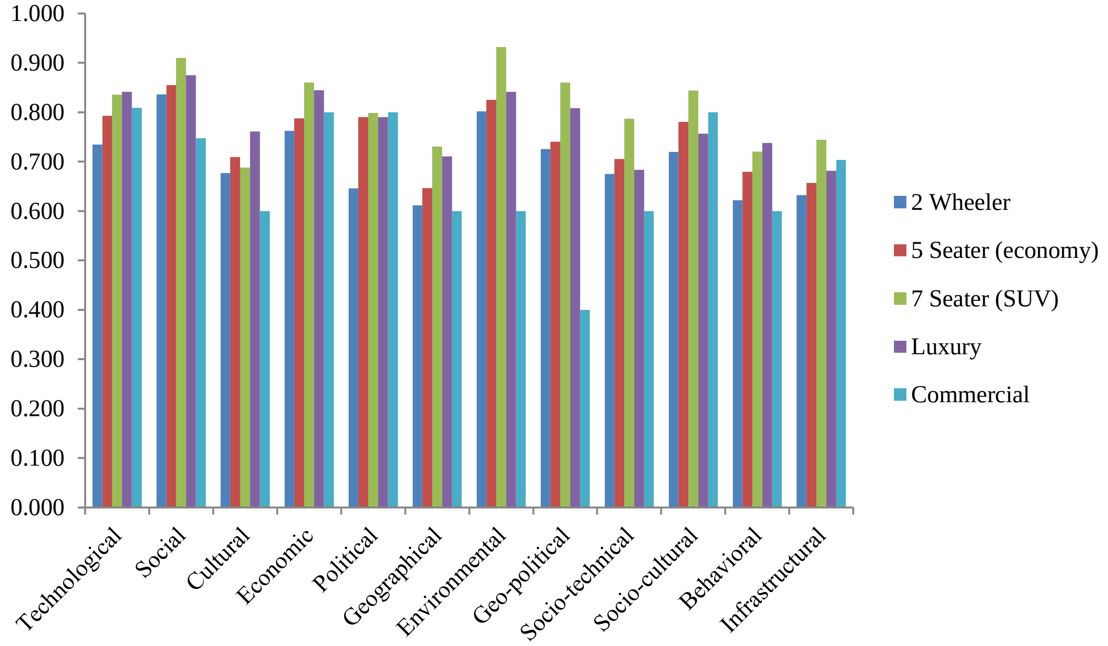

Figure 4-22 Relative importance index (Buying preference)

4.5.2 Importance index analysis of identified variables within factors

To cover a wide spectrum of the survey a total of 902 responses were obtained from all the regions of the country. These responses were analyzed on a five-point scale, where the importance index higher than 0.80 shows the 'very important' category. Similarly, an importance index higher than 0.60 and less than equal to 0.80 lies in the 'fairly important' category, while the important category carries the range of higher than 0.40 and less than equal to 0.60. The variables lie in the 'slightly important' category, which is having an importance index higher than 0.20 and less than equal to 0.40. Finally, less than equal to 0.20 importance index, variables come under the 'not important' category.

In the technical category, the highest importance of 0.848 is assigned to the variable 'improvement in battery technology'. The reason may be that it improves the cycling ability, energy density, battery life, operating temperature range while reducing charging time and battery cost as well. It also entails resolving overheating and fire-related issues. Further, the second priority is given to 'improvement in driving range of EV, followed by 'increase in battery life', and 'wireless vehicle charging technology'. While in technical factors, the least importance is given to variable 'vehicle to grid technology' with a weight share of 0.764. Here, variable 'vehicle to grid' is a cuttingedge technology that allows the energy stored in the battery to be returned to the grid to satisfy peak load demand.

Further, in the social category, the highest priority (0.827) is given to the ‘advertisement’ variable because it has enormous potential to drive the customer perception towards e-mobility. In addition, the variables ‘social appreciation’ and ‘training’ will also be the key variables for the easy adoption and development of EV market in India. Further, the cultural category considers the six variables, among which ‘masculine fascination with technology is the top priority variable with a maximum weight share of 0.863. The explanation for this could be that the variable ‘masculine preoccupation with technology' reflects the general attitude of customers toward electric mobility, for example, women prefer EVs because of environmental concerns, but men regard them as having greater technological advancements.

Further, the next important category is the economic category which has the six variables i.e., purchase cost, operating cost, maintenance cost, battery cost, replacement cost, and fuel price. All of these variables come into the category of being very important. As a result, it is apparent that the development and adoption of EVs in India are mostly determined by cost. The political category is the next most significant one because each sector's explicitly or implicitly growth is determined by state and federal government policies. For example, free charging facilities, parking spaces reserved for EV and higher taxes on fossil fuels may compel and encourage the customer to adopt EV. In the sixth important ‘geographical’ category, ‘availability of renewable energy sources is given the highest priority because all efforts for electric mobility will be in vain if vehicle power originates from a thermal source. Therefore, the government should formulate policies towards the maximum tapping of renewable energy potential and increase its contribution towards the sustainable growth of the country. The importance index for technological, social, cultural, economic, political, and geographical categories are provided in Figure 4-23.

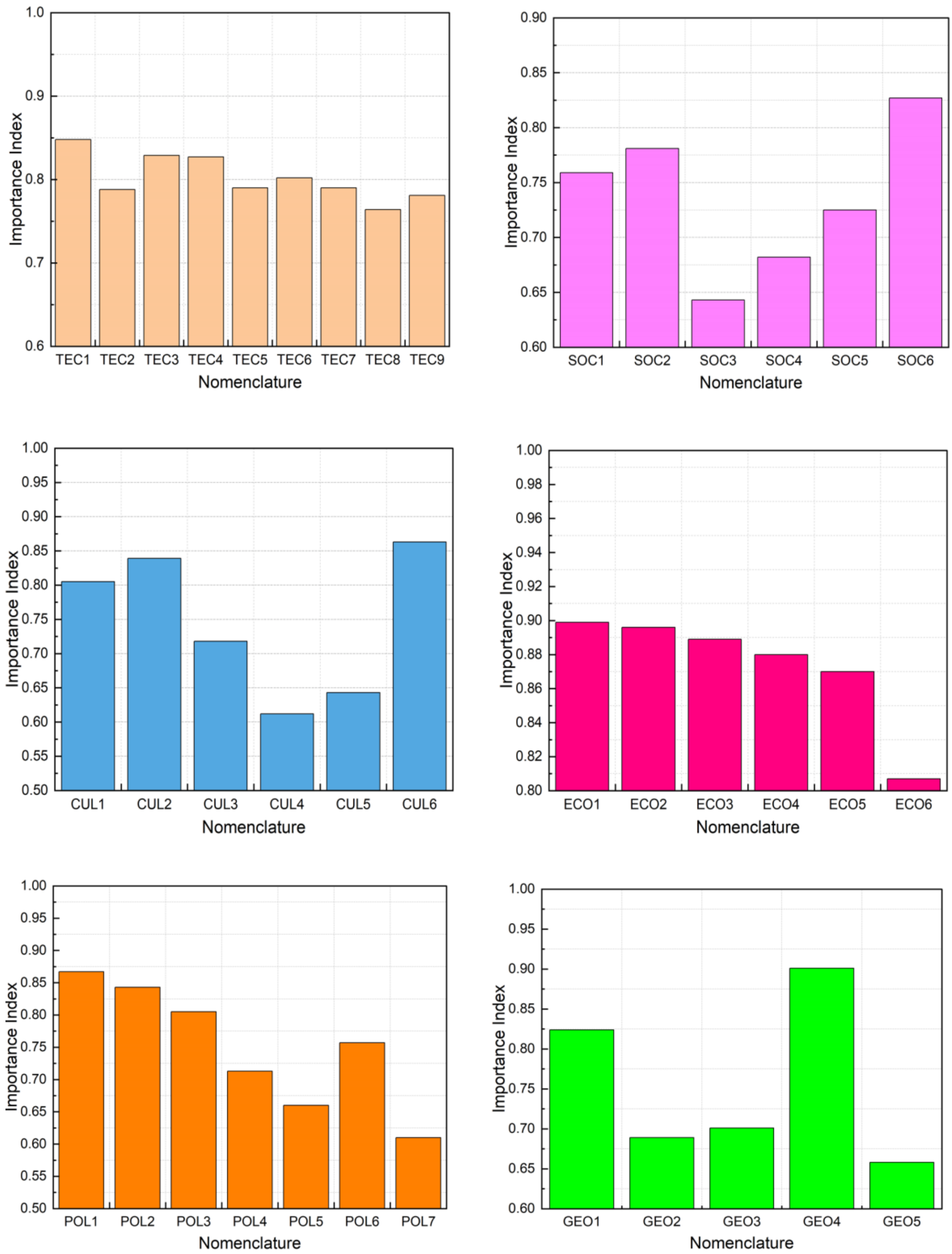

Figure 4-23 Importance index for technical, social, cultural, economic, political, and geographical factors

The primary goal of encouraging everyone to use and develop EVs is to preserve and safeguard environmental values. Here, the environmental category having the highest twelve variables, among which 'terrestrial acidification' carries the highest weight of 0.860. The priority order follows by 'photochemical oxidation formation', 'human toxicity potential', and 'freshwater eco-toxicity potential'. Therefore, future research should take into account these critical environmental variables in order to fully comprehend the environmental benefits of electric mobility. Following the environmental category, the 'geo-political' category has been explored. It takes into account five key variables, including lithium-ion reserves, rare earth elements supply, energy security, climate policy, and electricity cost subsidy for EV charging. Here, lithium-ion reserves, energy security, and electricity cost subsidy for EV charging are the most significant variables in the geo-political category. Further, in the socio-technical category, the variable 'aesthetic appearance of EV' is assigned the highest weight of (0.920), while the least preference to 'top speed of EV' (0.742).

In next socio-cultural category, income (0.708), occupation (0.667), education (0.653), and age (0.634) are the leading factors. The reason for placing the greatest emphasis on income could be that high-income families can easily afford an EV at a comparably high cost to low-income ones. Over there, educated and occupational persons are more likely to invest in more environmentally friendly or sustainable technologies. Further, driving distance, parking time, driving time, refueling frequency, and the number of trips per day all have a bigger impact in the behavioral category. Finally, a robust infrastructure of charging, service and repair, electricity, and research and development will inevitably be required for the easy adoption and development of EV. The importance index of variables of environmental, geo-political, socio-technical, socio-cultural, behavioral, and infrastructural categories are shown in Figure 4-24.

