Integrated Research and Action for Development
IRADe

SHAKTI SUSTAINABLE ENERGY FOUNDATION

ELECTRIC VEHICLES

CHARGING PATTERNS & IMPACT ON DISCOMS

IRADe-PR-83(2022)

20 YEARS Integrated Research and IRADe Action for Development

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About Shakti

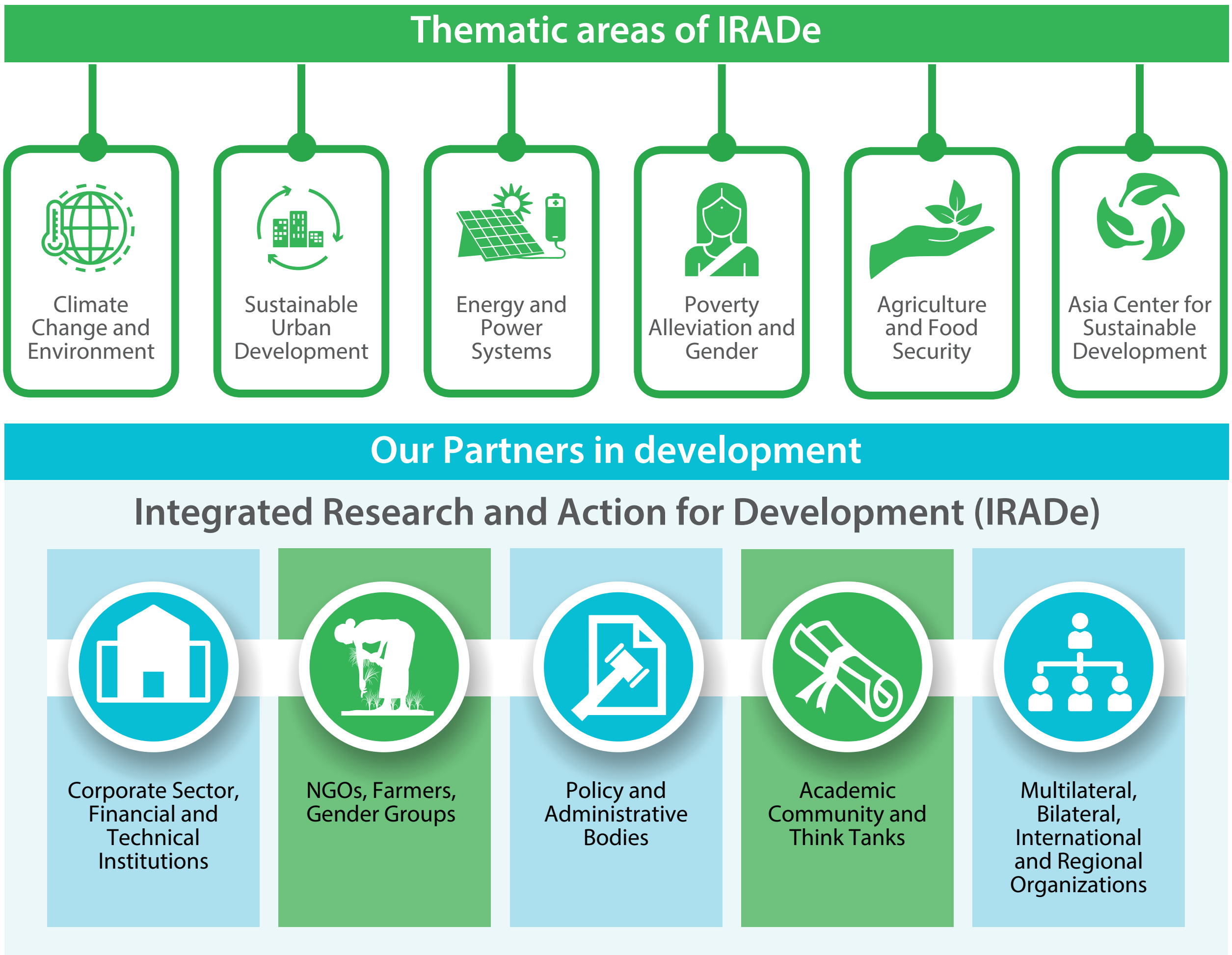
Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

Website: www.shaktifoundation.in

About IRADe

IRADe is an independent non-profit, advanced research institute which aims to conduct research and policy analysis to engage stakeholders such as government, non- governmental organizations, corporations, academic and financial institutions. Energy, climate change, urban development, poverty, gender equity, agriculture and food security are some of the challenges faced in the 21st century. IRADe's research covers these issues, as well as the policies that affect them. IRADe's focus is on effective action through multi-disciplinary and multi-stakeholder research to arrive at implementable solutions for sustainable development policy research and effective governance that accounts for techno-economic and socio-cultural issues. It also provides expertise to several ministries, national and international institutions, and partners with reputed organizations.

IRADe was established under the Society's Act, in 2002 at New Delhi. It is certified as a Research & Development Organisation by the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology (MoST), Government of India. It has also been selected as a Centre of Excellence by the Ministry of Housing and Urban Affairs (MoHUA), Government of India, for urban development and climate change.



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Abbreviations

AMI	Advanced Metering Infrastructure
BEV	Battery Electric Vehicle
CEF	Connect Europe Facility
CEM	Clean Energy Ministerial
CO2	Carbon dioxide
COP-21	Conference of Parties-21
DISCOMs	Distribution companies
DOE	Department of Energy
ELMO	Estonian E-Mobility Programme
EU	European Union
EVI	Electric Vehicle Initiative
EVs	Electric vehicles
EVSE	Electric Vehicle Supply Equipment
GHG	Greenhouse Gases
Gt CO2eq/yr	Gigatonnes of carbon dioxide equivalent per year
ICE	Internal combustion engines
MHDV	Medium and Heavy Duty Vehicle
MIIT	Ministry of Industry and Information Technology
NDRC	National Development and Reform Commission
NEDC	New European Driving Cycle
NHPP	National High way Performa Program
PHEV	Plug-in-Hybrid Electric Vehicle
RMB	Renminbi (Chinese Currency)
SIAC	Shanghai International Automobile City
TWh	Terra Watt-hour
UAP	Urban Air Pollution
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle Kilometers
ZEV	Zero Emissions Vehicle

Summary

The transport sector has emitted approximately 8 billion tonnes of CO_2 globally in 2018 which makes it world's second-largest emitter of carbon dioxide (CO_2). It accounted for 24% of CO_2 emissions from fuel combustion. Passenger vehicles accounted for 45% of overall transportation emissions, followed by road freight vehicles at 29%, aviation at 12%, foreign shipping at 11%, rail at less than 1%, and other modes of transportation at 2% (Global EV Outlook, 2020). India has also experienced rise in urban air pollution (UAP) levels in many cities. In response to the environmental issues, the federal and state governments have promoted e-mobility, which results in zero tailpipe emissions and lower operating and maintenance costs. However, transition to EV would require investment planning for the supporting infrastructure like charging facilities and local distribution grids.

One of the important stakeholders in EV ecosystem are the discoms as they are primarily responsible for preparing the charging infrastructure to support large scale EV penetration. Hence, it is important for DISCOMs to plan in advance and estimate the number of electric vehicles that are likely to be in use and their estimated impact on the grid. Keeping this objective in mind, Shakti Sustainable Energy Foundation (SSEF) funded the present study carried out by IRADe in which it has tried to assess the user behaviour and experience of early adopters of EVs in Delhi and estimated the impact of EV charging on Delhi's power demand and the hourly load on the local grid. For this purpose, primary surveys covering 500 respondents in four distinct segments: current private users of electric-2W and 4W, EV-4W institutional, e-rickshaws and prospective EV consumers (those who are planning to buy a vehicle over the next six months) was undertaken in Delhi NCR from August to September 2020. The survey tried to capture the socio economic characteristics, vehicle ownership patterns, transport and charging behaviour of early adopters of EV in Delhi and based on the assessed charging behaviour the study further estimated the impact on the grid of Delhi. In addition, a prospective consumer survey was also undertaken to assess and identify the factors that influence consumer's choice of buying or not buying EV.

The private consumers include EV-2W, 4W users and prospective consumers. The survey results show that the most of early adopters of EV 2W in Delhi belong to lower household expenditure groups as monthly average expenditure was Rs.18,506/month and around 1/3rd already have conventional 2W or 4W. Early adopters of EV 4W are from higher monthly household expenditure range with an average expenditure of 44,286 Rs/ month and already have conventional 2W or 4W. The early adopters of EV 2W and 4W in Delhi are all aware of air pollution compared to other environmental issues. Early adopters of EVs and prospective buyers prefer EVs for regular and short distance, mostly to work place.

To assess the charging pattern for EV 2W and 4W, the plugin and plug-out time reported by the respondents is collected in the survey. In this way, a 24-hour charging profile is obtained for a weekday and weekend. The charging pattern for EV 4W and 2W is through two modes, i.e., regular charging and top-up charging. The respondents do not require to use top-up charging on any day. For EV-2W, more than 90% of the respondents charge their vehicles at home on both working and non-working days and office charging and shop charging are almost negligible. The regular charging time on weekdays and weekends is from 7 pm to 8 am. On average, it takes 7-8 hours to completely charge an electric 2W vehicle. For, 4Ws the regular charging time in weekdays and weekends is from 5 pm to 7 am, considered as non-working hours. On average, it takes 9-10 hours in normal charging mode and up to 2 hours in fast charging mode to completely charge an electric 4W vehicle. All respondents have their private charging point at home, which is provided and installed by their EV manufacturers. The regular, once a day, slow charging satisfies their requirements of daily travel. Hence the fast-charging option is seldom used and required by the respondents.

Compared to early adopters among the Prospective Consumers, all women respondents preferred EV over conventional for their mobility needs. The average family expenditure of 2W EV intenders was 23971 Rs/month and for 4W EV intenders was 34,230 Rs/month. The major determinants of prospective consumer to buy an EV are range, charging time, Operating and maintenance cost, Resale value and Government policy. All EV intenders wanted lower prices, high range and hybrid batteries for their vehicles. Lack of parking spaces emerged as a significant hindrance for EV adoption. Analysis of the responses by early adopters of EV 2W and 4W and prospective consumers showed the importance of advertising and awareness campaigns to promote use of EV.

The public transportation includes E-rickshaws and institutional EV-4W. Both were owned and operated by men only and worked almost seven days a week. The drivers were found to be satisfied with EV 4W, despite issues with range and charging time. To increase use of electric vehicles by private and public companies, tax breaks may be considered for those who use electric cars to meet their transport requirements. Electric car use by government can be increased through mandates and policy stipulation. All E-Rickshaw drivers belonged to low income groups and self-financing is the major source to finance e-rickshaw so some easy finance schemes are required to boost e-rickshaw adoption.

Further, separate analysis of data for weekdays and weekends has been done through an excel based model to arrive at the electric load impact on the Delhi's grid due to EV charging. EVs can be charged through slow AC charging or DC moderate charging and hence impact of slow and moderate charging is kept separate to understand the hourly impact of such charging. The cumulative hourly impact of all electric vehicles on weekdays shows that the major impact and surges was due to the 4W vehicle charging, especially moderate DC charging, in the afternoons and early evenings. These hours are generally of peak load, and hence add to the load pressure on the grid. On the weekends, the 4W-institutional load is non-existent due to the non-plying of institutional vehicles on weekends (in the survey, institutional vehicle drivers mentioned that Saturday is working, hence considered Weekday while Off day is only on Sunday) and thus on these days, top-up charging by vehicles are relatively flat. IRADe estimated the vehicle count for each mode of vehicles in FY 2019-20 based on its road transport model. It shows that the impact of EVs is minor compared to the average hourly load in Delhi. This is primarily due to significantly lower count of EV-4W. The higher count of e-rickshaws is not putting much load on the grid because of the minimal size of batteries employed in the same. A far lesser impact of EVs is estimated when the charging behaviour of EVs during weekend is analysed.

IRADe estimated that Delhi would have a substantial number of EVs by 2030 i.e. EV population of 3W-1,20,013; 2W-14,93,632; 4W (Private)-6,97,935; 4W (Institutional)-51,862 and hence their impact on the grid would also be significant. The Central Electricity Authority (CEA) estimates for the year 2030, the peak load requirement in Delhi would be 11,575 MW. In 2030, a substantial impact will fall on grids due to large numbers OF the EV-4W and 2W. Comparison between the effect in 2030 with FY 2019-20 shows a significant difference. This is primarily due to the estimated count of vehicles. Another important observation to be made is that the impact of 4W-(Institutional) vehicles is substantially lower in 2030 and the noon charging peaks that were seen during the analysis of surveyed vehicles in 2019-20 is dampened out. This is because EV-4W (private) count is relatively high as compared to the EV-4W (Institutional). The impact of EV charging on the estimated hourly electricity load on peak and lean month shows that EVs in 2030 have the potential to contribute 17% over and above the peak month electricity load requirement. This contribution may increase to 54% of the total electricity requirement in the lean month. Hence, it is imperative for the distribution system to plan for EVs coming into the system. On weekends, compared to a weekday, the impact of EV charging on weekend is not as significant but still has the potential to be 4% of the hourly load in peak month and 10% of the total electricity load in the lean month of 2030.

Chapter 1: Introduction

In India, one of the main sectors driving economic growth is transportation. Rapid urbanization in recent years has resulted in critical urban air pollution (UAP) levels in many Indian cities. In response to the environmental issues, the federal and state governments have promoted e-mobility, which results in zero tailpipe emissions and lower operating and maintenance costs. The transition to electric vehicles (EVs) would eventually insulate the country from the volatility of global oil prices. If EVs account for 30% of new vehicle sales in India by 2030, India could save more than a trillion rupees (INR 1 lakh crore) in crude oil imports (CEEW, 2020).

According to LBNL's 2017 projections for India, the load added from Battery Electric Vehicle (BEV) sales in 2030 will be just 3.3 % of total electricity load (by energy) and 6 % of total peak load, despite reaching 100 % new vehicle sales as EV sales. However, in practical terms, this equates to approximately 82 Terra Watt hour (TWh) and 23 GW of peak EV charging load in 2030. NITI Aayog has projected that EV sales will penetrate approximately 80% of the market for two and three-wheelers, 50% for four wheelers, and 40% for buses by 2030 .

EVs are projected to be economically viable in 2030 and could be a preferred choice for new vehicle buyers. Assuming the current electricity tariff of INR 5/KWh, being prescribed by the Delhi Electricity Regulatory Commission, BEV will assist electric distribution utilities in earning more than 41000 crores by 2030. As a result, in the coming years, it will be a major business proposition for distribution utilities. As a consequence, it is crucial to plan for EV load management, particularly since it can impact grid peak load characteristics.

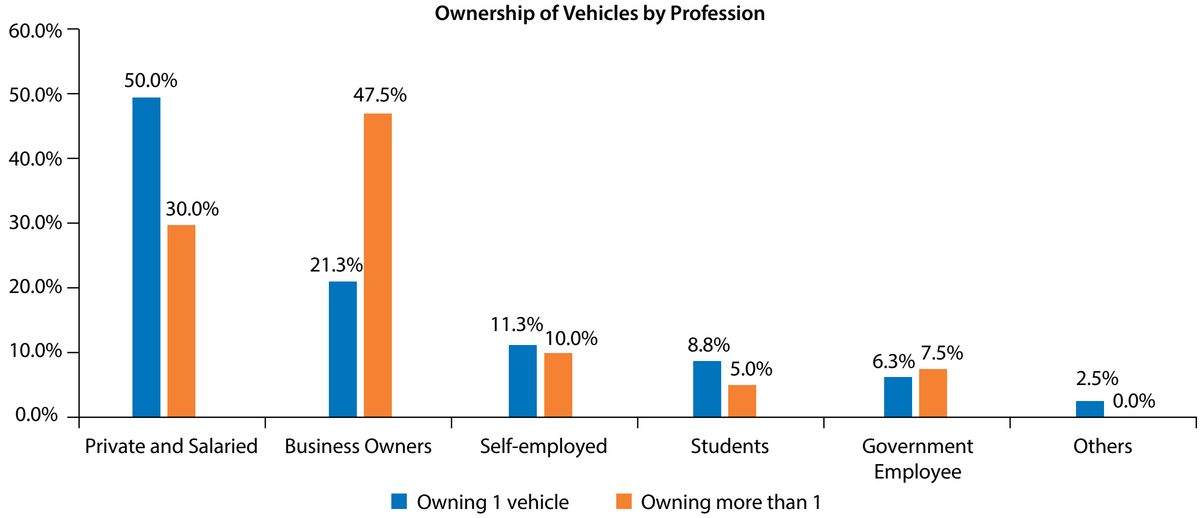
Background

While it is inevitable that the EV count on the roads will only increase from its current status, it also brings with it a separate set of challenges. These challenges include the need for vehicle batteries of higher capacities to reduce range anxieties, unavailability of easily accessible charging stations, developing quick/fast charging facilities to reduce vehicle's engagement time at charging terminals, impact on local distribution system owing to sudden load surges--especially during peak hours and harmonic imbalances, etc. Of all these challenges, the impact on local distribution system needs to be dampened for safe and economic operation of the grid. Hence, a proper study of the vehicular distribution and the vehicular load pattern at different times of the day due to EVs is necessary to design an economic and implementable plan for the electricity distribution system.

The transport sector is vast and complex, and it is the world's second-largest emitter of carbon dioxide (CO_2). Road, aviation, rail, and maritime transport are all included in this sector, and they are used to move both passengers and goods. As shown in Figure 1, this sector emitted approximately 8 billion tonnes of CO_2 globally in 2018, accounting for 24% of CO_2 emissions from fuel combustion. Passenger vehicles accounted for 45% of overall transportation emissions, followed by road freight vehicles at 29%, aviation at 12%, foreign shipping at 11%, rail at less than 1%, and other modes of transportation at 2% (Global EV Outlook, 2020).

[1]https://www.niti.gov.in/sites/default/files/2021-04/FullReport_Status_quo_analysis_of_various_segments_of_electric_mobility-compressed.pdf

Figure 1: Transport Emissions by Mode, 2018 (Billion Tons CO_2)



Data Source: Global EV Outlook, 2020

On road vehicles account for 72% of global transport emissions, accounting for an 80% increase from 1970 to 2010 (ibid). Railway emissions have reduced significantly as a major fraction has been powered by electricity. Economic development, population growth, a shift in transportation modes, changes in the fuel mix, and current government policies to limit CO_2 emissions, especially various fiscal and regulatory policy instruments, all influence emissions from the transport sector. Increased travel related to economic growth and distribution services, as well as a growing shift toward larger cars and SUVs, have all contributed to this sector's steady growth over the last few decades. Upper-middle-income and high-income countries account for the majority of transportation emissions, though South Asia and Sub-Saharan Africa contribute less than other regions.

Both developed and developing countries will continue using more energy in the mobility sector. However, in rapidly evolving economies, there are excellent prospects for both systemic and technical improvements in the area of low-carbon transportation.

The majority of energy scenarios that take into account current national commitments under the Paris Agreement indicate that transportation-related energy demand will continue to grow through 2050, with oil accounting for the majority of it. However, between 2000 and 2050, private transportation is projected to grow at a rate of 1.7 % per year. (International Renewable Energy Agency, 2018).

In order to meet the Paris Agreement's goal of keeping global warming below 2 degrees Celsius, preferably 1.5 degrees Celsius, a significant shift away from fossil fuels, as well as the implementation of long-term mitigation policies, is required; otherwise, emissions from this sector will rise at a much faster pace than emissions from any other energy end-use sectors and reach around 12 gigatonnes of carbon dioxide equivalent per year (Gt CO_2eq/yr.) by 2050 (ibid).

EVs Role in Decarbonizing the Transport Sector

As compared to internal combustion engines (ICE), EVs provide a promising solution to decarbonizing this sector due to reduced greenhouse gas (GHG) emissions by eliminating tailpipe emissions along with increased energy security. Global transport emissions increased by less than 0.5% in 2019, compared with 1.9% annually since 2000 owing to electrification, efficiency improvements, and greater use of biofuels (Tracking Transport Analysis, 2020).

While technological solutions exist for replacing the conventional ICE vehicles with lower-emitting options, reducing the costs and creating the enabling infrastructure to facilitate mass deployment and zero emissions is still a long way from where it needs to be. Some of the major challenges in promoting mass adoption of EVs are the rapid increase in demand for faster modes of transportation in developing as well as emerging economies and in convincing the stakeholders to make different purchasing and behavioral decisions.

Electric car deployment has been rapidly growing over the past ten years, with the global stock of electric passenger cars passing 5 million in 2018, an increase of 63% from 2017; more than 1.2 billion cars are currently in operation while another 100 million new vehicles are produced annually (Organisation Internationale des Constructeurs d'Automobiles, 2019). Just dealing with the emissions from cars will require replacing virtually all of these with zero-emission (ZE) vehicles or encouraging passengers to travel via other modes of transport. Even a complete ban on the sale of new fossil fuel-powered vehicles would take years to reduce emissions from cars in use to zero, as a significant number of older cars not affected by the ban would remain in use for 10 to 15 years given current patterns of fleet turnover.

To decarbonise this sector, an ambitious policy framework that primarily focuses on improving fuel efficiency standards, portfolio mandates for EVs, and purchase taxes or subsidies are required.

Impact of EVs on DISCOMs

EVs have the potential to reduce vehicular emissions significantly; however, as countries around the world promote the rapid transition to electric mobility, a major increase in the number of charging stations is needed.

Because of the ambiguity in the charging requirements of customers, the existence of energy demand from these charging stations is unpredictable. Consumers can charge their cars at various locations and for different periods of time, depending on their needs. This will have an impact on the grid in terms of power quality as well as increased asset stress on the power distribution network. Due to the skewed nature of power demand, the widespread use of EVs will result in unintended peaks in power consumption and resulting power quality problems, such as increased flow in power cables, transformer overload, voltage drop, and voltage imbalance.

The rapid adoption of EVs, as well as the development of supporting infrastructure, presents its own set of challenges. Power discoms play a critical role in addressing the above problems. The near participation of discoms during the planning stages of large-scale adoption of EVs is critical to streamlining the power supply for charging and ensuring the grid's resilience in the event of adversity.

To make the transition to electric mobility, a major overhaul of the grid is required. As a consequence, discoms must be granted a "leadership" position in promoting the widespread adoption of EVs. However, to handle the increased load in day-to-day operations that will result from the addition of more and more EV charging stations, discoms will need to build significant capacity. This will necessitate a united front and coordinated actions by both the federal and state governments. In order to ramp up grid infrastructure and implement technical solutions, discoms must also be provided with appropriate financial arrangements and benefits through tariff rationalization. To predict and analyse the load pattern and consumption of the variable power demand from EVs, an artificial intelligence and machine learning-based modelling approach can be used. Smart meters and Advanced Metering Infrastructure (AMI) can also play an important role in grid management as a stepping stone to a smarter grid.

Objectives

Given this background we conducted this study with the following objectives:

- To analyse global EV best practices
- To assess the socio-economic and technical factors influencing EV usage and adoption in Delhi
- To assess existing EV user profiles and charging trends for specific areas in Delhi
- To establish a format that will enable distribution utilities to estimate demand at the DT level
- To formulate policy recommendations for the growth of EVs in Delhi

Report Structure

Section 1

Provides a detailed introduction to the study and specific research concerns that this study attempts to address in subsequent sections, such as the role of EVs in decarbonizing the transportation sector and the impact of EVs on DISCOMs.

Section 2

Provides details about global EV outlook, international best practices in China, European Union (EU) and United States of America (USA), Case Studies and India EV policy landscape so far.

Section 3

Provides details about our data-collection strategy and the methodological approach adopted for this analysis along with the outcome of the EV survey carried out for current users (2W, 3W and 4W) and potential buyers.

Section 4

Reports the findings on EV growth and penetration scenarios emerging from the qualitative and quantitative data gathered from the survey of current users of EVs (2W, 3W and 4W) and potential buyers.

Section 5

Synthesizes the key findings emerging from the qualitative and quantitative analysis of the effect of EV penetration scenarios on electricity demand and the grid. Provides the implementation pathway for scaling up the deployment of EVs. Lists the major policy recommendations for key stakeholders and policymakers for EV growth in Delhi. And finally, based on an excel based model developed from the survey data to capture the charging behaviour of EV users, the impact of EVs on grid is calculated.

Chapter 2: **Global EV Outlook**

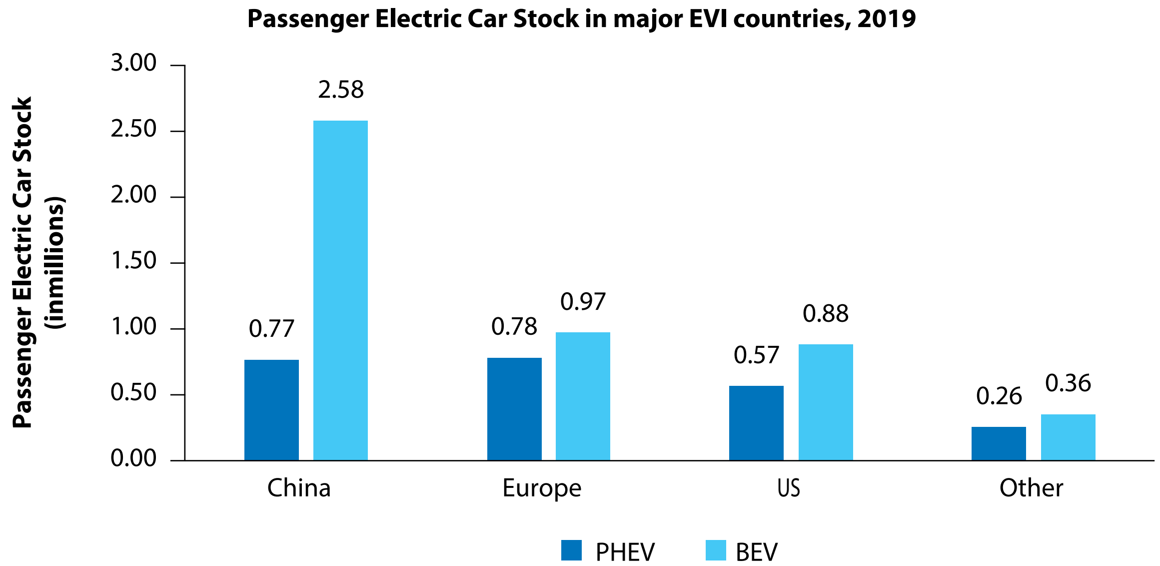
In the recent decade, the global EV sector has expanded. Many countries consider it to be an emerging industry, with goals in place to encourage large-scale development and acceptance.

2.1 Global Status of EVs in 2021

Expanding e-mobility will significantly reduce transport sector related pollution. Private cars, taxis, city buses, two/three-wheelers (particularly in Asia), commercial and freight vehicles are all being electrified. According to projections, in the coming years, the bulk of electricity used for EV charging from the grid will originate from renewable energy sources, resulting in zero lifecycle emissions from EVs. As compared to 2017, EV sales grew by 65 % in 2018. Sales of EVs increased by 9% year over year in 2019, reaching 2.3 million units, up from 2.1 million in 2018. EV sales in China remained consistent in 2019, with roughly 1.2 million units sold (a 3 % increase from 2018).

In 2010, there were just 17,000 electric cars on the road worldwide; by 2019, that number had soared to 7.2 million, with 3.4 million electric cars accounting for 47% of the total (as shown in Figure 2). The number of EVs sold in 2019 was 2.1 million, up to 6% from the previous year. About 1% of worldwide car stock and 2.6 % of global car sales were EVs.