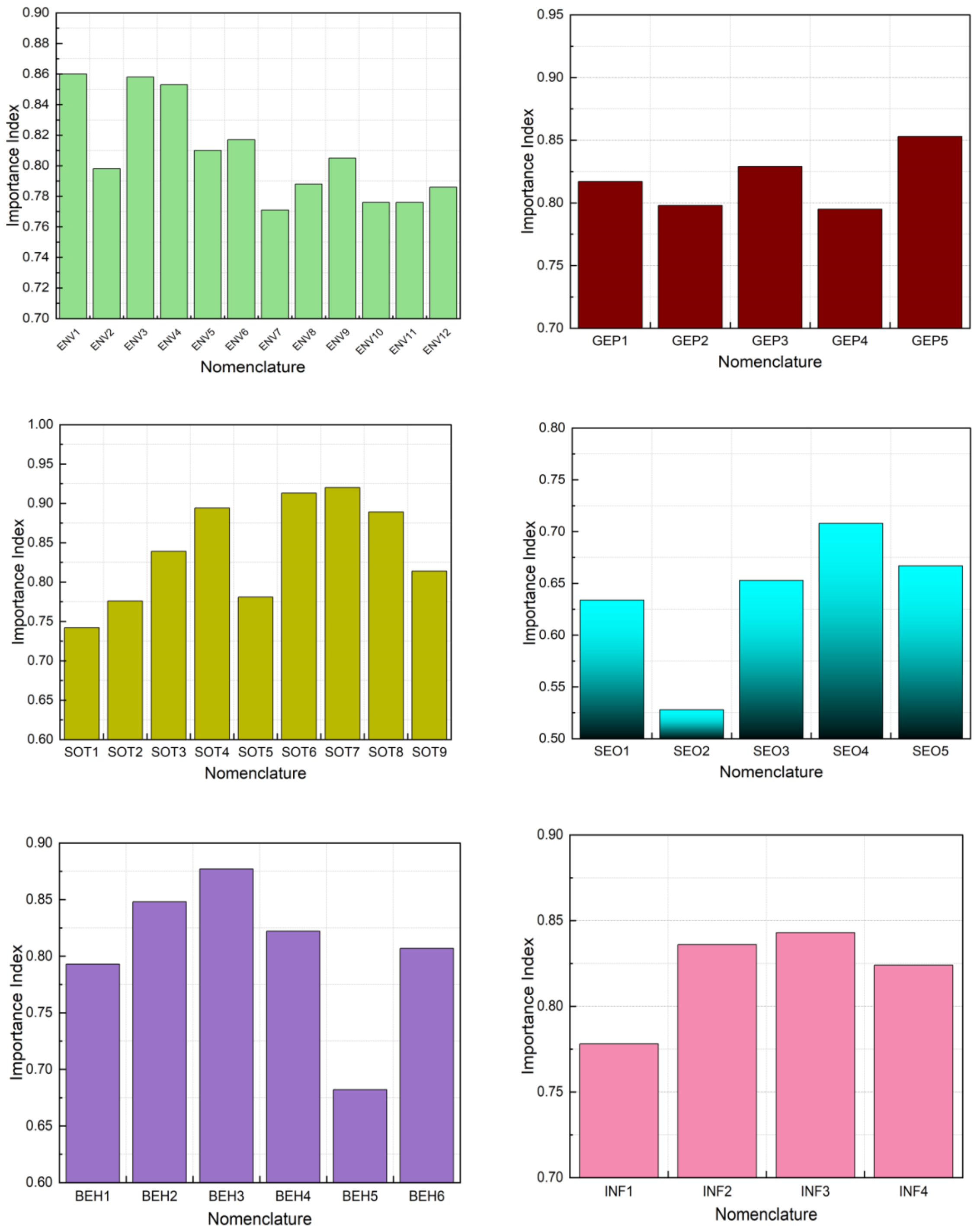

Figure 4-24 Importance index for environmental, geo-political, socio-technical, socio-cultural, behavioral, and infrastructural.

Sequentially based on the importance index values, the variables are categorized into the considered five categories. The very important category carries the highest (44) number of variables, followed by the fairly important (35), and important category (01), whereas, the slightly important and not important category does not carry any variable. **Table 4-1** shows the list of factors and their associated variables with the nomenclature and their importance index.

Table 4-1 Importance index of the considered variables

Factors	Variables	Nomenclature	Importance Index
Technological	Improvement in battery technology	TEC1	0.848
	Reduction in charging time	TEC2	0.788
	Improvement in driving range of EV	TEC3	0.829
	Increase in battery life	TEC4	0.827
	Power grid capacity	TEC5	0.790
	Wireless vehicle charging technology	TEC6	0.802
	R&D related to EV technology	TEC7	0.790
	Vehicle to grid (V2G) technology	TEC8	0.764
	Patent restrictions	TEC9	0.781
Social	Training	SOC1	0.759
	Social appreciation	SOC2	0.781
	Brand endorsements	SOC3	0.643
	Awareness	SOC4	0.682
	Status in society	SOC5	0.725
	Advertisements	SOC6	0.827
Cultural	Human-nature relationship	CUL1	0.805
	Feminine environmentalism	CUL2	0.839
	Long-term orientation	CUL3	0.718
	Face consciousness	CUL4	0.612
	Recycling mentality	CUL5	0.643
	Masculine fascination with technology	CUL6	0.863
Economic	Purchase cost	ECO1	0.899
	Operating cost	ECO2	0.896
	Maintenance cost	ECO3	0.889
	Battery cost	ECO4	0.880
	Replacement cost	ECO5	0.870
	Fuel price	ECO6	0.807
Political	Free public charging	POL1	0.867
	Reserved parking spots	POL2	0.843
	Fossil fuel taxes	POL3	0.805
	Government subsidy for EV purchase	POL4	0.713
	Vehicle insurance	POL5	0.660
	Tax exemption	POL6	0.757

Factors	Variables	Nomenclature	Importance Index
	Dedicated lanes for EV	POL7	0.610
Geographical	Regional difference in electricity price	GEO1	0.824
	Accessibility of charging infrastructure	GEO2	0.689
	Region of residence (Urban/sub-urban/rural)	GEO3	0.701
	Availability of Renewable energy resources	GEO4	0.901
	Availability of After-sales services	GEO5	0.658
Environmental	Terrestrial acidification	ENV1	0.860
	Particulate matter formation	ENV2	0.798
	Photochemical oxidation formation	ENV3	0.858
	Human toxicity potential	ENV4	0.853
	Global warming	ENV5	0.810
	Freshwater eco-toxicity potential	ENV6	0.817
	Air pollution	ENV7	0.771
	Noise pollution	ENV8	0.788
	Greenhouse gas emission	ENV9	0.805
	Metal resource depletion	ENV10	0.776
	Terrestrial eco-toxicity potential	ENV11	0.776
	Freshwater eutrophication potential	ENV12	0.786
Geo-political	Lithium ion reserves	GEP1	0.817
	Rare earth elements supply	GEP2	0.798
	Energy security	GEP3	0.829
	Climate policy	GEP4	0.795
	Electricity cost subsidy for EV charging	GEP5	0.853
Socio-technical	Top speed of EV	SOT1	0.742
	Acceleration of EV	SOT2	0.776
	Comfort of EV	SOT3	0.839
	Power of EV	SOT4	0.894
	Safety of EV	SOT5	0.781
	Aesthetic appearance of EV	SOT6	0.913
	Fuel economy	SOT7	0.920
	Seating and luggage capacity	SOT8	0.889
	Reliability of EV	SOT9	0.814
Socio-cultural	Age	SEO1	0.634
	Gender	SEO2	0.528
	Education	SEO3	0.653
	Income	SEO4	0.708
	Occupation	SEO5	0.667
Behavioural	Resistance to change	BEH1	0.793
	Driven distance	BEH2	0.848
	Parking time	BEH3	0.877
	Driving time	BEH4	0.822
	Number of trips driven per day	BEH5	0.682
	Recharging frequency	BEH6	0.807

Factors	Variables	Nomenclature	Importance Index
Infrastructural	Charging infrastructure for home, workplaces, public places, and highways	INF1	0.778
	Maintenance, service & repair infrastructure	INF2	0.836
	Reliable electricity infrastructure	INF3	0.843
	R&D infrastructure for EV manufacturing	INF4	0.824

As the slightly important and not important category does not carry any variables, we cannot ignore any of the variable and therefore, the further study proceeds with all the considered 80 variables which are shown in the result of importance index analysis at Table 4-2.

Table 4-2 Results of importance index analysis

Factors	Number of variables	Very Important	Fairly Important	Important	Slightly Important	Not Important
TEC	9	TEC1, TEC3, TEC4, TEC6	TEC2, TEC5, TEC7, TEC8, TEC9	–	–	–
SOC	6	SOC6	SOC1, SOC2, SOC3, SOC4, SOC5	–	–	–
CUL	6	CUL1, CUL2, CUL6	CUL3, CUL4, CUL5	–	–	–
ECO	6	ECO1, ECO2, ECO3, ECO4, ECO5, ECO6	–	–	–	–
POL	7	POL1, POL2, POL3	POL4, POL5, POL6, POL7	–	–	–
GEO	5	GEO1, GEO4	GEO2, GEO3, GEO5	–	–	–
ENV	12	ENV1, ENV3, ENV4, ENV5, ENV6, ENV9	ENV2, ENV7, ENV8, ENV10, ENV11, ENV12	–	–	–
GEP	5	GEP1, GEP3, GEP5	GEP2, GEP4	–	–	–
SOT	9	SOT3, SOT4, SOT6, SOT7, SOT8, SOT9	SOT1, SOT2, SOT5	–	–	–
SEO	5	–	SEO1, SEO3, SEO4, SEO5	SEO2	–	–
BEH	6	BEH2, BEH3, BEH4, BEH6	BEH1, BEH5	–	–	–
INF	4	INF2, INF3, INF4	INF1	–	–	–
Total	**80**	**44**	**35**	**1**	**0**	**0**

4.6 **Summary**

The present chapter analyzed a set of variables related to adoption of EVs in the Indian context. A total of 80 variables representing 12 factors were gathered through a thorough literature review. These variables were reviewed and evaluated by a panel of experts and specialists. The variables were then prepared in the form of a survey, with responses gathered from around the country. Finally, 902 responses were received, out of which 774 were male respondents and 128 were female respondents. The specialists were from the NGO's, academics, environmental, investment, and engineering areas. The responses were then studied cumulatively and categorically in order to determine their demographic distribution. The demographic distribution was then analyzed first on the basis of descriptive analysis and later an importance index analysis was performed to get an importance index value for each variable. As a consequence, 44 variables are identified as ‘very important,’ 35 as ‘fairly important,’ and 1 as ‘important.’ None found in the ‘slightly important' and ‘not significant' categories, on the other hand.

This chapter presents the reliability and validity analysis of the results obtained from descriptive analysis and importance index analysis. The reliability analysis was carried out by using two techniques viz. Internal consistency analysis and Item analysis, while the validity analysis has been performed by checking content validity and constructing validity using factor analysis. The chapter after establishing an inter-relationship among the factors suggests an ISM model, which provides a roadmap for implementation of sustainable manufacturing of EVs in India.

5.1 **Introduction**

For universal acceptance of results obtained from empirical or descriptive studies, the validation of their results is strongly required so as to confirm its reliability. The validation of results obtained from empirical or descriptive studies ensures that the results appropriately reflect the stated factors. Further, an experimentally proven results and parameters therein, can be applied to various populations directly. They also provide practitioners with useful tools for assessing, benchmarking, and evaluating their programmes over time.

Only statistically reliable and valid sustainability variables are usable for diverse applications, by different researchers, in different studies. The degree of dependability and stability of a performance measure is referred to as reliability (Vidhi & Shrivastava, 2018). It reflects the capacity of the performance metric to consistently produce the same response (Trahan et al., 2014). A performance measure has construct validity if it is measuring the concept that it was intended to measure (Churchill, 1979).

Any framework of factors and variables is useful for a research study or industrial implementation only if they are statistically reliable and valid. Therefore, the next step in this process is to check for reliability and validity. Reliability refers to the extent to which the identified variables are dependable and stable. Reliability analysis consists of two parts: internal consistency analysis and item analysis. Validity analysis checks for content validity and constructs validity. Construct validity is checked using factor analysis. In this research study, all the statistical analyses were performed in IBM SPSS Statistics 22.

In the following section, reliability and detailed item analysis are used to refine the variables (called items) of the sustainable factors for EVs manufacturing.

5.2 **Reliability Analysis**

The reliability of a factor can be measured using Cronbach's alpha. In internal consistency analysis, variables that lower the reliability of the factors is removed until an acceptable level of Cronbach's alpha is achieved. The higher the value of alpha, the more reliable is the factor. An alpha value above 0.7 is usually acceptable. The results of the internal consistency analysis are shown in Table 5-1. A total of 17 variables (3 from Technological, 1 from Cultural, 2 from Political, 4 from Environmental, 1 from Geo-political, 5 from Socio-technical, and 1 from Behavioural) were deleted in the process of improving the internal consistency. After deletion of 17 variables, all the 12 factors have Cronbach's alpha well above 0.7 indicating a reliable construct of factors. The remaining 63 variables are used for the item analysis.