Figure 2: Passenger Electric Car Stock in major EVI countries, 2019

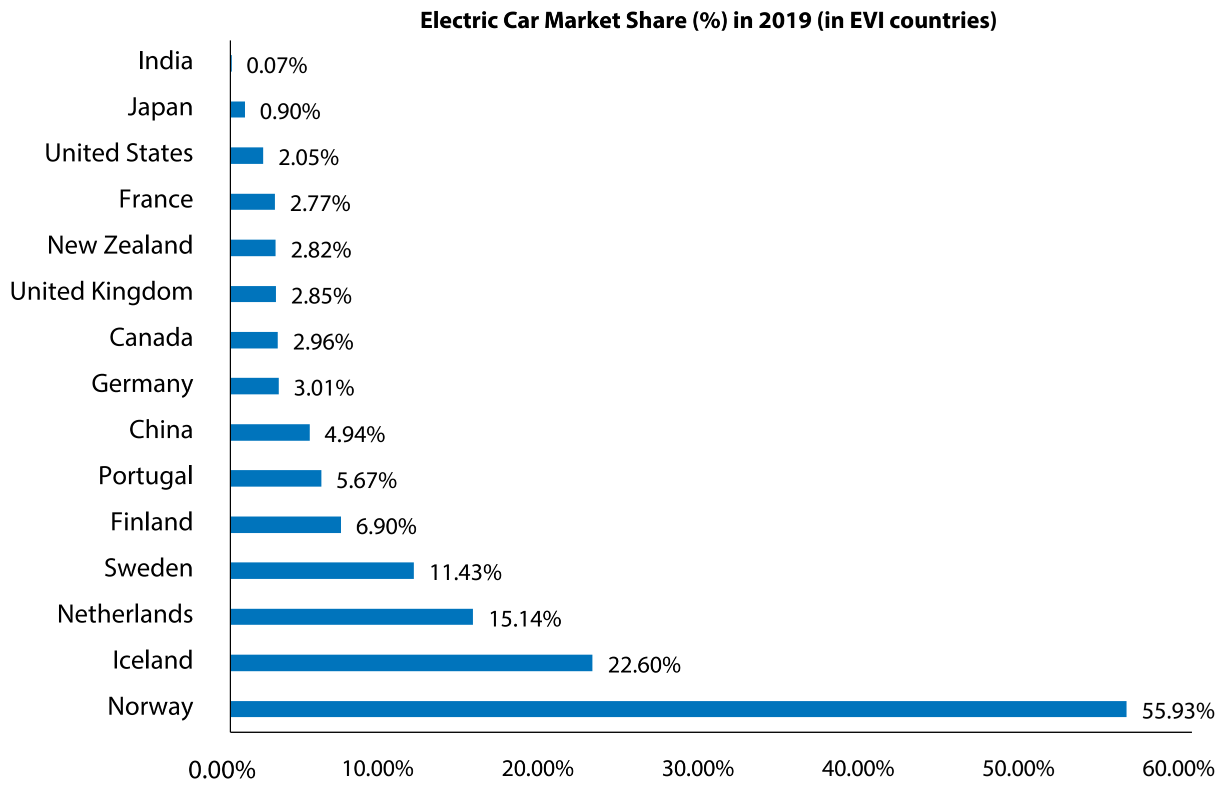


Data Source: Global EV Outlook, 2020

Figure 3. below illustrates that EV sales in Europe increased by 50% in 2019 over the previous year, a rate that is significantly greater than the previous year (32 %). Furthermore, Europe is home to the countries with the highest %ages of EV sales as a %age of overall vehicle sales. With 56% and 22%, Norway and Iceland stood at

first and second, place respectively. EVs now account for 15% of the market share in the Netherlands, up from 5% higher since 20 years ago. France, the Netherlands, and the United Kingdom all sold more than 50,000 EVs in 2019. Electric car sales in the United States fell by 10% in 2019 compared to 2018, when a surge of Tesla Model 3 deliveries accounted for a major part of new EV registrations.

Figure 3:Electric car market share (%) in major EVI countries, 2019



Data Source: Global EV Outlook, 2020

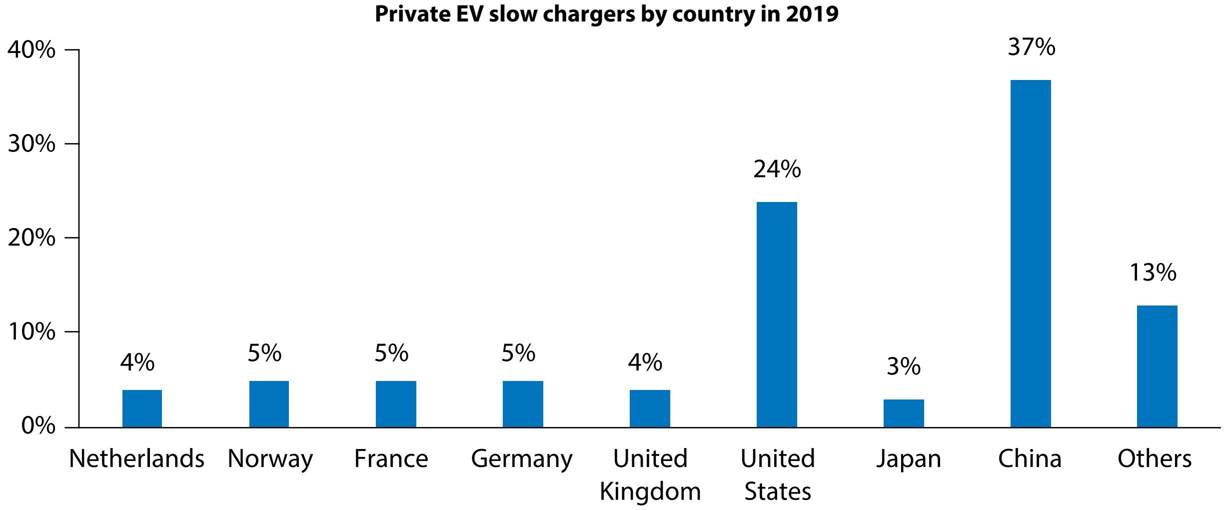
Due to their low cost and ease of operation, two-wheeler vehicles have become a popular means of transportation in congested areas. They're popular in China, India, and a number of other ASEAN nations . The Chinese government waived registration requirements, enabling low-speed and light-weight electric two-wheelers to be ridden on bicycle lanes, and several localities outlawed gasoline-powered two-wheelers entirely. With approximately 300 million electric two-wheelers on the road and 36 million units produced in late 2019, China has surpassed the United States as the world's top manufacturer and exporter. The global electric bus industry has risen, with 417,000 units on the road in 2019. This is due to governments focusing more on electrification of public transport services. China was the leading market in 2018 and 2019, accounting for nearly all global electric bus sales.

EV drivers are apprehensive that they won't be able to find a convenient charging station when they need one. In many global EV markets, home and office charging is preferred over public charging stations. Home charging rates are expected to decline in the coming years, while workplace and public charging rates are expected to rise, making home charging the preferred alternative. In general, there are three types of electric vehicle charging choices, which are described below:

1. **Stationary Slow Charging:** It consists of AC chargers that charge EVs at a lower cost but at a slower rate than fast chargers. The equipment is in growing demands among the working class because it is relatively inexpensive, especially in developing countries with huge populations and a need for low-cost charging.

Figure 4 shows that China installed 37% of the world's 6.5 million private EV slow chargers in 2019.

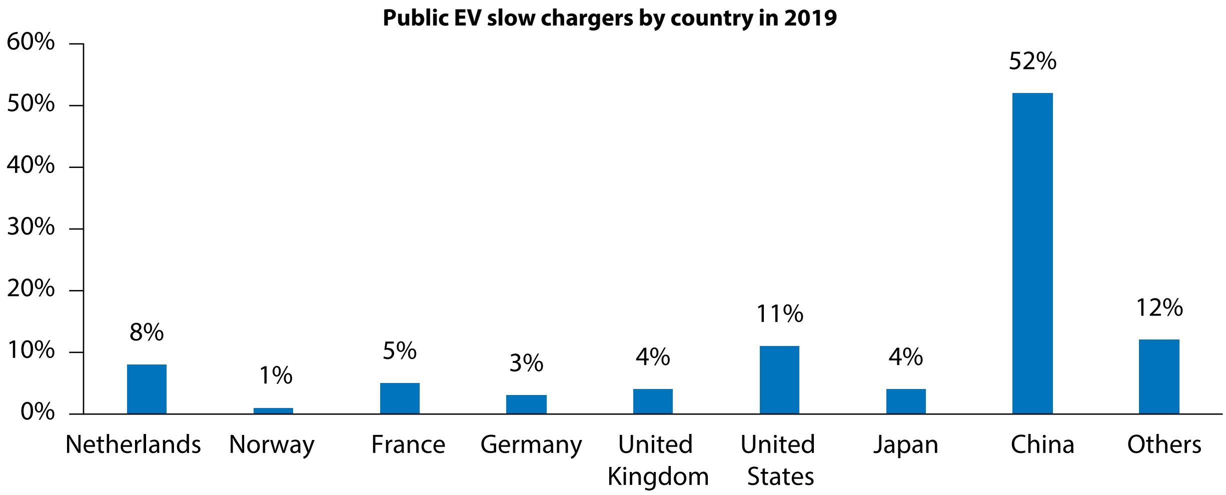
Figure 4: Private EV slow chargers by country, 2019



Data Source: Global EV Outlook, 2020

China installed 52% of the 598,000 (about 0.6 million) public EV slow chargers installed globally in 2019, as illustrated in Figure 5.

Figure 5: Public EV slow chargers by country in 2019

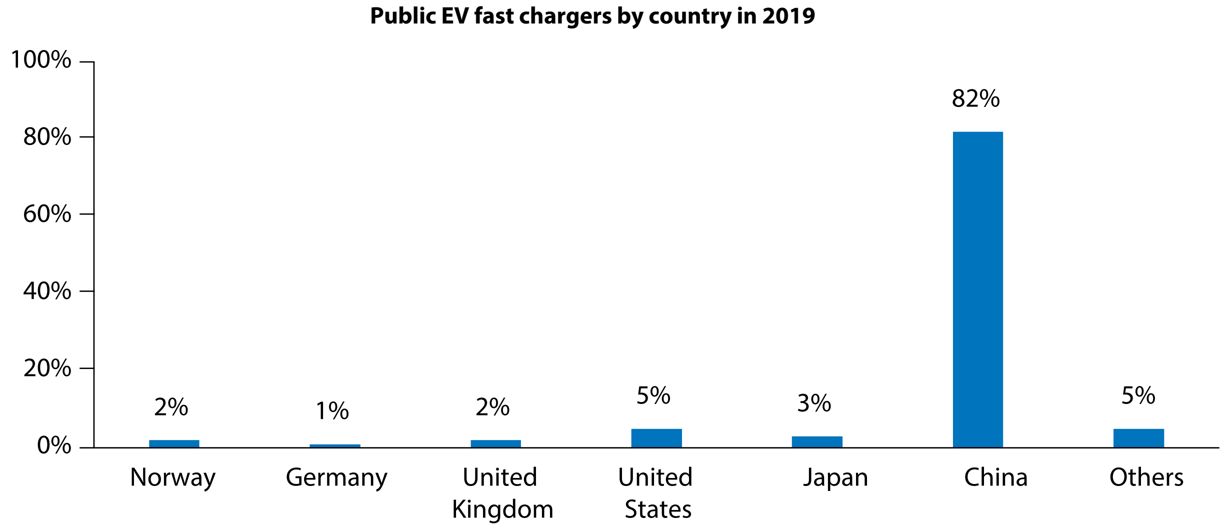


Data Source: Global EV Outlook, 2020

2. **Portable Charging**: EV drivers can charge their vehicles as and when they need them with a portable charger. They do away with the necessity for a fixed charging station. The new improved portable chargers should be able to deliver the same level of power as stationary charging stations.

3. **Fast Charging:** It takes about 15 minutes to fully charge an EV. The EVs' battery should be in good working order and capable of quick charging, which should take place at a moderate temperature. This EV charger is currently underutilised in the market, but as more EVs become compatible with it in the near future, it is projected to gain popularity. In 2019, China accounted for 82% of the global total of 264,000 (approximately 0.26 million) public EV fast chargers, as shown in Figure.6.

Figure 6: Public EV fast chargers by country in 2019



Data Source: Global EV Outlook, 2020

As shown in the graph above, the %age of global consumers who would consider purchasing an EV is rising, indicating that EVs have a bright future. The following section discusses the worldwide EV market drivers.

2.2 Global EV Market Drivers

The following are some of the significant EV market drivers that have resulted in greater EV penetration around the world:

1. **Growing concerns over environmental pollution:** Unlike internal combustion engines (ICE), EVs do not require fossil fuels or produce tailpipe carbon emissions. Improved air quality and reduced dependency on fossil fuels will be aided by increased EV uptake. Several government programmes to encourage EV acceptance have been launched around the world.

2. **EVs offered in variable range segments:** A potential EV buyer could come from any economic bracket. Higher-income consumers are clearly less price sensitive than lower-income consumers. From compact hatchbacks like the Nissan Leaf to high-end sedans like the Tesla Model 3, EVs have been provided in a variety of range categories to fulfil the needs of consumers from all income categories. Automakers are launching a growing number of EV models.

3. **Increased EV range per charge:** Extended ranges on a single charge are now offered by EV manufacturers, as well as home charging alternatives, which has enhanced user convenience.

4. **Favorable government policies and subsidies:** Strict CO_2 emission standards, as well as discounts and subsidies, have boosted EV sales.

As previously stated, governments around the world have implemented favourable EV policies that have aided in the adoption of EVs. In the following section, we reviewed and stated global EV policies with the aim of furthering EV penetration.

2.3 Policies for EVs Around the World

Governments across the world have taken a number of ambitious measures to encourage and structure the burgeoning EV industry. Methods for lowering adoption barriers and encouraging the establishment of the requisite charging infrastructure were amongst them. The growing demand for ZE EVs has been driven by various governments' rising demand for a cleaner environment. The list below includes a variety of EV policies from around the world that aim to boost the EV market in the coming years.

2.3.1 Paris Declaration on Electro-Mobility and Climate Change and Call to Action

This initiative was launched at COP21 in 2015 with the aim of promoting electro-mobility to a level compatible with a less than 2-degree pathway. It comprises individual and collective commitments from states, cities, businesses, and organisations to expand existing efforts and push for a concerted effort to electrify at least 20% of all vehicles by 2050. (Altran, 2018) Further, in COP26 the most significant takeaway was to have 100% zero emission vehicles (ZEVs). The declaration states that all new car and van sales will be zero emission by 2040 across the world and for the leading markets the target is set at 2035.

2.3.2 EV 30@30 Campaign

The International Energy Agency (IEA) was in charge of the EV 30@30 Campaign, which was launched at the 8th Clean Energy Ministerial (CEM)-Electric Vehicles Initiative (EVI) meeting in 2017 and drives demand for electric two- and three-wheelers, passenger vehicles, light commercial vans, buses, and trucks (including battery-electric, plug-in hybrid, and fuel cell vehicle types) (Clean Energy Ministerial, 2018). The eleven EVI countries now engaged in this programme are Canada, China, Finland, France, India, Japan, Mexico, the Netherlands, Norway, Sweden, and the United Kingdom (International Energy Agency, 2020).

The initiative's goal is to reach a 30% market share for EVs by 2030, which will be calculated as total EV sales in all EVI countries divided by total vehicle sales in all EVI countries (ibid). It also aims to collect government commitments that are in accordance with their goals and programmes. Pledges for EV procurement, public awareness campaigns, EV-friendly policy procedures, expanding vehicle charging networks, supporting policy-relevant research and analysis, and more could be included in the commitment.

2.3.3 Global EVI Pilot City Programme (EVI-PCP)

The EVI-PCP is one of the key pillars of the EV30@30 Campaign, and it was officially introduced on May 24, 2018 during the 9th Clean Energy Ministerial (CEM) conference (Clean Energy Ministerial, 2018). The IEA and Shanghai International Automobile City (SIAC) are leading this initiative; together, they form the Joint Secretariat of the EVI Global EV Pilot City Project, which intends to build a network of at least 100 cities over a five-year period (2018-2023) and collaborate on electric mobility promotion (ibid). This programme promotes knowledge transfer between cities and supports the replication of successful practices through webinars and seminars. Another important part is to use the network to draw on previous experience by creating empirical outputs and studies that will help cities and other stakeholders learn from prior member city experiences.

2.3.4 Drive to Zero Campaign

The campaign's operating agent, CALSTART, was introduced in September 2020 at Clean Energy Ministerial 11 (CEM11) (Calstart, January 2021). With the purpose of supporting governments and organisations in reaching global GHG emission objectives while simultaneously improving urban air quality, this programme focuses on the commercial vehicle space, which includes heavy-duty product movement, people mobility, and equipment.

It paves the way for additional ZE and near-ZE commercial medium and heavy-duty vehicles (MHDVs) to be deployed around the world, such as mass transit. It brings together governments, manufacturers, and fleet users to work on defining standards, legislation, and programmes to promote commercial vehicle electrification.

It also intends to speed up the development of worldwide ZE and near-ZE commercial vehicle technology, with the objective of making ZE technology economically competitive by 2025 and dominant by 2040 in "beachhead" vehicle segments and areas (China, United States led by California, the European Union, India, Canada, Japan, Mexico, and South America).

2.3.5 GEF-7 Global Programme on electro-mobility

This programme, which was introduced at COP25 in Madrid in 2019, was created to assist 17 developing countries in mass-deployment of EVs in order to enhance air quality and reduce their reliance on fossil fuels (Global Environment Facility, December 2019). The programme will also support policymakers in formulating regulations that would promote technology transfer, private sector engagement, and commercial finance for the deployment of electric bus, two-wheeler, three-wheeler, truck, medium-duty vehicle, and private car fleets. It will also build three regional platforms to aid the transition to electric mobility in Africa, Asia and the Pacific, and Latin America and the Caribbean. The Sustainable Cities Impact Program of the Global Environment Facility (GEF) will be closely linked to this activity. In conjunction with the IEA, the UN Environment Programme (UNEP) will launch the programme. .

2.4 EV Best Practices in China, European Union (EU) & USA

China, the European Union (EU), and the United States are the three major countries with the most competitive EV economies in the world. This section examines and discusses the best practices and approaches used by various countries to stimulate the adoption of EVs.

2.4.1 China

China experienced heavy urban pollution in the early 2000s as a result of rapid motorization, resulting in a significant reduction in the air quality index. The widespread adoption of EVs was viewed as the only long-term solution. In line with this, China's national strategy prioritizes the development of EVs and related infrastructure. As a result, the country's EV industry grew to become the world's largest in 2019, accounting for 4.9% of the global market.

China's global supremacy in the EV industry in such a short period of time can be attributed to massive capital expenditures and strong government programmes and incentives to not only boost manufacture, but also to construct statewide EV infrastructure to accompany EV adoption. The government and policymakers have promoted increased private investment in EV charging infrastructure, resulting in an increase in the number of charging infrastructure providers and total investment levels. China's EV policies are aimed at reducing oil imports. Many of China's EV rules favor domestic automakers and promote the use of Chinese-made batteries in vehicles, while simultaneously pushing foreign automakers to share innovations with Chinese joint venture partners. China promotes the purchase and use of EVs. Below, we discuss the significant measures in greater detail.

2.4.1.1 Expanded EV Charging Infrastructure – China

The lack of sufficient battery capacity and range remains a hurdle to EV adoption, necessitating the construction of more charging stations and infrastructure. As a result of key government policies that effectively addressed these concerns, China has become one of the world's major EV markets, as outlined below:

1. **Accelerated the installation of EV charging stations:** In 2015, the National Development and Reform Commission (NDRC) issued a directive to speed up the installation of EV charging stations in order to ensure that there is enough charging space for 5 million EVs by 2020.

2. **Fast-track construction of residential EV charging infrastructure:** In July 2016, the NDRC released a notice on speeding domestic EV charging infrastructure construction, which defined residential charging standards and processes and designated the Jing-Jin-Ji, Yangtze River Delta, and Pearl River Delta regions as demonstration zones for residential charging infrastructure development. All new residential projects are required to have EV charging infrastructure.

3. **Enhanced the number of EV charging stations in parking spaces:** EV charging was to be offered in 10% of parking spaces in large public buildings, with at least one public charging station for every 2,000 EVs. Shopping malls, supermarket stores, and major parking lots have all installed public chargers.

4. **90 million Renminbi (RNB) funding support to build charging infrastructure:** The Ministry of Finance, Ministry of Science and Technology, Ministry of Industry & Information Technology (MIIT), NDRC, and National Energy Administration issued the 13th Five-Year Plan for new energy vehicle infrastructure incentive programmes in January 2016 (NEA). The plan included funding of RNB 90 million for the construction of charging infrastructure, subject to the following conditions: charging stations must have a minimum number of charging posts, chargers must be installed in government buildings, and charger procurement must be open to any charging manufacturer.

5. **Installation of charging infrastructure in government buildings and municipal parking spaces:** Due to the high cost of land in China, most businesses have invested in EV charging infrastructure in order to obtain property at a reasonable price. To address this, China's central government took the initiative and began constructing charging infrastructure in government offices and municipal parking spaces.

6. **Charging infrastructure installed within shopping centres:** All large branded retailers have EV charging stations in their parking lots to comply with government laws and advertise green credentials. Furthermore, a number of Chinese real estate corporations have shown a strong desire to collaborate with charging networks on a site-by-site basis.

7. **Deployment of mobile charging units at highway fueling stations and other locations:** For the highway, grid companies currently have a near-monopoly on EV charging. The highway fueling stations in China are closely regulated by state-owned corporations. Independent charging networks are using mobile charging devices at highway filling stations and other locations, to overcome this impediment.

8. **Auto-makers having both EVs and their charging network:** Both Tesla and BYD have EVs and charging infrastructure. To develop EV charging networks, other automakers engage with particular charging network businesses. Tesla had deployed superchargers in 188 locations around China as of January 2019, whereas BYD had installed around 1,200 charging stations.

9. **Grid companies in China investing heavily in infrastructure upgrades:** According to an annual schedule, grid companies have been aiding independent charging companies in improving distribution-level networks for public and private vehicle use within cities. Existing grid companies are also significantly investing in infrastructure upgrades. They view improving EV supply as a public service for which they are reimbursed through their social responsibility budget.

10. **Variety of Apps available that allow EV users to share their private charging stations:** Officials in Hebei Province highlighted the challenge of providing EV charging in rural areas in January 2018, suggesting that locals be encouraged to rent or share residential chargers on a public basis.

11. **Bluetooth-enabled parking spot locking devices:** When an EV driver arrives, the vehicle unlocks. A plethora of apps have sprung up to make charging of EV easier in a variety of settings.

12. **On-street charging stations near streetlights and parking spaces:** These have been set up by the government as a potential source of power for EV charging as well as payment alternatives.

13. **Bulk of EV charging stations located in major cities:** Two of the most well-known charging networks are Tgood (Telaidian) and StarCharge. They frequently use proprietary payment mechanisms to provide both quick and level 2 charging.

14. **Subsidies for EV buyers:** Shenzhen offered new EV buyers up to 40,000 yuan in subsidies in 2020, as well as a replacement subsidy of 20,000 yuan or 10,000 yuan per car for transitioning to EV or plug-in hybrid, respectively.

15. **EV charging** at home or in public space is subsidised in over 30 different cities across the country.

16. **The Beijing municipal government** began mandating that all parking spots in new residential projects incorporate space for EV chargers in 2017, with new government or state-owned enterprise buildings expected to have chargers in 25% of parking spots.

2.4.1.2 Govt. Policies & Incentives for EV Adoption – China

China is stepping up its efforts to encourage people to buy EVs. Government initiatives and subsidies have pushed people to acquire EVs. Some of the most important policy measures and subsidies have been listed below:

1. In early 2018, the Chinese government modified their EV subsidies, connecting automaker fuel economy credits to new EV production targets. **Subsidies** are now **available for vehicles with a range of more than 150 km** on the Chinese test cycle, which is based on the New European Driving Cycle (NEDC). For the greatest subsidy, a NEDC range of 400 km is necessary.

2. **The efficiency standards for batteries have been tightened**. To be eligible for the subsidy, an EV battery must have an energy density of at least 105 Wh/kg, and at least 140 Wh/kg to qualify for getting maximum subsidy.

3. **Local governments are able to grant up to 50% more subsidies** than the national average.

4. **EVs** have been **exempted from sales tax until 2022.**

5. In China, non-monetary incentives have been utilised to encourage the use of EVs, such as **exemption of EVs from city license plate lotteries or restrictions.** Because procuring a license plate for a conventional vehicle might take years, this has been a big factor.

6. **EV number plates are available for free in Shanghai,** whereas regular plates cost over $12,000. Initially, EV license plates were only available through a basic queue. However, now they are distributed through a lottery system, with more plates available for EVs than for conventional vehicles.

7. **In 2009, China's central government began subsidising EV** purchases for government and public fleets, and in 2013, it began supporting individual car owners. In 2013, subsidies ranged from RMB 35,000 to RMB 60,000, depending on the vehicle's electric range, and have been gradually lowered since then. Manufacturers received subsidies directly depending on vehicle registrations and sales. Many firms, including some with no prior expertise in the automotive industry, were drawn to EV manufacturing as a result of these subsidies. A policy revision was motivated by criticism of the subsidies, as well as claims of fraud by enterprises receiving subsidies.

8. The **"dual-credit plan,"** which went into force in April 2018 and began enforcing mandatory quotas on automotive manufacturing in 2019, is another key policy initiative by the Chinese government. Vehicle manufacturers would be assessed on their fuel usage and EV manufacturing in order to apply for new energy

credits under this programme. Failure to meet the criteria will result in a fee or the obligation to buy credits from other vendors (only those selling at least 30,000 conventional vehicles annually will be affected).

9. **Vehicles with EV license plates may be granted additional privileges, such as access to restricted traffic zones.** Many large Chinese cities, like Beijing, restrict passenger car drivers from entering the city on specific days based on their license plate number, while EVs are exempted.

10. **EVs are not subject to traffic control measures** (rules that limit the number of cars on the road for a set period of time), they are allowed to use bus lanes, and are provided free parking slots in several Chinese provinces and cities.

2.4.1.3 Govt. Support for EV R&D – China

In China's major cities, transport sector emissions are a major contributor to ambient PM2.5 haze. A major reason to pursue EVs is to aid these cities in their efforts to reduce pollution and greenhouse gas emissions. As a result, it is vital to provide research & development (R&D) support to improve the adoption of EVs by lowering their costs and increasing their efficiency. The majority of R&D has been focused on batteries, which account for the majority of the cost of EVs.

By providing financial support for the development and operation of charging stations, as well as regulatory provisions to streamline charging infrastructure planning processes and encourage EV R&D, China's government has gained global dominance in the EV industry in such a short time.

2.4.2 European Union (EU)

In the EU, road transport is the second largest source of CO_2 emissions, accounting for around a quarter of total emissions (EEA, 2018). Oil currently covers over 94 % of the EU's transport energy needs (EC, 2016a). The automobile sector is faced with the challenge of reducing emissions while concurrently increasing transport demand. The EU Commission introduced Europe on the Move in May 2017, a package of legislation and other mobility-related measures aiming at making Europe a leader in clean, competitive, and connected mobility; they were implemented in three stages between 2017 and 2018. The EU EV market grew moderately, with a diverse picture at the national level, while Norway continues to outperform other Nordic countries and appears to be on the verge of wide market adoption. Other significant European markets, such as France, Germany and the United Kingdom, are still gaining traction. When the European Commission proposed new CO_2 targets for 2030, promoting the switch to EVs, it gave the electrification of mobility a substantial boost. This goal would compel manufacturers to reduce average fleet emissions by 30% by 2021. To meet this goal, the EU established a target of 15% of all sales being electric or plug-in hybrid (with CO_2 emissions below 50 grammes per kilometer) by 2025, and 30% by 2030.