Table 5-1 Results of internal consistency analysis

Factor	Original total number of items	Total number of items deleted	Remaining number of items	Cronbach's alpha
TEC	9	3	6	0.87
SOC	6	0	5	0.819
CUL	6	1	5	0.74
ECO	6	0	5	0.847
POL	7	2	5	0.733
GEO	5	0	5	0.739
ENV	12	4	9	0.954
GEP	5	1	4	0.84
SOT	9	5	6	0.833
SEO	5	0	5	0.833
BEH	6	1	4	0.753
INF	4	0	4	0.745
Total	**80**	**17**	**63**	

In item analysis, the correlation coefficient of variables was checked. A value above 0.4 is considered acceptable. A total of 8 variables (2 from Technological, 1 from Social, 1 from Cultural, 1 from Political, 1 from Environmental, 1 from Socio-technical, and 1 from Behavioural) were deleted after the item analysis, leaving a total of 55 variables. The summary of the item analysis is shown in Table 5-2.

Table 5-2 Summary of item analysis

Factor	Original total number of items	Total number of items deleted	Remaining number of items
TEC	6	2	4
SOC	5	1	5
CUL	5	1	4
ECO	5	0	6
POL	5	1	4
GEO	5	0	5
ENV	9	1	7
GEP	4	0	4
SOT	6	1	3
SEO	5	0	5
BEH	4	1	4
INF	4	0	4
	63	**8**	**55**

The remaining variables and the alpha value of factors after the item analysis are shown in Table 5-3. The correlation coefficient of all variables is above 0.4 and the Cronbach's alpha value of all factors is above 0.7.

Table 5-3 Remaining variables and Alpha value of factors

Factors	Internal consistency analysis			Remaining number of items (output to input)	Item analysis	
	Original total number of items	Total number of items deleted	Final Cronbach's alpha		Total number of items deleted	Remaining number of items
TEC	9	3	0.87	6	2	4
SOC	6	0	0.819	6	1	5
CUL	6	1	0.74	5	1	4
ECO	6	0	0.847	6	0	6
POL	7	2	0.733	5	1	4
GEO	5	0	0.739	5	0	5
ENV	12	4	0.954	8	1	7
GEP	5	1	0.84	4	0	4
SOT	9	5	0.833	4	1	3
SEO	5	0	0.833	5	0	5
BEH	6	1	0.753	5	1	4
INF	4	0	0.745	4	0	4
Total	**80**	**17**		**63**	**8**	**55**

Hence, after the reliability analysis, 12 factors and 55 variables remain in the framework as shown in Table 5-4.

Table 5-4 Variables remaining after item analysis

Factor	Cronbach's Alpha	Alpha if item deleted	Correlation Coefficient
Technological	0.87		
TEC2		0.851	0.653
TEC4		0.855	0.623
TEC5		0.849	0.678
TEC7		0.847	0.687
Social	0.765		
SOC1		0.726	0.535
SOC2		0.669	0.642
SOC3		0.709	0.574
SOC4		0.730	0.525
SOC6		0.684	0.497
Cultural	0.736		
CUL1		0.656	0.571
CUL3		0.716	0.455
CUL4		0.595	0.654
CUL5		0.721	0.455
Economic	0.847		
ECO1		0.830	0.604
ECO2		0.826	0.612
ECO3		0.796	0.722
ECO4		0.809	0.676
ECO5		0.812	0.672
ECO5		0.748	0.564
Political	0.734		
POL1		0.713	0.472
POL2		0.651	0.588
POL5		0.666	0.541
POL7		0.652	0.585
Geographical	0.739		
GEO1		0.684	0.525
GEO2		0.716	0.439
GEO3		0.71	0.47
GEO4		0.676	0.547
GEO5		0.681	0.546
Environmental	0.954		
ENV1		0.954	0.656
ENV2		0.952	0.725
ENV3		0.951	0.748

Factor	Cronbach's Alpha	Alpha if item deleted	Correlation Coefficient
ENV4		0.951	0.742
ENV6		0.952	0.698
ENV8		0.948	0.832
ENV10		0.949	0.812
Geo-political	0.840		
GEP1		0.806	0.654
GEP2		0.780	0.712
GEP3		0.803	0.660
GEP4		0.800	0.668
Socio-technical	0.833		
SOT4		0.827	0.426
SOT5		0.802	0.652
SOT9		0.813	0.566
Socio-cultural	0.833		
SEO1		0.827	0.527
SEO2		0.791	0.661
SEO3		0.798	0.639
SEO4		0.803	0.619
SEO5		0.773	0.721
Behavioural	0.761		
BEH1		0.687	0.588
BEH2		0.611	0.651
BEH3		0.727	0.555
BEH6		0.674	0.528
Infrastructural	0.745		
INF1		0.704	0.508
INF2		0.673	0.562
INF3		0.637	0.623
INF4		0.725	0.465

5.3 **Validity Analysis**

Reliability analysis is followed by validity analysis. Validity analysis consists of conducting Kaiser-Meyer-Olkin (KMO) tests and confirmatory factor analysis. KMO test represented degree of suitability of data for corresponding factor analysis. KMO value below 0.5 is undesirable and would require remedial action (Digalwar et al., 2013). KMO values of factors are shown in Table 5-5**.**

Table 5-5 KMO values

Factors	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SEO	BEH	INF
KMO	0.676	0.771	0.679	0.756	0.632	0.704	0.855	0.746	0.588	0.847	0.682	0.757

All factors have KMO values well above 0.6 implying a well-suited data ready for factor analysis. Summary of factor analysis are shown in Table 5-6.

Table 5-6 Summary of factor analysis

Factors	Item loading range	Eigen value	% variance explained	Number of factors extracted	Number of Variables	Remaining factors
TEC	0.790-0.845	1.979	65.968	1	3	TEC4, TEC5, TEC7
SOC	0.730-0.825	2.365	59.113	1	4	SOC1, SOC2, SOC3, SOC4
CUL	0.668-0.834	2.253	56.316	0	4	CUL1, CUL3, CUL4, CUL5
ECO	0.746-0.833	3.109	62.185	1	5	ECO1, ECO2, ECO3, ECO4, ECO5
POL	0.706-0.831	2.309	57.728	0	4	POL1, POL2, POL5, POL7
GEO	0.635-0.761	2.473	50.142	0	5	GEO1, GEO2, GEO3, GEO4, GEO5
ENV	0.708-0.869	3.915	65.249	1	6	ENV1, ENV2, ENV3, ENV4, ENV6, ENV10
GEP	0.809-0.848	2.705	67.618	0	4	GEP1, GEP2, GEP3, GEP4
SOT	0.649-0.816	1.633	54.427	0	3	SOT4, SOT5, SOT9
SEO	0.680-0.844	3.007	60.145	0	5	SEO1, SEO2, SEO3, SEO4, SEO5
BEH	0.795-0.859	2.038	67.925	1	3	BEH1, BEH2, BEH3
INF	0.686-0.728	2.271	56.766	0	4	INF1, INF2, INF3, INF4
Total				**5**	**50**	

Factor analysis is also conducted in IBM SPSS Statistics 22. Eigenvalue represents the number of variables explained by the factor. Eigenvalue should be greater than 1 (Saraswat and Digalwar, 2021b). The expected % variance explained is above 50%. As seen in the results, eigenvalues of all variables are above 1, and the (%) variable explained by these eigenvalues is more than 50%. Item loading range represents the correlation coefficient of the variables. A correlation coefficient above 0.4 is desirable. All the final variables within the factors have a correlation coefficient well above 0.65. Furthermore, in confirmatory factor analysis, if more than one factor is extracted from the factor analysis, then the redundant factor and its associated variables can be eliminated. Hence the final framework has 12 factors and 50 variables representing these factors. The final list of variables is shown in Table 5-7.

Table 5-7 Final list of variables for the development of EVs in India

S.No.	Factor	Code	Variables
1	Technological	TEC4	Increase in battery life
2		TEC5	Power grid capacity
3		TEC7	R&D related to EV technology
4	Social	SOC1	Training
5		SOC2	Social appreciation
6		SOC3	Brand endorsements
7		SOC4	Awareness
8	Cultural	CUL1	Human-nature relationship
9		CUL3	Long-term orientation
10		CUL4	Face consciousness
11		CUL5	Recycling mentality
12	Economic	ECO1	Purchase cost
13		ECO2	Operating cost
14		ECO3	Maintenance cost
15		ECO4	Battery cost
16		ECO5	Replacement cost
17	Political	POL1	Free public charging
18		POL2	Reserved parking spots
19		POL5	Vehicle insurance
20		POL7	Dedicated lanes for EV
21	Geographical	GEO1	Regional difference in electricity price
22		GEO2	Accessibility of charging infrastructure
23		GEO3	Region of residence (Urban/sub-urban/rural)
24		GEO4	Availability of Renewable energy resources
25		GEO5	Availability of After-sales services
26	Environmental	ENV1	Terrestrial acidification
27		ENV2	Particulate matter formation
28		ENV3	Photochemical oxidation formation
29		ENV4	Human toxicity potential
30		ENV6	Freshwater eco-toxicity potential
31		ENV10	Metal resource depletion
32	Geo-political	GEP1	Lithium ion reserves
33		GEP2	Rare earth elements supply
34		GEP3	Energy security
35		GEP4	Climate policy
36	Socio-technical	SOT4	Power of EV
37		SOT5	Safety of EV
38		SOT9	Reliability of EV
39	Socio-cultural	SEO1	Age
40		SEO2	Gender
41		SEO3	Education
42		SEO4	Income
43		SEO5	Occupation

S.No.	Factor	Code	Variables
44	Behavioural	BEH1	Resistance to change
45		BEH2	Driven distance
46		BEH3	Parking time
47	Infrastructural	INF1	Charging infrastructure for home, workplaces, public places, and highways
48		INF2	Maintenance, service & repair infrastructure
49		INF3	Reliable electricity infrastructure
50		INF4	R&D infrastructure for EV manufacturing

5.4 **Development of Factors Inter-Relationship**

The factors have been identified from literature review and field survey. Furthermore, experts from academics and industry have been invited for brainstorming over the responses to apply DEMATEL and ISM methods.

The study employs DEMATEL and ISM separately to identify main influencing factors and to construct multi-level hierarchical structured models of them, thus obtaining complete information. However, separate calculation processes are overly complex and have an excessive calculation burden. DEMATEL and ISM methods both express expert evaluation information via relation matrix and reflect the influence relationships between factors. Zhou, Zhang, and Li (2006) proposed a DEMATEL-ISM integration approach. They argue that as the total-relation matrix of DEMATEL contains more information than the reachability matrix of ISM, and the reachability matrix is more difficult to calculate, that the hierarchical structure of the complex system can be divided by the total-relation matrix of DEMATEL and then transformed into an ISM reachability matrix. However, this traditional integration approach has notable drawbacks and may lead to deviation in the ISM analysis results and drive down the effectiveness of any countermeasures implemented.

5.5 **DEMATEL Approach**

To achieve overall growth of the system the inter-relationship among the factors is to be well known. The factors are either driving or dependent factors. Hence, for the overall development of the system, concerns should be made on the development of the driving factors, as the driving factors themselves are responsible for the dependent factors.

Therefore, the study employed the DEMATEL, a multi criteria decision making approach (MCDM) to establish an inter-relationship among the factors.

The steps involved in DEMATEL approach are as follows:

1. **Defining the scale and composition of direct relation matrix**

The direct relation matrix is developed in the first step. The responses given by the sample population about the direct effect between each pair of elements are captured in the matrix. The pairwise comparison is made using a Likert scale, with 1 to 5 representing least important to most important. The initial direct relation matrix A is an *(n × n)* matrix, in which a_{ij} is denoted as the degree to which the element *i* affects the element *j* is formatted as $\mathrm{K} = [\mathrm{a_{ij}}]_{\mathrm{nXn}}$.