A variety of financial incentives have been offered by local, regional, and national governments of EU Member States to stimulate the purchase and use of EVs. These incentives aim to decrease the cost gap between EVs and conventional vehicles, increase convenience of charging infrastructure, and awareness activities to overcome fundamental barriers to enhanced consumer adoption of EVs. We discuss the major steps in further detail below.

2.4.2.1 Expanded EV Charging Infrastructure – EU

The ability to recharge batteries is the most critical characteristic of an EV-friendly infrastructure. Although the charging infrastructure for EVs has been growing at varied rates across the EU, much like the use of EVs, it is still insufficient in some Member States, and there is a lack of centralized information on all available charging sites.

The EU has taken initiatives to encourage Member States to expand the number of charging stations and to raise public awareness of their availability. Key steps undertaken are highlighted below:

1. **Installation of EV charging infrastructure is supported by a number of EU countries:** For example, as part of its national electric car mobility system, ELMO, Estonia has assisted in the installation of a nationwide fast-charging EV network, ensuring the presence of quick charging stations 40-60 kilometers apart on all roads with heavy traffic. All population centres with a population of over 5,000 people are served.

2. EU adopted the **Alternative Fuels Infrastructure Directive (in 2014)** that recommends introducing a minimum level of infrastructure for charging EVs across the EU, i.e., around one public charging point for every 10 EVs, and also gives consideration to wireless charging and battery-swapping (as per estimates by the EU commission, around 2 million publicly accessible charging points will be needed in EU by 2025).

3. In the UK, the Electric Vehicle Home Charge Scheme enables individual buyers of eligible EVs to receive a grant for up to 75% (capped at GBP 350, inclusive of VAT) of the total purchase and installation costs of one EV charger for their home and the associated installation costs. Company cars and leased cars are also eligible.

4. In the UK, the Workplace Charge point Grant is a voucher-based scheme that **provides the upfront costs for the purchase and installation of EV charging points at workplaces:**
   - Until 1st of April 2020: Firms can cover 75% of purchase and installation costs (up to a maximum of GBP 500 for each socket), maximum of 20 across all sites.
   - After the 1st of April 2020: firms can cover 75% of all purchase and installation costs, up to a maximum of GBP 350 for each socket, for up to a maximum of 40 across all sites

5. **Inductive/wireless charging of passenger cars:** This charging technology has reached a point wherein it is being used on a modest scale for electric bus projects, for example, at Proov in Utrecht.

6. Some local governments in the **UK offer the On-Street Residential Charge Point Scheme** (ORCS), which helps with the cost of installing on-street charging points.

2.4.2.2 Govt. Policies & Incentives for EV Adoption – EU

The need to transition away from carbon-emitting vehicles and toward greener modes of transportation has never been greater. The EU Member State governments have implemented a number of policy initiatives and incentives to encourage the adoption of EVs. Some of them are featured in the list below:

1. **Purchase grants available - EU provides non-reimbursable grants from the Connecting Europe Facility (CEF) and the structural and investments funds available** for the development of charging infrastructure and the acquisition of electric buses.

2. The amount of these incentives, the method of calculating them, and the sorts of vehicles that are eligible vary considerably from one government to another. In France, for example, swapping a diesel car (older than 2001 model) with a new electric car entitles the owner for up to €11,000 in state grants.

3. **Germany's scrappage scheme, popularly known as "Umweltpramie," was introduced in 2009** with a total budget of € 5 billion, the largest to date, and the model for the United States' scrappage plan. This scrappage programme served as an economic stimulus for the automobile sector. It paid US$3,590 as a purchasing incentive for a new Euro 4 compliant car for each vehicle (vehicle age>9 years) that was scrapped. This strategy resulted in new automobile sales totaling 2 million, accounting for a sizable 71% of the 2.8 million totally new cars delivered in Germany through August 2009 (up 27% YoY).

4. **The vehicle scrappage programme was implemented in the United Kingdom in 2009,** with an initial investment of £300 million aimed at replacing three lakh vehicles that were more than ten years old at the time. The UK government granted a USD 1,000 grant per new car purchase; however, this was contingent on the OEMs providing an equal refund. During its duration, the programme accounted for 20% of all new automobiles sold in the UK, with purchased vehicles emitting 26.8% less pollution than destroyed ones.

5. To encourage **the scrapping of obsolete and inefficient ICE vehicles,** the French government has expanded the reach of its **flagship cash-for-clunker plan** to a larger section of French families and doubled the amount for the 200,000th first demand to USD 5700 for electric automobiles.

6. To **meet the target of reducing carbon emissions in the transport sector** by 2030**, the Italian government has devised a scrappage scheme** in which the buyer shreds an old car classified Euro 1-4. Battery electric vehicles (BEVs)/fuel cell electric vehicles (FCEVs) and a few highly efficient pugged-in hybrid electric vehicles (PHEVs) are eligible for a subsidy of up to USD 6800. Otherwise, the reward is set at USD 4,500.

7. In Germany, **the federal government** offered a **purchase subsidy for both BEVs and PHEVs as part of its "Climate Action Programme 2030" to encourage EV sales.** Subsidies for EVs purchased below a sticker price of USD 45,200 range between USD 6800 for BEVs and USD 5600 for PHEVs. Subsidies for BEVs and PHEVs with higher sticker prices between USD 45,200 and USD 73,400 are USD 4500 for BEVs and USD 3750 for PHEVs.

8. In the United Kingdom, **the Plug-in Motorcycle Grant provides a grant of up to £1,500 (1,758 euros) for scooters and motorbikes. Purchase subsidies of up to 6,000 euros are available to EV customers for electric and hybrid vehicles.**

9. **Free parking spots, reserved parking spots,** and open access to bus lanes are among the local incentives for EVs in Germany.

10. EVs and plug-in hybrid vehicles (PHEVs) are free from the London Congestion Charge until 2025.

11. **Norway has zero purchase tax and zero VAT on the purchase of EVs.** Also, the **BEVs are exempted from VAT (i.e., 25%) and three purchase taxes** (i.e., Weight, CO_2 and NOx based taxes). There is a 75-90% tax cut for annual road tax, for both fully-electric vehicles and plug-in hybrids, and a 50% discount on company car tax for both fully-electric vehicles and plug-in hybrids. In Norway, EVs are exempted from both the acquisition tax and the country's 25% value-added tax. EV drivers are also exempt from paying parking charges, tolls, and road taxes. They have free access to bus and taxi lanes.

12. From the date of their first registration, EVs in Germany are exempted from the annual circulation tax for a duration of ten years.

13. EVs in Austria are exempted from consumption/pollution taxes, ownership taxes, and company car taxes.

14. In Italy, the BEVs are provided with an exemption from the annual vehicle tax during the first five years and also benefits from reduced tax levels in the future.

15. In Germany, fully-electric vehicles registered between 2011 and 2025 will have a 10-year exemption from ownership tax. Plug-in hybrid EVs pay the fee, but it's lower for them than diesel/gasoline vehicles, in proportion with their lower CO_2 emissions.

16. German employees who use their company cars privately are taxed 1% of the list price for the vehicle. But this has been halved to 0.5% for EVs purchased or leased from the 1st of January 2019 to the 31st of December 2021.

17. In June 2020, the German government came up with a reduction in VAT rate from 19% to 16% (till 2030) for electric cars priced up to USD 67,800 and for all the other EVs. The tax rate depends upon the engine size and CO_2 emissions (i.e., USD 110 per annum & USD 560 per annum for a medium-sized vehicle and for high-end cars respectively).

2.4.2.3 Govt. Support for EV R&D – EU

1. The EU has taken steps to improve the way emissions are measured during vehicle and trailer type-approval procedures, in order to reduce the gap between emissions measured during tests and actual on-road emissions.

2. As part of the next long-term (2021-2027) EU budget, in June 2018, the Commission proposed to spend 60% of the CEF €42.3 billion budget on projects that contribute to achieving climate objectives, for instance, through the development of charging infrastructure for EVs.

3. Projects focusing on research and innovation in electric mobility can obtain support from the EU's Horizon 2020 programme or the European Investment Bank.

2.4.3 USA

Transport sector accounted for the largest share, i.e., 28% of the total U.S. GHG emissions in 2018 (U.S. EPA, 2020). For years, the country, has been promoting enhanced adoption of EVs and low-emitting vehicles at the federal level (the Corporate Average Fuel Economy Standards date from the 1970s). The enhanced use of EV will be beneficial for reducing air pollution in highly populated areas and a promising opportunity to assist energy diversification and reducing GHG emissions. Government policies, incentives and support in the EV industry depend on the status of existing technology or market in the country. EV usage in the US is mostly limited to consumers in urban areas, affluent individuals who can afford private charging stations and areas where state and local governments have invested in EV charging infrastructure. The US federal and state governments are aiming widespread adoption of EVs. The major steps by the government for expanding EV charging infrastructure, supportive government policies & incentives and providing R&D support to come up with cutting-edge EV technology and relevant infrastructure have been discussed in detail in the next section.

2.4.3.1 Expanded EV Charging Infrastructure – USA

In the US, with long-range EVs and low off-peak rates, 80% of charging takes place at home. The country had over 67,000 non-residential EV charging posts located at approximately 24,000 charging stations as on January 2019. Wireless charging is still in a development phase.

Charging at workplaces in the US is on the rise and going forward will account for a sizeable portion of chargers. To achieve widespread EV adoption, it will be crucial to provide an accessible public charging network. Additionally, drivers will need charging along highways and interstates to feel confident in their ability to drive longer distances and charge along the way. Some key initiatives are given below:

1. **45 utilities across the US have time of usage (TOU) rates** targeted for EVs. This will enable effective shifting of EV Load to off-peak hours.

2. As per the **Washington Administrative Code:**

    a. 5% of parking spaces in new buildings to be equipped with EV charging infrastructure; excludes occupancies with fewer than 20 parking spots.

    b. The electrical room must be designed to accommodate 20% of all parking spaces with 208/240V & 40-amp.

3. As per the **California Green Building Standards Code:**

a. It applies to new buildings in California designated as "green" buildings.

b. Stricter voluntary standards under "Tier 1" and "Tier 2" for installing Electric Vehicle Supply Equipment (EVSE) parking.

3. As per EV Readiness Ordinance in San Francisco, California:

a. It requires all new residential and commercial buildings to configure 10% of parking spaces to be "turnkey ready" for an EV charger installation.

b. Additional 10% to be "EV flexible" for potential charger installations and other upgrades.

c. 80% of parking spaces will be "EV capable," ensuring conduit is run in the hardest-to-reach areas of a parking garage to avoid future cost barriers.

4. Independent Charging Network in the US includes ChargePoint, EVgo, Blink, Greenlots. As of January 2019, ChargePoint operates the largest EV charging network in the US with over 58,000 charging posts, most of which are Level 2 chargers. Blink and Greenlots provide EV charging systems across the US. While the former employs a subscription-based model for EV charging, the latter offers end-to-end EV charging services to business, governments, fleet owners, utilities and others.

5. **State regulator's approval in setting up of EV charging infrastructure by California's all the three investor-owned utilities,** i.e., Southern California Edison, San Diego Gas & Electric and Pacific Gas & Electric.

6. **California Public Utilities Commission** has approved over $750 million in IOU EV charging investments and related customer rebates. Utilities outside California, viz., Seattle City Light, Kansas City Power & Light, Ameren (Missouri Utility), American Electric Power- Ohio have also taken various initiatives to develop EV charging infrastructure in both slow as well as fast charging technology.

7. In the US, **Tesla operates its EV charging network while other auto manufacturers, viz., Nissan, BMW, etc. partner with Independent Charging Network Companies** to provide EV charging services. Tesla uses its proprietary charging standard while others opt for more common Level 2 Combined Charging Systems (CCS) charge points or CHAdeMO plug to provide their services.

8. In the US some **states and local governments also offer rebates and tax incentives to businesses/ retailers for installing EV chargers.** Some are given below:

a. The Charge Ahead Colorado program offers businesses tax credits up to $16,000 for installing public chargers.

b. California offers a loan program at low interest for business installing chargers.

c. Los Angeles Water and Power offer incentives of up to $4,000 per charger installed at businesses.

d. An incentive of $2,500 was offered by Idaho Power to stores for installing EV charging infrastructure for a limited time.

5. The sharing economy has brought into the limelight several apps and services which facilitates EV charging. In the US, **Plugshare and Tesla appear to be the only two sharing-economy EV charging apps or partnerships.** This model is yet to kick in at large in the US, and it would be interesting to witness its evolution.