2. **Composition of normalized direct relation matrix Y**

The normalization of the initial direct relation matrix is done in this step. The normalized direct relation matrix $Y = b_{ij}$ can be obtained from the following equations.

$$Y = \frac{1}{s}K$$

$$s = \max\left[\begin{matrix} max \\ 1 \leq i \leq n \end{matrix}\sum_{j=1}^{n} a_{ij}\, , \begin{matrix} max \\ 1 \leq j \leq n \end{matrix}\sum_{i=1}^{n} a_{ij}\right] i,j\{1,2, \ldots .n\}$$

where *1st* equation represents the normalized initial direct relation matrix and *2nd* equation represents the maximum values of the sums of all the rows and the sums of all the columns.

3. **Computing the total relation matrix**

The total relation matrix is computed in this step. The total relation matrix is computed by using the following numerical calculation: where 1 to m represents the power. Hence, when m tends to infinity, the matrix will converge. Furthermore, this is the identity matrix.

$$T = Y^1 + Y^2 + \cdots \ldots \ldots \ldots . + Y^h = Y\,X\,(1 - Y)^{-1} = \left[b_{ij}\right]_{nxn} h \rightarrow \infty$$

4. **Computation of row sum and column sum**

The sum of rows and columns of matrix is calculated in this step. The sum of rows and the sum of columns are separately denoted as R_{sum} and C_{sum}.

5. Obtain a threshold value and draw cause-effect diagram

It is necessary to set up a threshold value to filter out some negligible effects. Thus, only the effects, which are bigger than the determined threshold value, are chosen and converted into a causal relationship diagram (digraph).

The lack of scientific standard for setting the threshold value is also problematic. Various threshold-setting techniques have been formulated by experts or decision-makers according to actual problems, but there is no unified scientific standard. Directly setting the threshold to non-0 or 1 actually negates the advantage of DEMATEL's inclusion of the level of influence between factors. Other threshold determination techniques include the mean method, median method, ($\mu + \sigma$) and ($\mu + 1.5\sigma$). In this study, threshold value is selected as the average of the elements in total relation matrix.

In the matrix, R_{sum} is the sum of each row and the rows show the degrees of direct and indirect impacts over the other criteria, and C_{sum} is the sum of each column where columns indicate the degrees of influences from other criteria. Numeric variable therefore, represents the factors that influence others, $(R_{sum}+C_{sum})$ represents the strength of relationships between factors; $(R_{sum}-C_{sum})$ represents the strength of influences among factors. In other words, ($R_{sum}+C_{sum}$) and ($R_{sum}-C_{sum}$) represent the so called prominences and relations, respectively.

The direct relation matrix from DEMATEL is shown Table 5-8 below.

Table 5-8 Direct relation matrix

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SEO	BEH	INF
TEC	0	3	2	4	2	1	3	2	4	0	0	1
SOC	1	0	2	1	1	1	3	0	0	0	3	3
CUL	1	2	0	0	1	1	3	0	0	0	3	0
ECO	1	2	3	0	1	1	0	0	1	0	0	0
POL	2	3	3	3	0	1	3	1	0	0	3	1
GEO	0	2	2	1	2	0	2	0	0	0	1	2
ENV	1	1	1	2	3	0	0	0	0	0	0	1
GEP	2	1	1	2	3	2	1	0	0	0	1	1
SOT	2	2	2	4	1	0	1	0	0	0	2	1
SEO	0	2	2	1	0	0	1	0	1	0	2	0
BEH	0	3	2	2	0	0	3	0	0	0	0	0
INF	0	1	1	3	4	1	3	0	3	0	2	0

Finally, total relation matrix was obtained through normalizing direct relation matrix as shown in Table 5-9.

Table 5-9 Total relation matrix

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SEO	BEH	INF	R_{sum}
TEC	0.102	0.299	0.263	0.345	0.232	0.112	0.308	0.106	0.224	0.102	0.144	0.134	2.371
SOC	0.194	0.122	0.197	0.163	0.251	0.184	0.265	0.115	0.247	0.197	0.215	0.179	2.329
CUL	0.081	0.173	0.085	0.087	0.112	0.07	0.228	0.012	0.024	0.085	0.189	0.049	1.195
ECO	0.182	0.195	0.199	0.07	0.173	0.273	0.196	0.211	0.166	0.147	0.173	0.243	2.228
POL	0.158	0.282	0.276	0.269	0.129	0.153	0.302	0.163	0.055	0.012	0.242	0.12	2.161
GEO	0.049	0.181	0.179	0.136	0.169	0.038	0.202	0.012	0.032	0.038	0.129	0.134	1.299
ENV	0.087	0.129	0.129	0.166	0.189	0.035	0.095	0.016	0.033	0.095	0.071	0.082	1.127
GEP	0.144	0.171	0.168	0.206	0.225	0.133	0.182	0.022	0.048	0.022	0.137	0.104	1.562
SOT	0.143	0.21	0.208	0.281	0.135	0.048	0.177	0.018	0.05	0.105	0.175	0.098	1.648
SEO	0.032	0.151	0.148	0.1	0.047	0.023	0.12	0.005	0.058	0.112	0.141	0.033	0.97
BEH	0.038	0.192	0.154	0.144	0.063	0.028	0.206	0.006	0.018	0.235	0.06	0.042	1.186
INF	0.081	0.195	0.019	0.074	0.176	0.093	0.079	0.019	0.165	0.079	0.199	0.069	1.248
C_{sum}	1.291	2.3	2.025	2.041	1.901	1.19	2.36	0.705	1.12	1.229	1.875	1.287	

Analysis of DEMATEL requires the calculation of row sum (R_{sum}), column sum (C_{sum}), (R_{sum}+C_{sum}) and (R_{sum}-C_{sum}). DEMATEL involves three components viz ranking based on (R_{sum}+C_{sum}), categorization of factors as driver or dependent based on (R_{sum}-C_{sum}), and plotting the causal diagram. Factors having higher (R_{sum}+C_{sum}) values are ranked higher than those with lower (R_{sum}+C_{sum}) values. Higher (R_{sum}+C_{sum}) value implies that the factor has a very strong relation with other factors. Here, the political factor is the strongest one among the 12 factors. Socio-cultural is the factor with the least (R_{sum}+C_{sum}) value, implying that it has very little dependence on other factors. Similarly, (R_{sum}-C_{sum}) values can be used to categorize the factors as driver and dependent. Drivers drive the dependent factors. Based on the (R_{sum}-C_{sum}) values, the 12 factors have been categorized as driver and dependent. Social, technological, political, economic, geographical, geo-political and socio-technical factors are categorized as drivers whereas cultural, environmental, socio-cultural, behavioural and infrastructural factors are categorized as dependent factors. The results of DEMATEL are shown in Table 5-10.

Table 5-10 Results of DEMATEL

Factors	Nomenclature	$(R_{sum}+C_{sum})$	Rank	$(R_{sum}-C_{sum})$	Factor type
Technological	TEC	3.662	4	1.08	Driver
Social	SOC	4.629	1	0.029	Driver
Cultural	CUL	3.22	6	-0.83	Dependent
Economic	ECO	4.269	2	0.187	Driver
Political	POL	4.062	3	0.26	Driver
Geographical	GEO	2.489	10	0.109	Driver
Environmental	ENV	3.487	5	-1.233	Dependent
Geo-political	GEP	2.267	11	0.857	Driver
Socio-technical	SOT	2.768	8	0.528	Driver
Socio-cultural	SEO	2.199	12	-0.259	Dependent
Behavioural	BEH	3.061	7	-0.689	Dependent
Infrastructural	INF	2.535	9	-0.039	Dependent

The causal diagram is a plot having $(R_{sum}+C_{sum})$ on the *X-axis* vs $(R_{sum}-C_{sum})$ on the *Y-axis* that visually represents the results of DEMATEL. The causal diagram can be understood in two ways: Moving from left to right, the inter-relationship of the factors increases, i.e., the rank of factor increases. Factors above the x-axis are driver factors and those below the x-axis are dependent factors. Hence, a causal diagram gives an easy depiction of the results of DEMATEL. The causal diagram plotted for the analysis is shown in **Figure 5-1**.

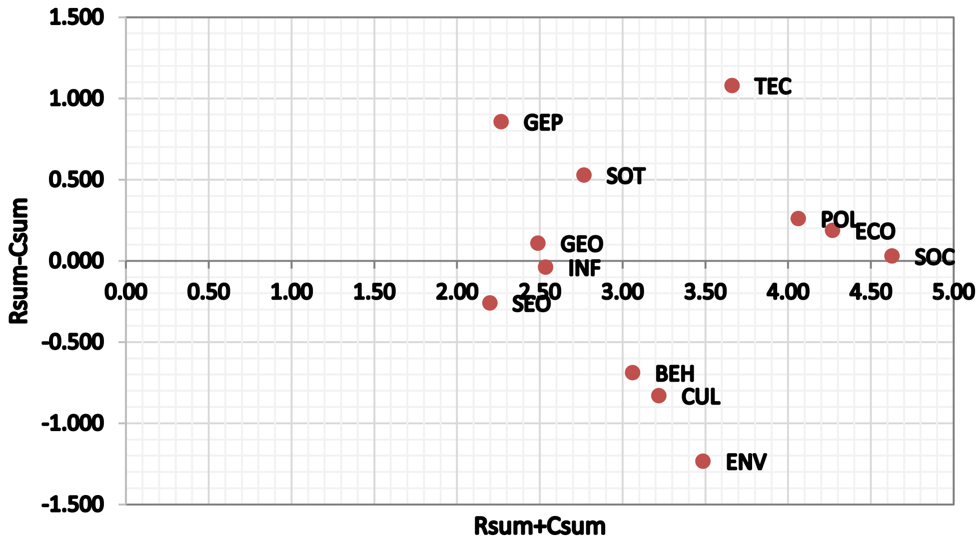

Figure 5-1 Causal diagram

According to the results, the social factor is the most significant driver. Introducing social variables such as awareness, brand endorsement and social appreciation for adopting EVs can help India's EV sector flourish. Other driving factors, such as economic, political, technological, socio-technical, geographical, and geo-political factors aid in the adoption and development of EVs manufacturing in India. Efforts made in the direction of these driver factors will in turn have an impact on dependent factors like environmental, cultural, behavioural, infrastructural and socio-cultural factors. Hence, DEMATEL analysis gave an insight on those factors on which focus needs to be shifted.

5.6 **Interpretive Structural Modelling (ISM)**

ISM is a technique that is used to systematically structure complex directly or indirectly related factors in a comprehensive or systematic way. To deal with the considered factors a systematic ISM model is developed through structural self-interaction matrix (SSIM) (as shown in Table 5-11) followed by reachability matrices (as shown in Appendix-II).

The steps involved in ISM approach are as follows:

1. **Identification of criteria**

The elements are selected on the basis of relevancy to the problem, so the first point is identification of elements. This can be done by secondary research or primary research techniques (survey).

2. **Establishing contextual relation between dimensions or indicators**

The contextual relation must be cogently stated as a possible statement of relationship among the elements. Relations may be of several types, such as influencing, comparative, temporal, or neutral.

3. **Construction of structural self-interaction matrix (SSIM) by pairwise comparison**

During this phase, the participants must decide upon the pairwise relationship between the elements. The contextual relationship for each element, the relationship between any two sub elements (i and j), and the associated direction of the relation are asked. The four symbols used to denote the direction of the relationship between the elements i and j are given below:

V = for the relation from i to j but not in both directions;

A = for the relation from j to i but not in both directions;

X = for both-direction relations: from i to j and j to i; and

O= if the relation between the elements does not appear to be valid

4. The development of a reachability matrix from the SSIM and transitivity check

This phase is concerned with the construction of the reachability matrix M. It is a binary matrix, since the entries V, A, X, and O of the SSIM are mapped into 1 and 0 as per the following rules:

- If the *(i, j)* entry in the SSIM is V, then the *(i, j)* entry in the reachability matrix becomes 1and the *(j, i)* entry becomes 0.
- If the *(i, j)* entry in the SSIM is A, then the *(i, j)* entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
- If the *(i, j)* entry in the SSIM is X, then both the *(i, j)* and *(j, i)* entries of the reachability matrix become 1.
- If the *(i, j)* entry of the SSIM is O, then both the *(i, j)* and *(j, i)* entries of the reachability matrix become 0.