2.4.3.2 Govt. Policies & Incentives for EV Adoption – US

The various govt. policies & incentives in the US to accelerate transport electrification have been highlighted below:

1. **Car Allowance Rebate System (CARS)** was launched in US in July 2009, i.e., 'Cash for Clunkers,' a three-billion-dollar programme. The vehicles that entered the programme for exchange had to be 25 years old and have a fuel efficiency up to 18 miles per gallon (mpg). This programme focused on the gross weight of vehicles of up to 10 tonnes.
2. **First-come, first-served incentives in the State of California** to individuals, company owners and governmental agencies for purchase or leasing of qualified new light-duty EVs and PHEV's of up to $2,500. A supplementary rebate of $2,000 is also granted to persons with low and medium incomes. In the framework of the Public Fleet Pilot Project, State and local authorities are granted a discount of up to $7,000 and $5,000 in respect of the purchase of BEVs or PHEVs.
3. **Hydrogen and Electric Automobile Purchase Rebate Program** in Connecticut provides a rebate of up to $5,000 on the purchase or lease of EV, $3,000 on BEV and $300 incentives for dealers.
4. **Delaware Clean Vehicle Rebate Program** offers businesses, individuals and government a rebate of up to $3,500 for the purchase, lease or conversion of BEV and $1,500 for PHEV.
5. **Residents of Massachusetts** can purchase or lease an EV with a rebate of up to $2,500.
6. **Drive Clean Rebate Program** in New York, offers the purchase or rent of an EV with a battery capacity of 4 kWh for up to $2,000.
7. **Zero Emission Vehicle (ZEV) Rebate Program** in Oregon, provides rebates of $1,250 - $2,500 for the purchase of specific EVs with battery capacities above 10KWhr and $750 - $1,500 for EVs with battery capacities less than 10 kWh. Further, additional rebates of $1,250 - $2,500 are available for low and moderate-income group households and households that voluntarily retire or scrap vehicles that are 20 years old.
8. There are many **federal bills in the US** that attempt **to increase financing for EVs and its infrastructure.** One such act is the '**Appropriations Law 2021'**, which President Trump signed on 27 December 2020, that authorizes funding and support of programmes for further development of the transport industry in the US. It includes the following:
9. **Surface Transportation Block Grant Program:** $647.5 million for charging infrastructure along corridor-ready or corridor-pending alternative fuel corridors;
10. **Clean Transit Buses:** $125 million for the low or no emission grant program;
11. **Alternative Fuel Refueling Property Credit:** extended through 2021, the tax credit provides $30,000 for businesses and $1,000 for residential properties to install alternative fuel facilities, including EV charging stations;
12. **$2.6 billion over three years for a reauthorization of the Department of Transportation's sustainable transportation research program,** which would be directed toward RD&D and commercial application activities within the Offices of Hydrogen and Fuel Cell Technologies, Vehicle Technologies, and Bio-energy Technologies.
13. **A single tax credit of up to $3,000 is offered in Maryland** when a qualified EV is purchased or leased through mid-2020. A business entity can also claim tax credit for a maximum of ten vehicles.

14. Louisiana offers up to $2,500 in tax credits for each electric passenger vehicle.

15. In 2019, the US Congress extended its federal charging infrastructure tax credits, irrespective of the continuation of the federal tax credit for EVs. It covers 30% of new EVs (USD 1,000) installation costs through the 2020 fiscal year.

2.4.3.3 Govt. Support for EV R&D – USA

In order to decarbonize the transport sector by 2050, the current US federal government is aiming to electrify much of the US vehicle fleet — and make the power sector 100% carbon-free by 2035. As per estimates, building 500,000 new public EV chargers is "a key strategy" for reducing emissions. The federal funding for EV charging infrastructure on US highways is available through 15 programs.

The National Highway Performance Program (NHPP), for instance, has a budget of $23.1 billion for FY 2021 and the Surface Transportation Block Grant Program was funded at $10.2 billion for FY 2021. Each could be accessed to construct chargers and support training related to EVs.

The U.S. Department of Energy (DoE) also announced new research funding opportunities, including $10 million to reduce the cost of direct current fast charging equipment and $20 million for community-based public-private partnerships that support charging infrastructure. DOE has also marked $4 million aimed at boosting workplace charging.

Chapter 3: EV Survey

A primary survey of existing EV users and prospective EV consumers was undertaken by IRADe covering 500 respondents for four distinct segments: electric-2W, electric-rickshaw, electric-4W (private + institutional), and prospective EV consumers (planning to buy a vehicle over the next six months) in partnership with Nielsen India during August to September 2020, with the reference period being February 2020 (pre-Covid19 period).

The survey was done in two stages, starting with a pilot survey and then the larger primary surveys. IRADe team used the pilot survey's findings and shortcomings to fine-tune the questionnaires for the final primary surveys. The survey was aimed at studying the consumer profile, travel pattern, consumer preference and charging pattern of 2Ws, 3Ws and 4Ws (private and institutional) vehicles and to identify possible measures for adoption of EV charging in the existing power system. (*Please see annexure-4 for the choice of sample size for the report*)

The subsequent sections discuss the survey work in considerable detail.

3.1 EV Two-Wheeler

A survey was carried out in September 2020 for a sample of 122 respondents who own electric two-wheeler vehicles. The sample of owners was chosen randomly and contacted for interview. Those who agreed to be interviewed were approached for the survey. The survey respondents were spread across Delhi city and composed of individuals of varying ages, gender, profession, educational background and monthly expenditure. The survey responses analysed below provided a perspective on:

- The social and economic profile of those who purchased EV 2W.
- The ownership pattern of EV users – number and type of other vehicles owned.
- Social/economic group-wise usage and distance travelled by EV 2W.
- When, how, and where do users of EV 2W charge their EV 2W?
- Technological parameters associated with charging.
- Consumer preference of factors that determine purchase and usage of EV 2W.
- Consumer satisfaction for EV 2W and constraints for its adoption.

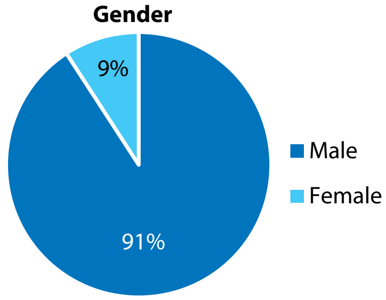
The analysis of the survey responses on the above-listed points is provided in the discussions below:

3.1.1 Survey Results

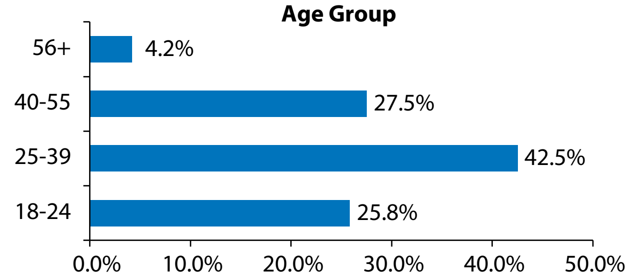
3.1.1.1 Demographic Profile

The demographic profile of the two-wheeler respondents consists of questions on their gender, profession, educational qualifications, age, and income of the respondents.

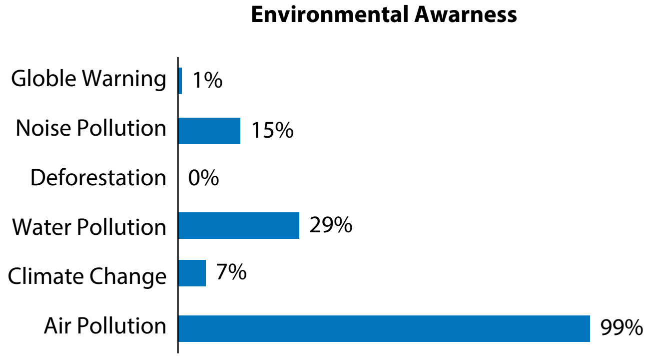
Figure 7: Profile of Respondents



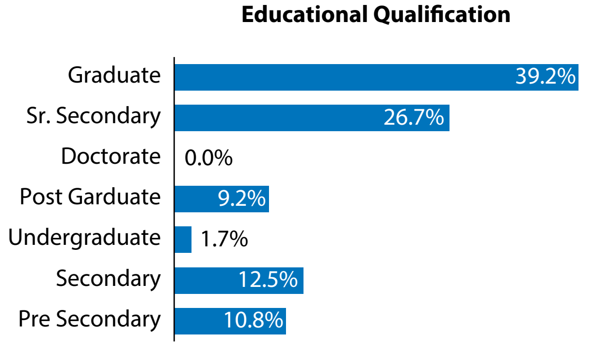
(a) Share of Respondents by Gender



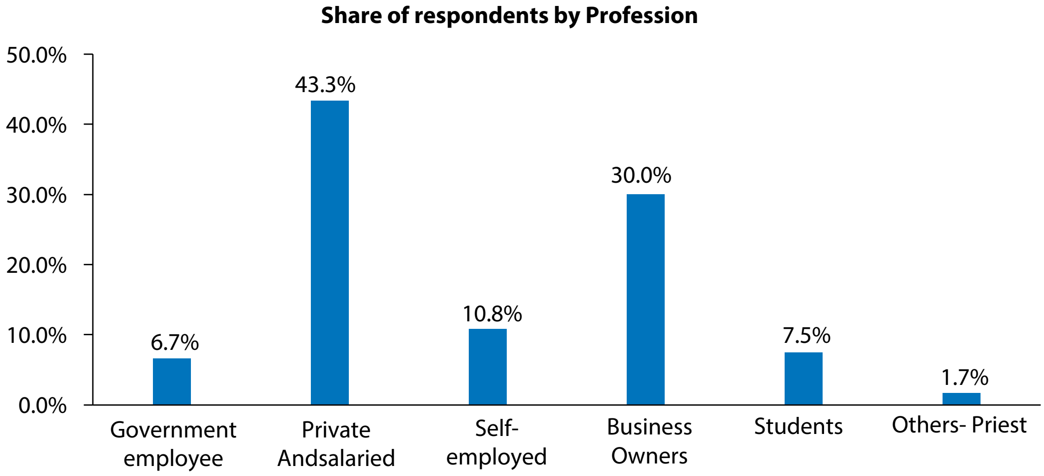
(b) Share of Respondents by Age Group



(c) Share of Respondents by Environmental Awareness



(e) Share of Respondents by Educational Qualification

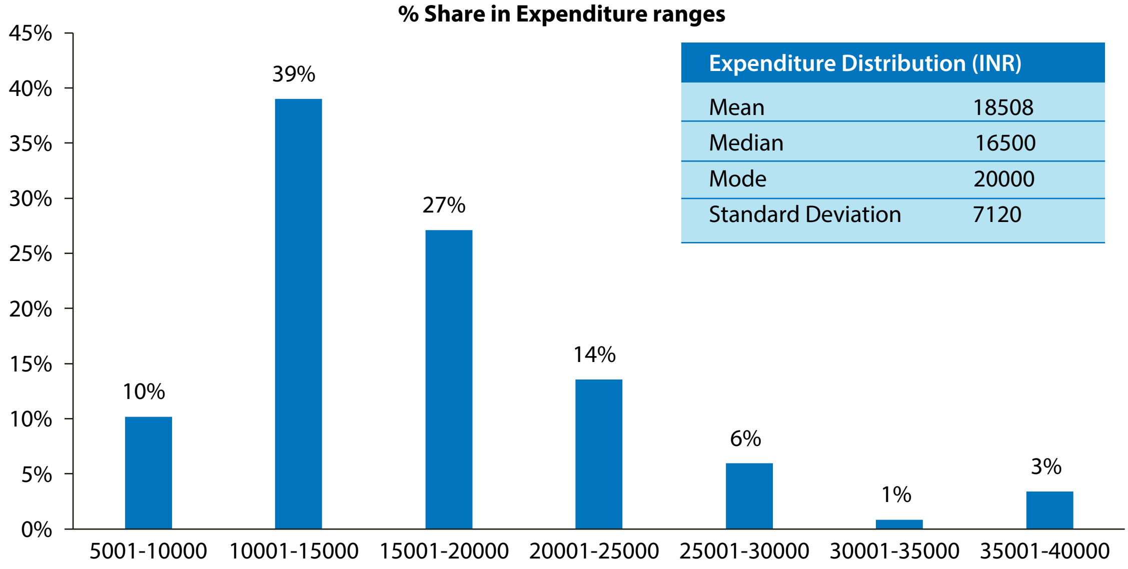


(e) Share of Respondents by Profession

Figure 7 shows the results of the analysis of the demographic profile of the respondents. In the total responses to the survey, 91% of the respondents are male and 9% of the respondents are female. In terms of their occupation, 43.3% of the respondents are private and salaried, 30% are business owners and the rest 26.7% are government employees, self-employed, students, and others.

Educational qualification-wise, most of the respondents are graduates with a share of 39.2% followed by senior secondary educated with a share of 26.7%. For the respondents who studied till secondary, the level was 12.5%, 10.8% are pre-secondary educated and the rest are categorized in post-graduate and undergraduate education levels. The maximum number of respondents of around 43% belong to the age group of 25 to 40 years.

Figure 8: Expenditure Profile of Respondents



3.1.1.2 Environmental Awareness

In terms of awareness of environmental issues, almost all the respondents were found to be aware of air pollution as an environmental issue, 29% are aware of water pollution, 15% are aware of noise pollution and only 7% are aware of climate change. In terms of their knowledge of EVs, the respondents were aware of their environmental benefits.

The respondents of the survey were asked for their average monthly household expenditure instead of their income, similar to the National Sample Survey Organisation (NSSO) household expenditure survey in India. Monthly household expenditure data is considered more reliable than income which can vary when occasional income from all family members is combined.

As shown in figure 8 above, the average monthly household expenditure of the respondents in the survey is INR 18,506. The expenditure range lies between INR 7000 and INR 40,000. 39% of the respondents lie in the INR 10k-15k range followed by 27% in the INR 15k-20k range. It shows that most of the owners are in the lower median range. As their monthly expenditure increases, they may go for cars, rather than staying with two-wheelers.

3.1.1.3 Vehicle Ownership

This section discusses the responses of the respondents on the type, technology, and fuel type of other vehicles owned by them apart from electric 2W. Figure 9 shows the vehicle ownership by type, i.e., owning only two-wheeler vehicles and owning both two and four-wheeler vehicles.

It can be seen that 91% of the respondents own only two-wheeler vehicles and 9% of the respondents own both two and four-wheeler vehicles. The vehicle ownership by expenditure graph shows that the ownership of four-wheelers increases with the increasing expenditure of the respondents.

It can be seen from Figure 10 that 66% of the respondents own only one EV two-wheeler vehicle and 34% of the respondents in addition to electric 2W own a second or a third vehicle in the form of conventional two-wheelers and/or four-wheelers. Among the respondents who own a second or third vehicle, 47% own a petrol 2W, followed by 29% who own electric two-wheelers, and 24% who own petrol 4W as the second or third vehicle. This implies that people opting for a second 2W and people already owning a 2W and/or a car has a high chance of possessing an electric 2W as their second or third vehicle.