5. Level partition on reachability matrix

The level partition is carried out to know the placement of elements level-wise. The reachability and antecedent sets for all the elements are determined.

6. Development of the diagraph

The elements are arranged graphically in levels, and the directed links are drawn as per the relationships shown in the reachability matrix. An easier version of the initial diagraph is obtained by eliminating the transitive relationships step by step, examining their interpretation from the knowledge base. Only those transitive relationships may be retained whose interpretation is crucial.

Table 5-11 Structural self-interaction matrix

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SEO	BEH	INF
TEC		A	V	A	A	V	V	A	X	V	V	X
SOC			V	V	V	V	V	O	V	V	V	V
CUL				A	A	A	A	O	A	A	X	O
ECO					A	V	V	A	V	V	O	V
POL						O	V	X	V	V	V	V
GEO							X	A	O	V	V	A
ENV								A	A	V	V	A
GEP									V	V	V	V
SOT										V	V	O
SEO											V	A
BEH												A
INF												

There are 7 levels in the developed model as shown in **Figure 5-2**. Cultural and behavioural factors occupy the topmost level, representing the most dependent element in the structure. Elements in the lower levels help achieve the elements in the upper levels. Hence, social factor (level 7) has the maximum driving power in that respect and requires the maximum attention. Social factors help achieve political and geo-political factors, which in turn helps achieve the economic factors and so on. Hence, this model provides a roadmap for adoption of EVs and their sustainable manufacturing in India.

According to the findings, efforts should begin with a focus on social factors. The most important drivers that will aid in the achievement of other factors are social considerations. Awareness is the first step toward the successful adoption of cleaner vehicle technologies. In addition, customers must receive adequate training in order to become acquainted with a new way of life. Finally, social appreciation and brand endorsements give a way for buyers to explore something new. After dealing with social factors, the focus should shift to political and geo-political factors. Introducing new regulations that encourage people to switch to EV will encourage them to do so. Free public charging, reserved parking areas for EV, insurance models for EV, and dedicated lanes for EVs could all help to boost EV adoption. Once the customer mind-set has been established and correct policies have been implemented, efforts must be made to improve the economic elements such as bringing down the cost of the battery will bring down the total cost of ownership of the vehicle.

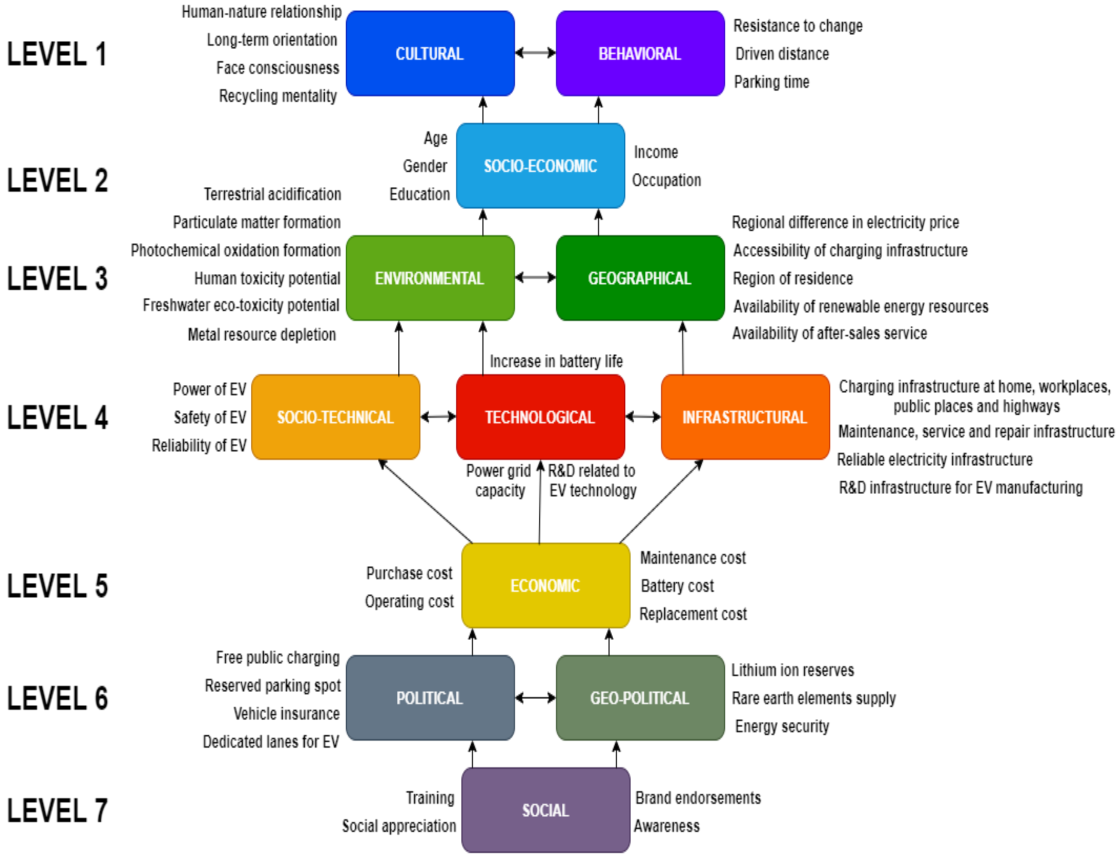

Figure 5-2 Level partitioning of factors

The next stage of implementation is socio-technical, technological, and infrastructural elements. Increasing the performance of EV, such as top speed, acceleration, reliability, and safety, will appeal to technology aficionados. Simultaneously, supporting infrastructure must be established. Customers will not prefer EV if supporting infrastructures such as regular public charging stations and maintenance and repair stations are not readily available. Working on these factors will have an impact on other aspects such as the environmental, geographical, and socio-cultural. The air quality and all other forms of pollution will also be significantly improved. At the end of the implementation process, cultural and behavioural factors must be addressed. So that the interaction between humans and nature will improve, and users will develop a long-term perspective. Finally, efforts should be taken to break down client resistance to change. As a result, working systematically and addressing the variables in a hierarchical manner will aid in speedier adoption and acceptance of EV among users, resulting in easier adoption and development of EV in India.

5.7 **Summary**

The study developed a comprehensive framework for evaluation of factors and variables that could aid in the smooth adoption and stabilization of India's EV market. The reliability and item analysis are used to statistically validate the survey results. As a consequence, the study chose fifty variables from the twelve categories and discovered a strong correlation between the survey results and statistical analysis. Furthermore, the research effort categorized the components based on their driving and dependent nature utilizing the DEMATEL-MCDM approach, which would suggest an improvement in the overall system or dependent factors' performance. Moreover, the study also used an ISM method to create a hierarchy of elements that would serve as a roadmap for the smooth adoption and sustainable manufacturing of EVs in India.

Chapter 6 ANALYSIS OF SOCIAL FACTORS RESPONSIBLE FOR ADOPTION OF EVs IN INDIA: A CASE STUDY

This chapter present a case study to identify and analyse social factors responsible for adoption of EVs in India. Capital city of India, Delhi was selected for the study. This study analyzed the social acceptability and sustainability of EVs. It also built inferences from the results obtained and helps in orienting the manufacturers and decision makers towards faster adoption of the EVs.

6.1 Need of the Study

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.

6.2 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?

6.3 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 (CPCB, 2020). 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 PM_{10} particular matter with an air quality index (AQI) of 292 micrograms particulate matter per cubic meter, 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 (Arpan Chatterji, 2020). These factors make Delhi a suitable site for this pilot study.

6.4 **Identification of Factors**

Axsen et al., (2013) have evaluated customer perception in the UK and discussed the impact of social influences on these perceptions. Digalwar & Giridhar, (2015) have implemented interpretive structural modelling (ISM) approach for prioritizing factors which are barriers to deployment of EVs in India. She et al., (2017) performed a similar study in Tianjin, China and found that most of the people recognized the importance of EVs, while a few people adopted ‘wait and watch attitude’ because of various concerns associated with EVs. Westin et al., (2018) studied the adoption of EVs in Sweden and their results mention that social influence plays a crucial role on the adoption of EVs. M.-K. Kim et al., (2018) have also analysed such social factors in Korea and found that people were satisfied with the driving experience of EVs. From such an exhaustive literature survey, presented in Chapter 2 and Chapter 3 of this thesis, a total of 14 factors were identified and frequency analysis of these factors was done as shown in Table 6-1 and based on the suitability; these 14 identified factors were grouped in three factor types as financial factors, vehicle performance factors and infrastructure factors.

Table 6-1 Frequency analysis of various factors affecting the adoption of EVs (EVs)

S.No.	Citation	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
1	(She et al., 2017)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	(Digalwar & Giridhar, 2015)	✓	✓	✓	✓	✓	✓		✓	✓					
3	(Zheng et al., 2018)	✓	✓	✓	✓	✓	✓				✓	✓	✓		✓
4	(Park et al., 2018)	✓	✓	✓		✓	✓	✓	✓		✓	✓			✓
5	(Axsen et al., 2013)	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓
6	(Kushnir & Sandén, 2012)	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		
7	(Westin et al., 2018)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	(Shalender, 2018)	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	
9	(Bennett et al., 2016)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
10	(Oliveira et al., 2015)	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓

S.No.	Citation	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
11	(Schmidt et al., 2015)	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		
12	(Shang & Shi, 2013)	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
13	(Kimble & Wang, 2013)	✓		✓	✓		✓	✓		✓	✓	✓			
14	(Pilkington & Dyerson, 2006)	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	
15	(Naor et al., 2015)	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
16	(Bennett & Vijaygopal, 2018)	✓	✓	✓	✓	✓	✓	✓	✓	✓					
17	(Byrne & Polonsky, 2001)	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		
18	(A. G. Kumar et al., 2015)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
19	(Saxena et al., 2014)					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20	(Berkeley et al., 2017)	✓	✓		✓	✓	✓	✓	✓	✓	✓				
21	(Yong & Park, 2017)	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	
22	(Soltani-Sobh et al., 2017)	✓	✓	✓	✓	✓	✓	✓	✓						
23	(Z. Zhang et al., 2017)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
24	(Steinhilber et al., 2013)	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
25	(O. Egbue & Long, 2012b)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
26	(Budde Christensen et al., 2012)	✓	✓	✓	✓	✓	✓	✓	✓						
27	(Wikström et al., 2015)	✓				✓		✓	✓			✓			✓
28	(Rezvani et al., 2015)	✓	✓	✓			✓		✓	✓	✓		✓	✓	✓
29	(Madina et al., 2016)	✓	✓			✓	✓	✓	✓			✓	✓	✓	
30	(Sierzchula, 2014)	✓	✓	✓	✓				✓	✓	✓				
31	(Haddadian et al., 2015)	✓		✓	✓		✓	✓	✓				✓	✓	
32	(Hardman et al., 2016)	✓	✓	✓	✓	✓	✓	✓			✓	✓			
33	(Morrissey et al., 2016b)	✓		✓	✓				✓			✓	✓		
34	(Jakobsson et al., 2016)											✓	✓	✓	✓
35	(Wikström et al., 2016b)	✓	✓	✓	✓	✓		✓	✓		✓				✓
36	(Contestabile et al., 2017)					✓	✓	✓	✓	✓	✓	✓	✓		
37	(Quak et al., 2016)	✓		✓	✓			✓	✓				✓	✓	✓
38	(H. Zhang et al., 2018)	✓			✓	✓				✓	✓	✓	✓		
39	(Margaritis et al., 2016)	✓				✓				✓	✓				✓

6.4.1 **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 (R. Kumar et al., 2021). 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 (Jiao & Evans, 2016).

Thus, battery cost indirectly becomes a financial factor that influences the adoption of EVs in the automotive market. Although purchase cost of an EV is comparatively higher than that of a conventional fossil fuelled vehicle (CFFV), the lower fuel and maintenance costs of EVs make them better choice in the long run (Weldon et al., 2018).