Figure 9: Vehicle Ownership by Type and Expenditure

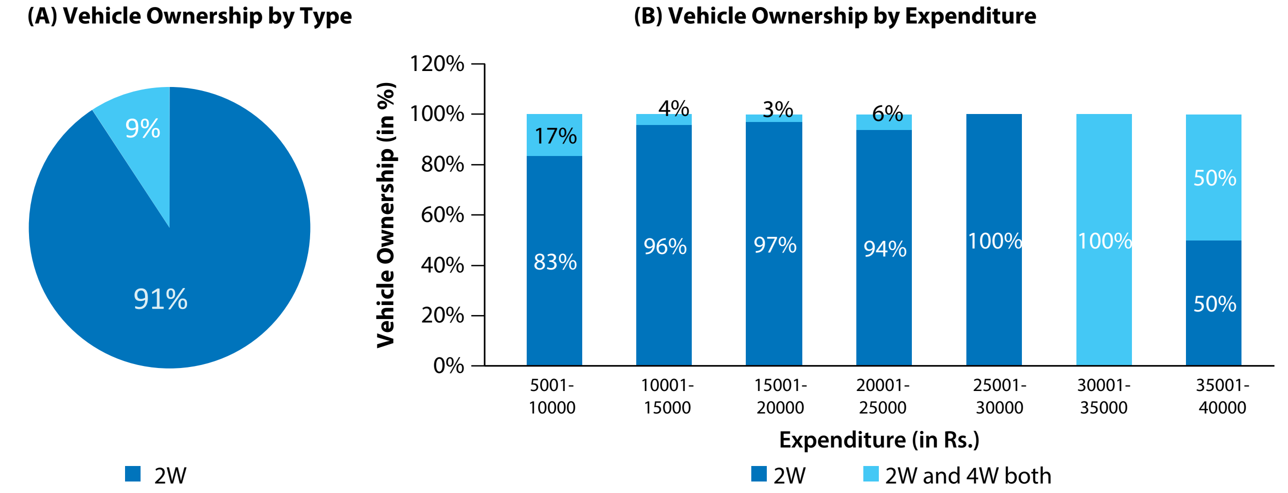


Figure 10: Vehicle ownership profile

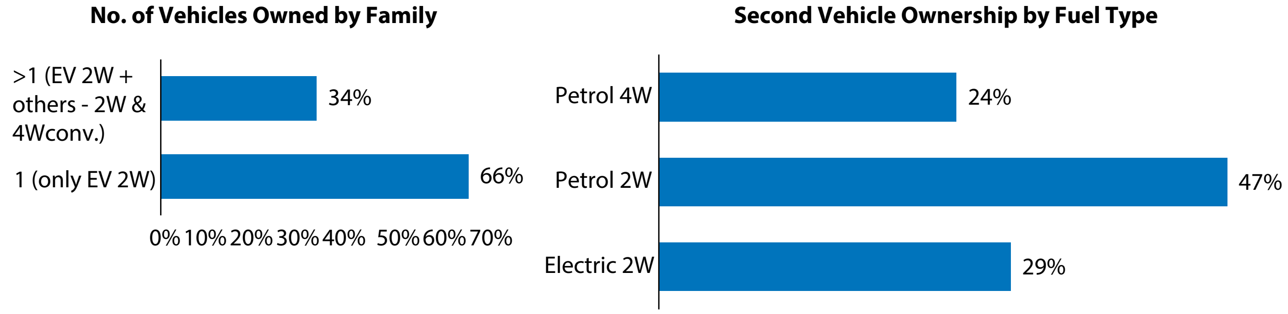
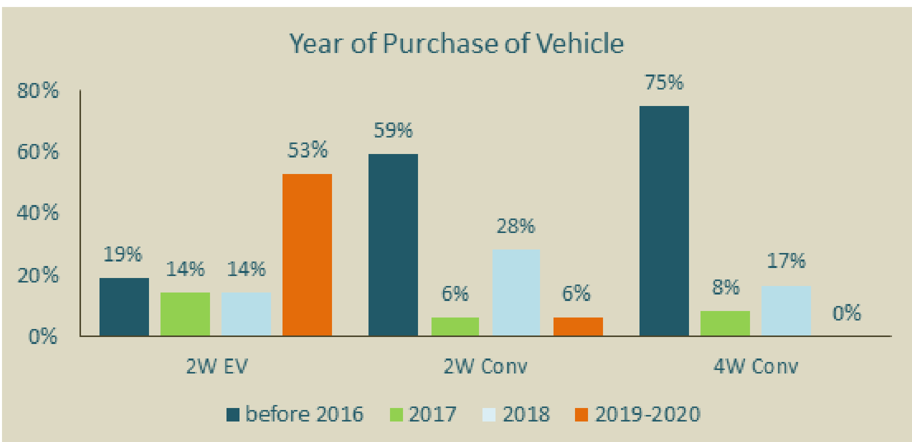


Figure 11 represents the year of purchase of different vehicles by type. The years have been categorized as before 2016, 2017, 2018, and 2019-20. A total of 165 vehicles are owned by respondents with the vehicles categorized as conventional two-wheelers and four-wheelers and two-wheeler EVs. Nearly 50% of the electric two-wheeler vehicles were purchased in 2019-2020 and the majority of the conventional two and four-wheeler vehicles were purchased before 2016 implying an increase in preference for electric 2W in recent times.

Delhi is more affluent in comparison to India as the GDP per capita of Delhi is approximately 2.7 times higher than that of India for the year 2018-19, which indicated that the purchasing power of people are comparatively higher. So, the purchase of 2W vehicles in Delhi is more than the average purchase of vehicles in India.

Figure 11: Year of Purchase of Vehicles



3.1.1.4 The Status of Occupation or Profession

Figure-12 shows that 50% of the private/salaried class own one 2W only and Business owners own approx. 47.5%. Figure 13 shows the distribution of types of vehicles owned by the profession of the respondents. The vehicle type is categorised as four-wheelers conventional, two-wheelers conventional, and EVs. In the categories of private-salaried, self-employed, and students, more than 80% of the respondents own one electric two-wheeler vehicle. While in the government employee and business owner's category, more than 60% of the respondents own one electric 2W. Within the profession of business owners, 27% have conventional 2W in addition to an EV 2W and 12% own a conventional 2W and 4W apart from electric 2W.

Figure 12: Ownership of Vehicle by Profession

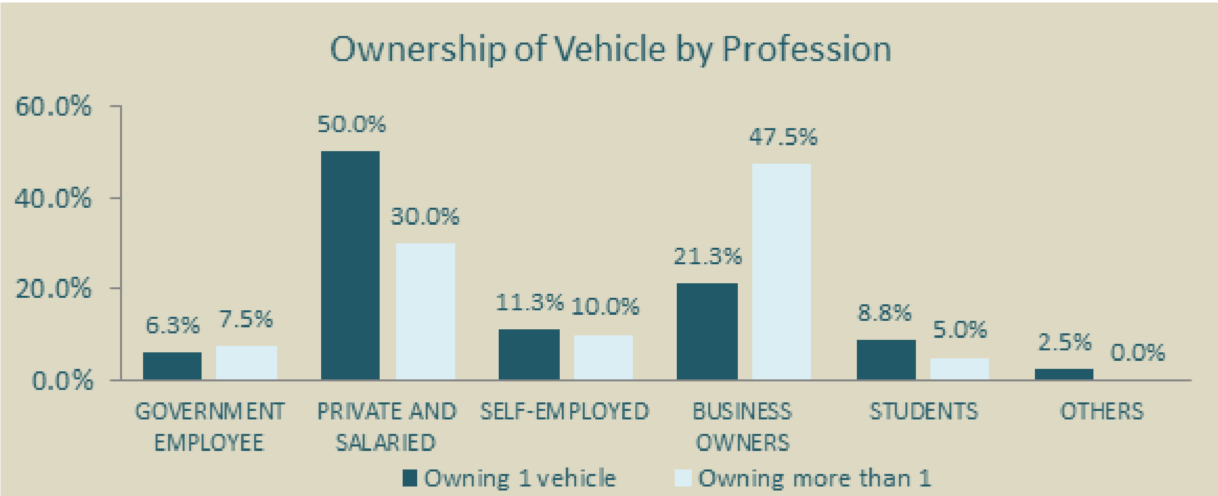
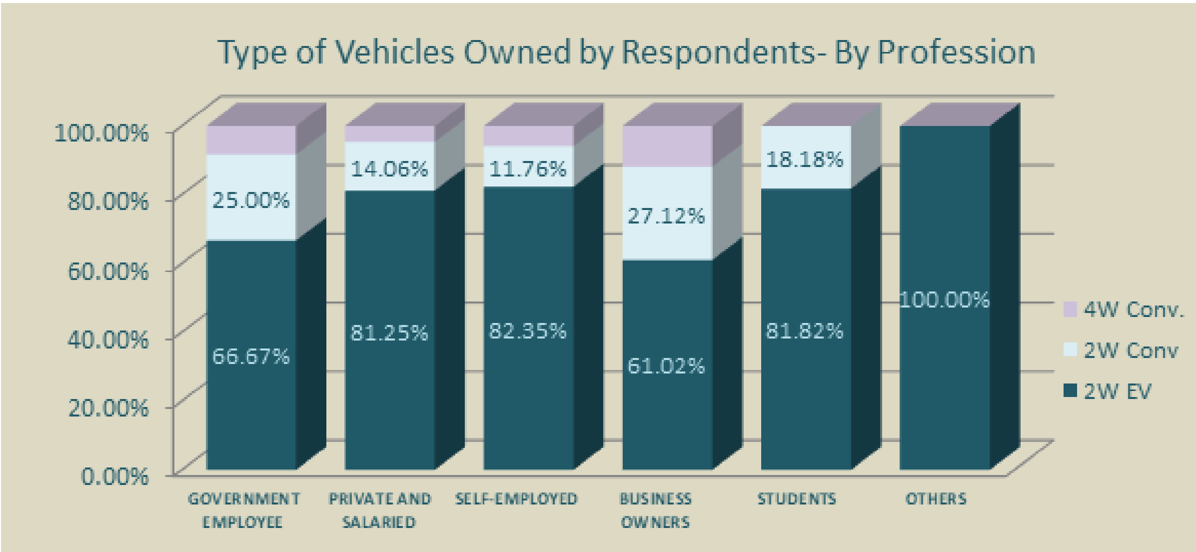


Figure 13: Types of Vehicles Owned - By Profession



3.1.1.5 Vehicle Usage Pattern

This section discusses the pattern of usage of vehicles on working and non-working days, distance travelled by the respondents using electric two-wheelers, conventional two and four wheelers, and public transport on working and non-working days.

Working days can be defined as those days when the individual spends the day doing their usual work. Similarly, non-working days are days when the individual has an off day or holiday at his place of work and spends the day otherwise. Usually, this would correspond to weekdays and weekends, but in the case of some category of individuals--like business owners and self-employed--this may be different.

Table 1 shows for each profession category the total number of working days/non-working days and the number of days of use of their electric two-wheelers during working and non-working days in a week.

Table 1: Frequency of Usage of EV 2W in Working Days and Non-working Days

Average Frequency of usage of EV 2W - In Working Days				
	Government Employee	Private & Salaried	Self-Employed	Business Owners
Total No. of Working Days	5	6	6	7
Frequency of Usage	5	6	6	6
Total No. of Non-Working Days	2	1	1	0
Frequency of Usage	1	1	1	0

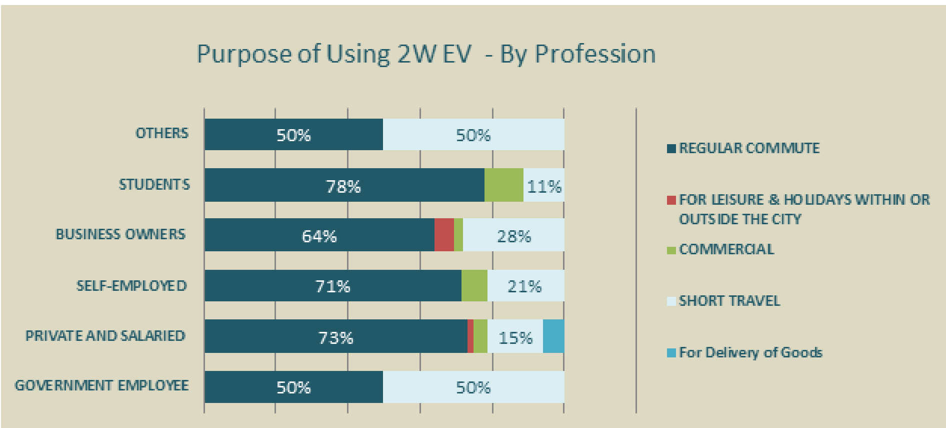
From Table 1, it can be stated that EVs are used regularly by respondents of all professional groups. private salaried and self-employed use their EV 2W on all working and non-working days while business owners use their EV on 6 out of 7 working days and government employees use them on all their working days as well as for one of their two working days. This is reflective of the fact that EVs are being used by the survey respondents for regular and short commuting purposes, as shown in Figure 14.

3.1.1.6 Pattern of use and Travel by Profession

Since travel demand is mainly due to work and profession related reasons, it is important to analyse the purpose for which EV is used by individuals of various professions. This is provided in Figure 14 which shows that the main purpose of using electric two-wheeler vehicles is for regular commute followed by short travel across all professions. Electric 2Ws are used by government employees and other professions equally for regular commute and short travel.

For all the other categories of professionals, more than 60% of the respondents use EV 2W for regular commute. The other major purpose for which EV 2W is used is short travel. Few respondents among business owners and private & salaried have reported using EV for leisure & holiday travel. This may imply that users generally prefer EV 2W for travelling in fixed and known distances. We further investigate the distances travelled using EV 2W by respondents of various professions.