6.4.2 **Vehicle performance factors**

The biggest problem with EVs is their range. There is a trade-off between seating capacity and range. If seating capacity is increased, the range decreases. A typical EV with seating capacity of four persons has an average range of 130 km, which is enough for the daily driving of a customer (Adepetu & Keshav, 2017). However, this may not be able to fulfil the requirement of long-distance tours as they need battery charging. Also, it takes around 10 hours to charge the battery with a normal 220V 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. Safety of EVs is also a sensitive factor as it has been seen that the battery explodes upon crash of an EV (Machura & Li, 2019). 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 (Richa et al., 2017). Few important factors to be considered in case of EVs are reliability, performance consistency and trustworthiness.

6.4.3 **Infrastructure factors**

For the successful deployment of EVs, charging infrastructure needs to be available throughout the country. The charging stations are of two types – fast charging grid system and slow speed charging system(D. Han et al., 2016). 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 (Taefi et al., 2016). **Table 6-2** provides a clear understanding of the public perception.

Table 6-2 Factor type, grouping and explanation

Factor Type	Alias	Factor	Explanation
Financial Factors	F1	Purchase Cost	Purchase price of the EV without subsidy
	F2	Battery Cost	Cost of a new battery once its life ends
	F3	Unawareness about maintenance	The routine servicing cost of the vehicle
	F4	Unawareness 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 the passengers during the EV's lifetime
	F8	Reliability	Trustworthy and performance consistency
	F9	Life of battery	Time from purchase to disposal of battery
	F10	Vehicle power	Top speed, acceleration of EV
Infrastructural Factors	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

This study assumed that financial factors, vehicle performance factors, and infrastructural factors are all barriers to EV adoption from customer perspective and negatively impact the public perception for EVs.

6.5 **Methodology**

6.5.1 **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 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 license. The criterion of vehicle ownership was relaxed as many people may be using vehicles which are owned by their family members.

6.5.2 **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 (Morton et al., 2016). 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.

6.5.3 **Chi-square test**

This study employed the chi-square test to investigate statistical association among variables by testing the null hypothesis of no association between a set of groups and outcomes for a response. Positive value of path coefficient *(β)* means the test rejects the null hypothesis in favour of the alternative hypothesis of general association. We use the standard 5% for defining a statistically significant difference. Therefore, the associated p-value < 0.05 would mean there is significant evidence of an association between variables. Based on the previous studies, the following hypotheses will be tested in this study.

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.

6.6 **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.

6.6.1 **Descriptive statistics**

Table 6-3 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 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 6-3 Descriptive statistics of possible factors affecting the adoption of EVs.

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

Table 6-4 presents the results of the analysis of responses for part 4 of the questionnaire. It indicates that more than 54% 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.

Table 6-4 Descriptive statistics of public adoption of EVs

Survey Questionnaire	1 (Strongly unwilling)	2 (Unwilling)	3 (Confused)	4 (Willing)	5 (Strongly willing)
Willing to purchase EV	5.68%	28.39%	11.61%	51.22%	3.10%
Willing to recommend EV	1.22%	5.21%	28.47%	49.94%	15.16%
Ready to have more EVs in market	0.15%	3.18%	16.87%	62.17%	17.63%

6.6.2 **Structural equation model**

The path diagram shown in Figure 6-1 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.

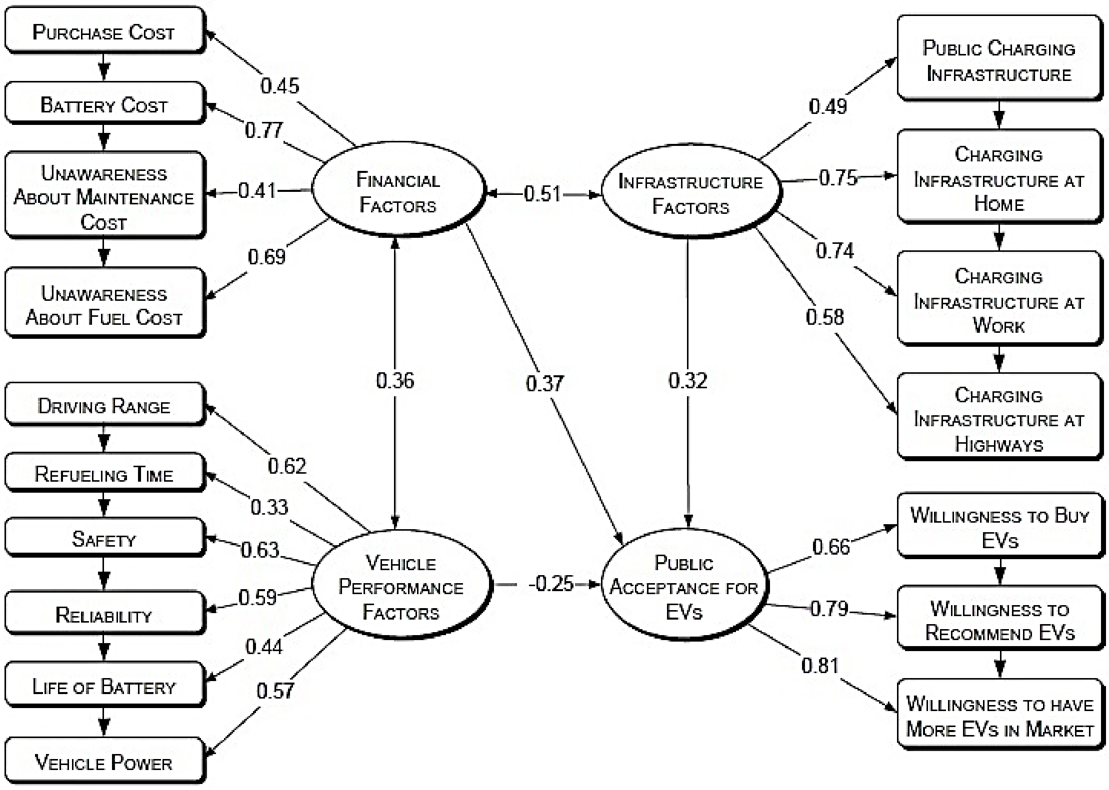

Figure 6-1 Structural equation model (SEM) path diagram

The Cronbach's alpha values and values of composite reliability (CR) for each factor were also computed to check the reliability of the factors. The estimated parameters of structural equation model (SEM) are also shown in Table 6-5.

Table 6-5 Reliability of structural equation model constructed variables

Factor	Items	Cronbach's alpha (α)	Composite Reliability
Financial factors	F1, F2, F3, F4	0.63	0.77
Vehicle performance factors	F5, F6, F7, F8, F9, F10	0.69	0.68
Infrastructure factors	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

6.6.3 **Hypothesis testing**

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

The path coefficients shown in the path diagram (β = 0.37, P = 0.021) do not support the hypothesis, and hence we reject the null hypothesis Table 6-6. 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 as shown in Table 6-6, 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 (β = –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 6-6 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.

The path coefficients from the path diagram (β = 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. 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.

Table 6-6 Estimated parameters of the structural equation model

Grouping of factors	ß	P	S.E.
Financial Factors			
Purchase cost	0.45	<0.001	0.054
Battery cost	0.77	<0.001	0.074
Unawareness about maintenance cost	0.41	<0.001	0.066
Unawareness 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

6.7 **Conclusion**

The study is based on 543 responses collected through a survey conducted in Delhi and the data thus collected is analysed. The statistics show that despite having a positive attitude towards the growth of the EV market, people are reluctant to switch to EVs because of the various barriers associated with them. The SEM suggests that the respondents, for whom vehicle performance is the most significant factor, are most reluctant to EVs and are not ready to adopt them. Current government policies include subsidies only for purchase cost and infrastructure building while these policies lack on the grounds of safety and reliability which can be improved by providing incentives like insurance subsidy and salvage value subsidy etc. Besides the steps being taken by the government, the manufacturers must also work on improvement of vehicle performances by allocating more funds on research and development activities.

The battery cost and purchase cost are the top concerns and are ranked 1st and 2nd by 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 are being allocated by the government to the FAME India scheme. Meanwhile, there are customers with a "wait-and-watch" attitude, waiting until the purchase cost for EVs comes at par with the cost for a CFFVs and switching to EVs would be affordable. Providing subsidy on the modification of a CFFV to EV might be a promising idea. The awareness about low maintenance cost and ultra-low running cost must also be promoted. By exercising the proposed measures, the customers should be convinced that the total cost of ownership of EV would be reduced to 50% even after a higher purchase price.

The public charging infrastructure is ranked 3rd in 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 the infrastructures and public adoption, which again is the result of large funding allocated for creation 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 the 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 electric vehicles into the Indian market.

Indian EVs industry is expected to compete at a global level. To develop a core competency in the global market, it is necessary to understand the multi-dimensional aspects of the manufacturing of EVs that have suppressed or accelerated their growth in the past. Hence, a three-stage approach was formulated to develop a framework to evaluate the important factors for easy adoption and sustainability of EVs manufacturing in India. Initially, thorough literature review has been carried out to identify the effective factors and variables. The variables are constituted under the factors using Churchill's paradigm and nominal grouping techniques. Finally, 80 variables were selected under the 12 major factors. To analysed the importance of variables and factors in Indian conditions a survey instrument has been developed, for the empirical investigation and understanding the reliability and validity of the theoretically developed factors and their variables. A total of 902 responses have been collected and classified them into five categories based on the importance index. Results of analysis showed, total 44 variables are very important, 35 variables are important, and the important category carries only 1 variable. None of the variable came in slightly important and not important categories. It shows the empirical validation of the research findings.

In the next stage, the inter-relationship among the factors was determined using the DEMATEL method; the 12 factors were categorized as either driver or dependent. Results of DEMATEL showed that social factor is the most significant driver. Other driving factors like technological, political, geographical, and economic factors also contribute to the sustainable manufacturing of EVs. Efforts made towards these driver factors will in turn have an impact on dependent factors like environmental, cultural, behavioural, infrastructural and socio-cultural factors. Hence, DEMATEL analysis gave an insight to the decision and policy makers.

The final stage of the study was to create a roadmap for the effective implementation of strategies that will maximize the effort towards sustainable development of EVs manufacturing in India. ISM approach has been adopted for solving the complex problem that involved many factors. ISM model was developed which segmented the factors into 7 stages of implementation. As per the results, efforts should begin with a focus on social factors. Social factors are the most prominent drivers that will help achieve other factors. Successful adoption of the cleaner vehicle technology begins with awareness. Proper knowledge must be provided to the customers to get familiarized with a new choice of lifestyle. Social appreciation along with brand endorsements will create a mind-set to try something new among the customers. Once Social factors are tackled, the focus should be on political and Geo-political factors. Bringing new policies in the favour of electric mobility will prompt users to shift to EVs. Policies like free public charging, reserved spots for EVs, insurance models for EVs, and dedicated lanes for EVs could bring about a positive vibe about EVs. Once the mind-set is created among the customers and proper policies are laid, efforts must be made to improve the economic factors. Bringing down the cost of the battery will bring down the total cost of ownership of the vehicle. Socio-technical, technological, and infrastructural factors form the next upper level that needs implementation. Improving the performance of EVs like top speed, acceleration, reliability, affordability and safety of EVs will attract technology enthusiasts. Supporting infrastructure also needs to be developed simultaneously. Customers will not prefer EVs if supporting infrastructures like public charging stations at frequent intervals or maintenance and repair stations are not available upon requirement. Working on these factors will bring about changes to other factors like environmental, geographical, and socio-cultural. There will be a significant improvement in air quality and all other forms of pollution. At the final stage of implementation, efforts must be put to work on cultural and behavioural factors. The human-nature relationship will improve; Users will develop a long-term orientation. Finally, efforts must be made to loosen up the resistance to change among the customers. Thus, working systematically and tackling the factors in a hierarchical manner will help achieve faster adoption and acceptance of EVs among users, which in turn drive the sustainable development of EVs manufacturing in India.

Suggestions based on the framework could be used by policymakers, original equipment manufacturers, or researchers working on R&D related to EVs manufacturing for effective implementation. Similar models can be developed for any nation by studying the factors and understanding the extent of inter-relationship that exists among the factors.

Present study, also demonstrated the pilot study in capital of India, Delhi in which study analysed the social factors responsible for the growth of electric vehicles in India. A questionnaire has been developed for understanding the customer’s perception towards EVs. The results of the survey are analysed using structural equation model (SEM). The results of the study were based on three hypotheses. The findings showed that the financial and infrastructure factors have positive impact on rate of adoption of EVs in India, whereas the vehicle performance factors have a negative impact on EVs adoption, implying that the respondents of the survey who feel that the vehicle performance factors are the most imperative have a more passive mind-set towards the electric vehicles adoption.

7.1 **Implication of Research Outcome**

Firstly, the study will assist the Indian government in reaching international commitments such as lowering GHG emissions intensity per unit of GDP by 30-35 % from the level of 2005, and adopting and developing green or sustainable automotive technologies (Saraswat et al., 2021). Furthermore, it will aid in the resolution of major concerns such as energy security and climate change, making the country economically stronger and environmentally safe. The study also identified significant variables for the government for further action, such as free public charging, reserved car parking spots, and tax on fossil fuel. This will make it easier for the government to develop appropriate policies and make choices. Furthermore, the survey suggested that when manufacturers take into account important qualities including comfort, power, safety, reliability, affordability, and aesthetic appeal. Buyers can be enticed by taking these things in mind, and sellers can also sell the product very easily. The study will also encourage customers because of the advantages of EV, such as the human-nature interaction, social appreciation, long-term orientation, social status, and so on. Overall, it is obvious that the study aids in the seamless adoption and growth of EVs in India, benefiting people from all walks of life.

7.2 **Specific Contribution**

The specific contributions of the thesis are as follows.

- Identification and analysis of factors responsible for adoption and sustainable development of EVs manufacturing in India.
- Descriptive analysis and importance index analysis of identified factors and variables.
- Reliability and validity analysis of variables grouped in factors.
- Development of interrelationship between factors and variables.
- Development of frame work using interpretive structure modeling (ISM).
- A case study, to access the impact of social factors on adoption of EVs.

7.3 **Limitations and Future Scope**

The extensive research study presented in this work has its own set of limitations. The methodology examines the respondents' average conscience. Industrial specialists, academicians, manufacturers, suppliers, and customers are all stakeholders in the study. The respondents' knowledge or awareness of variables that are not linked to their area, which may have an impact on the outcome. Furthermore, the nature of several factors utilized in the study is extremely dynamic and reliant on the survey timeframe; the respondents' opinions on those variables may change over time. If the same research is repeated after a period of time, the structure of the ISM model developed may vary. The findings of this study are based on the stakeholders' perceptions at the time of the survey. These constraints, however, can be eliminated with a more focused analysis of determinants based only on the responses of the respective stakeholders.

This research work has immense scope for applications at the holistic level and the factor level. At the holistic level, policymakers can drive their decisions based on the knowledge of drivers and dependent factors in the ISM model. On a factor level, analysts can use the variables to develop quantitative and qualitative key performance indicators (KPIs) for the various factors in order to further investigate the factors. The Indian government can utilize the entire roadmap framework as a guide to develop a strategy for future regulations to boost the growth of cleaner fuel vehicles in the country. In addition, original equipment manufacturers (OEMs) can use the relative significance of variables under the factors to prioritize which variables to work on. Researchers working on sustainability can concentrate on the environmental factors and conduct in-depth analyses of variables to explore the inter-relationships among the variables. Similar to the ISM developed at the factor level, separate ISMs can be developed at the variable level to analyse and understand the factor. Researchers and other stakeholders can select alternatives using factors or variables in the appropriate MCDM methodologies to resolve multi-criteria decision-making difficulties. As a result, this study serves as a foundation for future research examining the impact of these aspects from the consumer's, suppliers, and manufacturer's perspectives.

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BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI
Pilani Campus
Arpit Rastogi, Ph.D. Research Scholar, Mechanical Engineering Department

Cover Letter

Dear Sir/Madam,

I am Arpit Rastogi pursuing my doctoral thesis in the area of "Sustainable Manufacturing" at Birla Institute of Technology and Science, Pilani under the supervision of Prof. (Dr.) **Abhijeet Keshaorao Digalwar**. It gives me immense pleasure to interact with professionals like you.

With growing awareness of environmental issues like global warming, CFC emission and depleting reserves of fossil fuels, the government and thereby the whole manufacturing sector including automobile industries have come under tremendous pressure to reduce the environmental impacts from transportation. Lack of comprehensive list of factors for sustainable growth of electric vehicles manufacturing is a big challenge for developing countries like India.

In this context, I request you to kindly fill the attached questionnaire, which is an important component of my research work. Your honest response will assure substantial outcomes in this study and help to carry out the same successfully. I will be happy to acknowledge the same.

Please make it convenient to spare only 10-15 minutes from your valuable time to complete the questionnaire. The collected information will be kept confidential and utilized for research purpose only. If you wish not to disclose your and/ or your company's identity, you can skip that information. I welcome your suggestions and queries.

If you are not associated with this subject then forwarding this mail to the concerned person will be of a great help.

Please click here to fill the questionnaire https://forms.gle/C5N8347sZHYXhwkC8

Thanking you.

Yours truly,

Arpit Rastogi

Section-A

Personal Information

Kindly put a ✔ mark against the appropriate option wherever required in the question.

1)	Name	:Mr. /Ms. /Dr. ……………………………………			
2)	Age group	:18-30	31-45	46-60	above 60
3)	Gender	:Male	Female		
4)	Education	:Up to+2	UG	PG	Doctorate
5)	Technical qualification:	Yes	No		
6)	Monthly income	: >25k	25k-50k	50k-75k	75k-1lac
7)	City of residence	:Rural	Urban	Metro	NCR
8)	State of residence	:Select from drop-down menu			

Section-B

Travel pattern

Kindly put a ✔ mark against the appropriate option wherever required in the question.

1) How much distance do you travel daily in km?

   0-25km   25-50km   50-75km   More than 75km

2) How frequently you refuel your vehicle?

   Daily   Alternate day   Weekly   Monthly

3) How frequently would you like to visit workshop for scheduled maintenance?

   2000km   5000km   10000km   More than 10000km

4) Which kind of driving pattern do you follow?

   Steady/Economy driving   Fast/Power/Accelerated driving   Racing mode

Section-C

Social Factors

A five-point Likert scale (1-5) is used as per the importance level with the following notions:

Level of Importance	**Extremely Low**	**Low**	**Medium**	**Moderate**	**High**
Associated Weightage	1	2	3	4	5

1) For you what are the barriers to the deployment of E-vehicles in India?

S.No.	**Barrier**	**Extremely Low**	**Low**	**Medium**	**Moderate**	**High**
1	Recharging time					
2	Availability of charging station					
3	Maintenance cost					
4	Distance per full changing					
5	Purchase price					
6	Appearance/ Aesthetics/ Ergonomics					
7	Safety					
8	Road side assistance					
9	Resale value					
10	Government policies					
11	Limited model choice					

2) For you what are the drivers for the deployment of E-vehicles?

S.No.	**Driver**	**Extremely Low**	**Low**	**Medium**	**Moderat e**	**High**
1	Running cost					
2	Noise level					
3	Ease of driving					
4	Eco- friendly					
5	Subsidy					
6	Less emission					
7	Less vibrations					

Section-D

Interpersonal Factors

Kindly put a ✔ mark against the appropriate option in the question.

1) How would you rate your interest towards E-vehicles?

a. No interest
b. Little interest
c. Moderate interest
d. High interest

2) What is your general opinion on future of E-vehicles in India?

a. They will completely replace gasoline fuel in following years.
b. They will be a part of transport system, but will never take over the gasoline powered vehicles.
c. They will always be limited to research and will remain beyond the reach of masses.

3) Are you willing to change the lifestyle to use E-vehicle?

a. Yes
b. No
c. Can't Say

4) Do you think that buying an E-vehicle will have positive effect on your social image?

a. Yes
b. No
c. Can't Say

5) Are you environment conscious?

a. Yes
b. No
c. Can't Say

6) Do you plan to buy E-vehicle in future?

a. Yes
b. No
c. Can't Say

7) If all the vehicles are available as E-vehicles, what type of vehicle would you like to buy?

a. 2 Wheeler
b. 5 Seater (Economy sedan/ Hatchback)
c. 7 Seater (Compact SUV)
d. Luxury vehicle
e. Commercial vehicle

1) How many hours time would you like to spare for charging?
   a. Less than 2
   b. 1-2
   c. 2-4
   d. up to 5

2) In case you own an E-vehicle, where will you be charging it?
   a. Home / apartment parking
   b. Parking area of an office
   c. Public charging stations

3) How much would you be willing to pay for a new E-vehicle instead of new gasoline powered vehicle?
   a. Less than conventional vehicle
   b. Same as conventional vehicle
   c. More than conventional vehicle
   d. Cost doesn’t matter

4) Should the government provide incentive to promote E-vehicle deployment?
   a. Not at all
   b. May be
   c. Definitely

5) Which kind of incentive should government provide for encouraging adoption of E-vehicles?
   a. One time incentive like subsidy, rebate in registration/ road tax etc.
   b. Incentive for a certain period like rebate in toll tax/ parking/ insurance premium etc.

6) What according to you is the main barrier for people not buying an E-vehicle in India?
   a. The technology is not mature enough
   b. Expensive when compared to conventional I.C. engine vehicles
   c. Lack of charging infrastructure
   d. Lower range with fully charged E-vehicle
   e. Less available choices for E-vehicle

7) How likely that your next vehicle will be an E-vehicle?
   a. I want to buy electric vehicle as soon as possible
   b. I want to buy E-vehicle during next 5 years
   c. I want to buy E-vehicle during next 10 years
   d. I don't want to buy E-vehicle

8) How important for you is someone's advice regarding choice of an E-vehicle?
   a. Not important at all, I rely on my own knowledge
   b. I will take into consideration opinion of my family and friends
   c. I will take into account advice of professionals
   d. I will pay attention to every suggestion, I can receive

	TEC	**SOC**	**CUL**	**ECO**	**POL**	**GEO**	**ENV**	**GEP**	**SOT**	**SCU**	**BEH**	**INF**	**Reachability Set**	**Antecedent set**	**Intersection**	**Level**
TEC	1	0	1	0	0	1	1	0	1	1	1	1	1,3,6,7,9,10, 11,12	1,2,4,5,8,9, 12	1,9, 12	
SOC	1	1	1	1	1	1	1	0	1	1	1	1	1,2,3,4,5,6,7, 9,10,11,12	2	2	
CUL	0	0	1	0	0	0	0	0	0	0	1	0	3,11	1,2,3,4,5,6, 7,9,10,11	3,11	1
ECO	1	0	1	1	0	1	1	0	1	1	0	1	1,3,4,6,7,9, 10,12	2,4,5,8	4	
POL	1	0	1	1	1	0	1	1	1	1	1	1	1,3,4,5,7,8,9, 10,11,12	2,5,8	5,8	
GEO	0	0	1	0	0	1	1	0	0	1	1	0	3,6,7,10,11	1,2,4,6,7,8, 12	6,7	
ENV	0	0	1	0	0	1	1	0	0	1	1	0	3,6,7,10,11	1,2,4,5,6,7, 8,9,12	6,7	
GEP	1	0	0	1	1	1	1	1	1	1	1	1	1,4,5,6,7,8,9, 10,11,12	5,8	5,8	
SOT	1	0	1	0	0	0	1	0	1	1	1	0	1,3,7,9,10,11	1,2,4,5,8,9	1,9	
SCU	0	0	1	0	0	0	0	0	0	1	1	0	3,10,11	1,2,4,5,6,7, 8,9,10,12	10	
BEH	0	0	1	0	0	0	0	0	0	0	1	0	3,11	1,2,3,5,6,7, 8,9,10,11,12	3,11	1
INF	1	0	0	0	0	1	1	0	0	1	1	1	1,6,7,10,11, 12	1,2,4,5,8,12	1,12	

Iteration-1

	TEC	**SOC**	**CUL**	**ECO**	**POL**	**GEO**	**ENV**	**GEP**	**SOT**	**SCU**	**BEH**	**INF**	**Reachability Set**	**Antecedent set**	**Intersection**	**Level**
TEC	1	0	1	0	0	1	1	0	1	1	1	1	1,6,7,9,10,12	1,2,4,5,8,9, 12	1,9,12	
SOC	1	1	1	1	1	1	1	0	1	1	1	1	1,2,4,5,6,7,9, 10,12	2	2	
CUL	0	0	1	0	0	0	0	0	0	0	1	0				1
ECO	1	0	1	1	0	1	1	0	1	1	0	1	1,4,6,7,9,10, 12	2,4,5,8	4	
POL	1	0	1	1	1	0	1	1	1	1	1	1	1,4,5,7,8,9, 10,12	2,5,8	5,8	
GEO	0	0	1	0	0	1	1	0	0	1	1	0	6,7,10	1,2,4,6,7,8, 12	6,7	
ENV	0	0	1	0	0	1	1	0	0	1	1	0	6,7,10	1,2,4,5,6,7, 8,9,12	6,7	
GEP	1	0	0	1	1	1	1	1	1	1	1	1	1,4,5,6,7,8,9, 10,12	5,8	5,8	
SOT	1	0	1	0	0	0	1	0	1	1	1	0	1,7,9,10	1,2,4,5,8,9	1,9	
SCU	0	0	1	0	0	0	0	0	0	1	1	0	10	1,2,4,5,6,7, 8,9,10,12	10	2
BEH	0	0	1	0	0	0	0	0	0	0	1	0				1
INF	1	0	0	0	0	1	1	0	0	1	1	1	1,6,7,10,12	1,2,4,5,8,12	1,12	

Iteration-2

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SCU	BEH	INF	Reachability Set	Antecedent set	Intersection	Level
TEC	1	0	1	0	0	1	1	0	1	1	1	1	1,6,7,9,12	1,2,4,5,8,9,12	1,9,12	
SOC	1	1	1	1	1	1	1	0	1	1	1	1	1,2,4,5,6,7,9,12	2	2	
CUL	0	0	1	0	0	0	0	0	0	0	1	0				1
ECO	1	0	1	1	0	1	1	0	1	1	0	1	1,4,6,7,9,12	2,4,5,8	4	
POL	1	0	1	1	1	0	1	1	1	1	1	1	1,4,5,7,8,9,12	2,5,8	5,8	
GEO	0	0	1	0	0	1	1	0	0	1	1	0	6,7	1,2,4,6,7,8,12	6,7	3
ENV	0	0	1	0	0	1	1	0	0	1	1	0	6,7	1,2,4,5,6,7,8,9,12	6,7	3
GEP	1	0	0	1	1	1	1	1	1	1	1	1	1,4,5,6,7,8,9,12	5,8	5,8	
SOT	1	0	1	0	0	0	1	0	1	1	1	0	1,7,9	1,2,4,5,8,9	1,9	
SCU	0	0	1	0	0	0	0	0	0	1	1	0				2
BEH	0	0	1	0	0	0	0	0	0	0	1	0				1
INF	1	0	0	0	0	1	1	0	0	1	1	1	1,6,7,12	1,2,4,5,8,12	1,12	

Iteration-3

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SCU	BEH	INF	Reachability Set	Antecedent set	Intersection	Level
TEC	1	0	1	0	0	1	1	0	1	1	1	1	1,9,12	1,2,4,5,8,9,12	1,9,12	4
SOC	1	1	1	1	1	1	1	0	1	1	1	1	1,2,4,5,9,12	2	2	
CUL	0	0	1	0	0	0	0	0	0	0	1	0				1
ECO	1	0	1	1	0	1	1	0	1	1	0	1	1,4,9,12	2,4,5,8	4	
POL	1	0	1	1	1	0	1	1	1	1	1	1	1,4,5,8,9,12	2,5,8	5,8	
GEO	0	0	1	0	0	1	1	0	0	1	1	0				3
ENV	0	0	1	0	0	1	1	0	0	1	1	0				3
GEP	1	0	0	1	1	1	1	1	1	1	1	1	1,4,5,8,9,12	5,8	5,8	
SOT	1	0	1	0	0	0	1	0	1	1	1	0	1,9	1,2,4,5,8,9	1,9	4
SCU	0	0	1	0	0	0	0	0	0	1	1	0				2
BEH	0	0	1	0	0	0	0	0	0	0	1	0				1
INF	1	0	0	0	0	1	1	0	0	1	1	1	1,12	1,2,4,5,8,12	1,12	4

Iteration-4

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SCU	BEH	INF	Reachability Set	Antecedent set	Intersection	Level
TEC	1	0	1	0	0	1	1	0	1	1	1	1				4
SOC	1	1	1	1	1	1	1	0	1	1	1	1	2,4,5	2	2	
CUL	0	0	1	0	0	0	0	0	0	0	1	0				1
ECO	1	0	1	1	0	1	1	0	1	1	0	1	4	2,4,5,8	4	5
POL	1	0	1	1	1	0	1	1	1	1	1	1	4,5,8	2,5,8	5,8	
GEO	0	0	1	0	0	1	1	0	0	1	1	0				3
ENV	0	0	1	0	0	1	1	0	0	1	1	0				3
GEP	1	0	0	1	1	1	1	1	1	1	1	1	4,5,8	5,8	5,8	
SOT	1	0	1	0	0	0	1	0	1	1	1	0				4
SCU	0	0	1	0	0	0	0	0	0	1	1	0				2
BEH	0	0	1	0	0	0	0	0	0	0	1	0				1
INF	1	0	0	0	0	1	1	0	0	1	1	1				4

Iteration-5

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SCU	BEH	INF	Reachability Set	Antecedent set	Intersection	Level
TEC	1	0	1	0	0	1	1	0	1	1	1	1				4
SOC	1	1	1	1	1	1	1	0	1	1	1	1	2,5	2	2	
CUL	0	0	1	0	0	0	0	0	0	0	1	0				1
ECO	1	0	1	1	0	1	1	0	1	1	0	1				5
POL	1	0	1	1	1	0	1	1	1	1	1	1	5,8	2,5,8	5,8	6
GEO	0	0	1	0	0	1	1	0	0	1	1	0				3
ENV	0	0	1	0	0	1	1	0	0	1	1	0				3
GEP	1	0	0	1	1	1	1	1	1	1	1	1	5,8	5,8	5,8	6
SOT	1	0	1	0	0	0	1	0	1	1	1	0				4
SCU	0	0	1	0	0	0	0	0	0	1	1	0				2
BEH	0	0	1	0	0	0	0	0	0	0	1	0				1
INF	1	0	0	0	0	1	1	0	0	1	1	1				4

Iteration-6

	TEC	SOC	CUL	ECO	POL	GEO	ENV	GEP	SOT	SCU	BEH	INF	Reachability Set	Antecedent set	Intersection	Level
TEC	1	0	1	0	0	1	1	0	1	1	1	1				4
SOC	1	1	1	1	1	1	1	0	1	1	1	1	2	2	2	7
CUL	0	0	1	0	0	0	0	0	0	0	1	0				1
ECO	1	0	1	1	0	1	1	0	1	1	0	1				5
POL	1	0	1	1	1	0	1	1	1	1	1	1				6
GEO	0	0	1	0	0	1	1	0	0	1	1	0				3
ENV	0	0	1	0	0	1	1	0	0	1	1	0				3
GEP	1	0	0	1	1	1	1	1	1	1	1	1				6
SOT	1	0	1	0	0	0	1	0	1	1	1	0				4
SCU	0	0	1	0	0	0	0	0	0	1	1	0				2
BEH	0	0	1	0	0	0	0	0	0	0	1	0				1
INF	1	0	0	0	0	1	1	0	0	1	1	1				4

Iteration-7

Journal Publications:

1. Rastogi, A., Digalwar, A.K., Thomas, R.G., (2021) "An Identification and Analysis of Social Factors Responsible for Adoption of Electric Vehicles in India", Journal for Current Science, Vol. 121, No. 9, 2021. (DOI: 10.18520/cs/v121/i9/1180-1187) (SCI IF 1.102)

2. Digalwar, A.K., Thomas, R.G., Rastogi, A., (2021), "Evaluation of Factors for Sustainable Manufacturing of Electric Vehicles in India", Procedia CIRP, Vol. 98, pp. 505-510. https://doi.org/10.1016/j.procir.2021.01.142 (Scopus Indexed CS 3.9)

3. Digalwar, A. K., Saraswat, S. K. and Thomas, R.G., Rastogi, A., (2021), "A Comprehensive Framework for Analysis and Evaluation of Factors Responsible for Sustainable Growth of Electric Vehicles in India", Journal of Cleaner Production. (Accepted, JCLEPRO-S-21-31325) (SCI IF 9.297)

4. Digalwar, A. K. and Rastogi, A., (2021), "Assessment of social factors responsible for adoption of electric vehicles in India: A case study, International Journal of Energy Sector Management. (DOI:10.1108/IJESM-06-2021-0009) (Scopus Indexed SC 3.2)

Conference Publications:

1. Thomas, RG, Saraswat, S.K., Rastogi, A., Digalwar, A.K. (2021), "On grid system evaluation for EV charging stations using renewable sources of energy", IEEE Xplore, (DOI: 10.1109/IPRECON49514.2020.9315235) (Scopus Indexed)

2. Rastogi, A., Digalwar, A.K., Jain, S,, (2018) "Sustainability Assessment of Diesel and Electric Buses: A Case Study" at 12th ISDSI Annual Conference, organized by S.P.Jain Institute of Management and Research, Mumbai from 26-31 Dec-2018.

3. Digalwar, A.K. Rastogi, A. Saraswat, S.K. (2021) "Fostering Adoption of Electric Vehicles in India: A Comprehensive Framework to Evaluate the Driving Factors" at ISDSI-Global Conference 2021.

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Arpit Rastogi is a Ph.D candidate in the Department of Mechanical Engineering at Birla Institute of Technology and Science, Pilani, Rajasthan, India. He is pursuing his Ph.D in Sustainability in manufacturing from BITS Pilani, India. He has done his masters of engineering from Birla Institute of Technology and Science, Pilani, Rajasthan (2009-2011). After that, he worked with industry for 3 years. The field of his research interests are sustainable manufacturing, manufacturing excellence, industrial and production management.

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Dr. Abhijeet Keshaorao Digalwar, is presently working as Associate Professor in Mechanical Engineering Department of BITS Pilani. He has received Ph.D in 2006. He has over 24 years of teaching and research experience. His area of research includes sustainable development, decision sciences, manufacturing systems engineering and management. He has published more than 100 research papers in national, international journals and proceedings. He has supervised 6 Ph.D (3 completed, 3 undergoing) and more than 50 post graduates. He has successfully delivered 2 government funded projects and presently working on DST-YASH, another funded project.

He is on the editorial advisory boards of reputed national and international journals like production planning and control, international journal of production research, international journal of services and operations management, international journal of business excellence.

Dr. Digalwar has delivered expert talks before various national and international forums and has a global research experience in the countries like Denmark, Norway, Finland, Singapore, Malaysia, Sri Lanka, Dubai. He worked as a Visiting Researcher at University of Southern (SDU) Denmark. In addition to the member of professional societies like ISTE, IIIE, IIE, PMA-UK and DSI-USA, he has served as a President (Indian Subcontinent), Decision Sciences Institute, Atlanta, USA subsequently for two years (2016-2018).