Figure 14: Purpose of Using 2W EV - By Profession

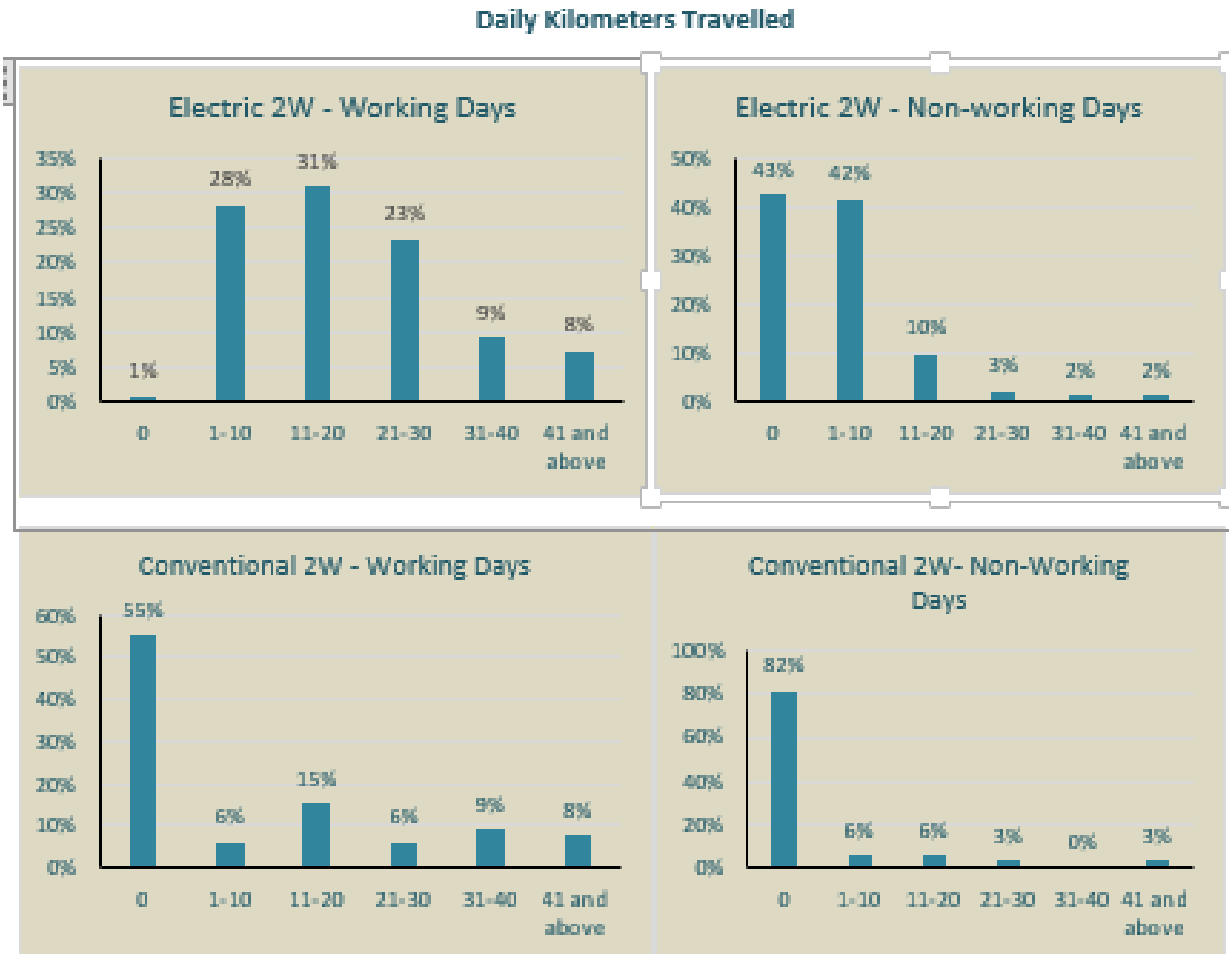


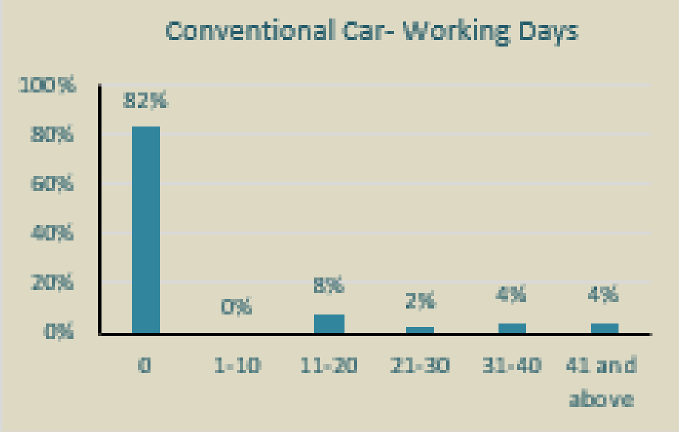
As can be observed from Figure 15 below, a significant proportion of respondents have answered zero for distance travelled using their electric 2W, conventional 2W, and conventional 4W on non-working days. This implies that they do not use their conventional 2W or 4W and even electric 2W on non-working days or weekends. The proportion of respondents using their EV 2W or conventional 2W and 4W are significantly higher on working days compared to non-working days. Figure 15 also shows that 55% of the respondents who own a conventional 2W, apart from EV 2W, do not use it even on working days.

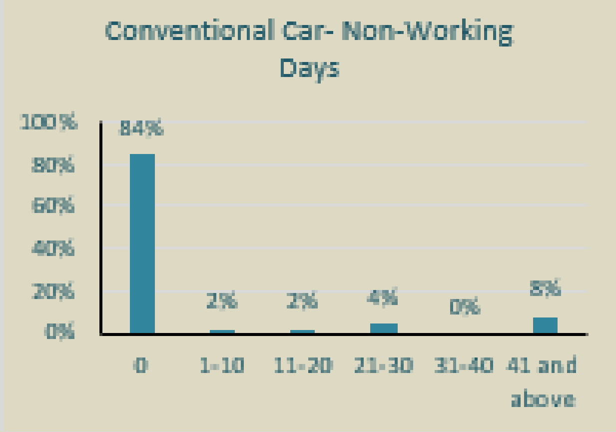
Similarly, 82% of respondents who own a conventional 4W, apart from EV 2W, also do not use it on their working days. Thus, it can be concluded that most people who purchased EV 2W in Delhi have replaced their conventional 2W and 4W with it for their travel needs. Most respondents use their EV 2W for travelling short distances on both working and non-working days. The conventional car is being used for a short distance on a working day and long distances on a non-working day.

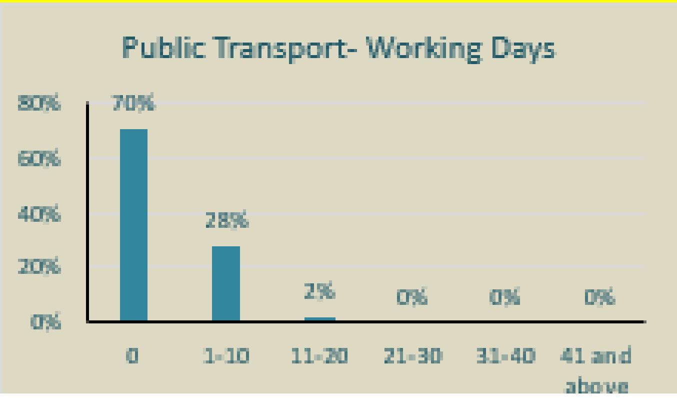
The responses also showed that public transport is not used by 70% of the survey respondents on working days and 66% of respondents on non-working days. Only 28% and 25% of respondents reported using public transport for travelling short distances of 1-10 km. It can be stated that electric two-wheelers, conventional two-wheelers, and public transports are being used the most for both short-distance travel in a working day and non-working day. The conventional car is being used for a short distance on a working day and long distances on a non-working day

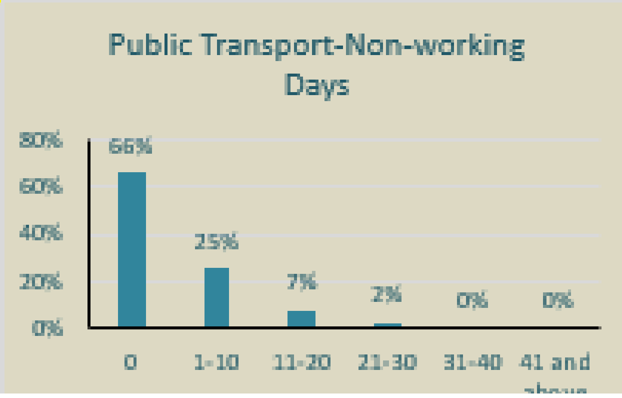
Figure 15: Daily Kilometers travelled by vehicle type











From Table 2, it can be stated that the average kilometers travelled by conventional cars are 41km followed by conventional two-wheelers (29 km) and Electric 2W (22 km) suggesting that electric and conventional 2Ws are being used to travel short distances and a conventional car is being used for long-distance travel on a working day. Similarly, on a non-working day, conventional cars are being used for long-distance travel (51 km), conventional 2Ws (22 km) being used for medium-distance travel, and electric 2Ws (11 km) being used for short-distance travel. All the values are calculated assuming that respondents with no responses are considered as 0 and all variables with 0 values are not taken into consideration for the calculation.

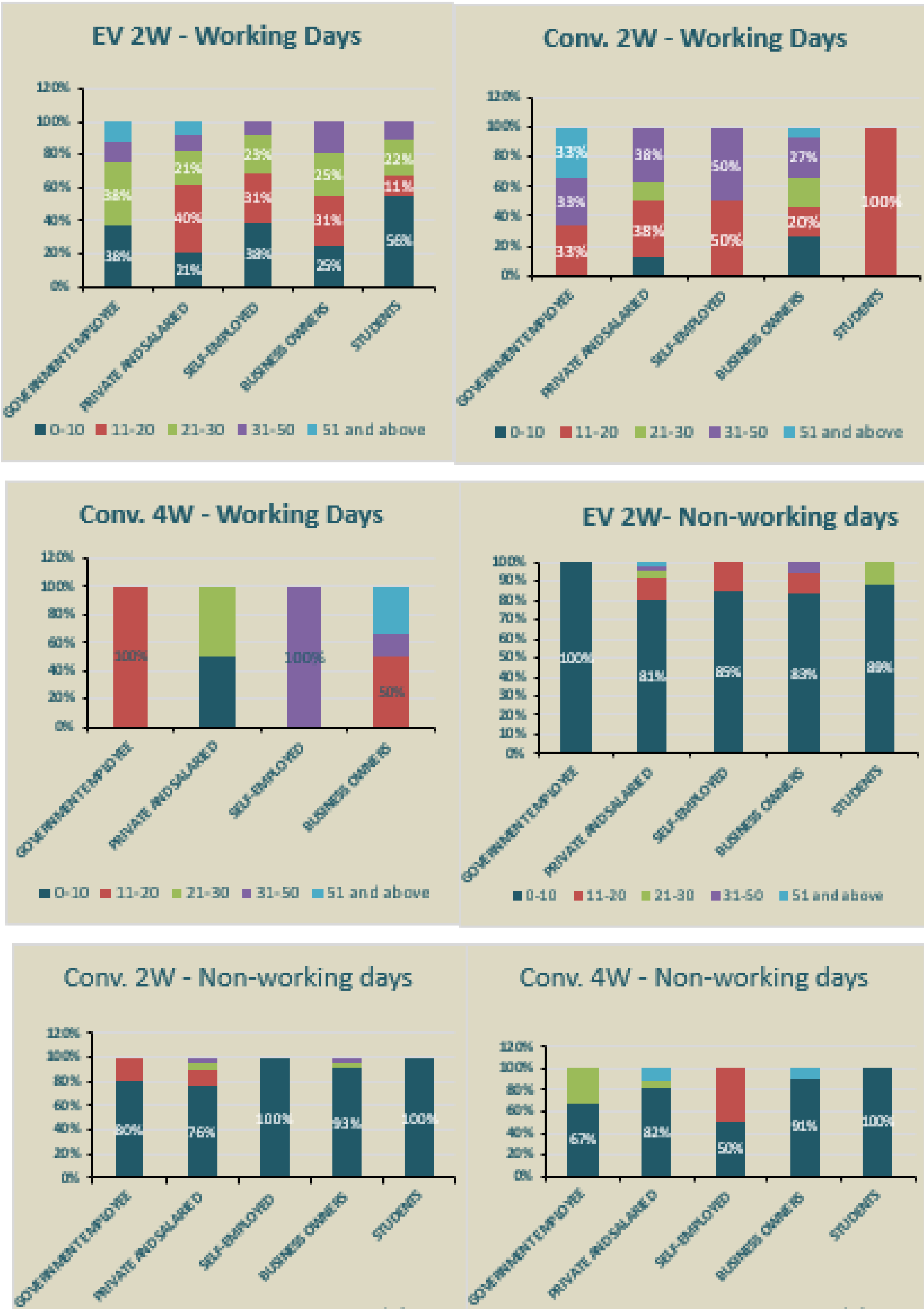
Table 2: Descriptive Statistics of Avg. Vehicles Kilometers Travelled on Working and Non-Working Days

	Electric 2W	Conventional 2W	Conventional Car	Public Transport
Mean (Working)	22	29	41	9
Sample Variance (Working)	210	342	861	8
Mean (Non-working)	11	22	51	10
Sample Variance (Non-Working)	134	229	1132	31

In general, owners of 2Ws (electric and conventional) are characterized by short distance travel requirements of 1-30 km, and hence electric 2Ws perfectly suit their requirements. The analysis of the responses shows that electric 2Ws are being used extensively by those who have purchased them. Figure 16 below shows the distribution of the distance traveled in a day by respondents using electric two-wheelers on working and non-working days for the different professional categories.

It can be seen from Figure 16 that on working days people are travelling more on shorter distance like 0-10 km and 11-20 km by EV's, while conventional 2W and 4W are being used more for travelling longer distances like 11-20 km, 21-30 km, 31-50 km and above 50 km. On the non-working days, both electric and conventional vehicles are used similarly for travelling more for shorter distances like 0-10 km. The average distance travelled on weekdays by EV, conventional 2W, and 4Ws is 22 km, 29 km, and 41 km respectively. Similarly, on weekends, the average distance travelled by EV, conventional 2W, and 4W is 11 km, 22 km, and 51 km respectively which suggests that respondents used EV more for travelling shorter distances, and conventional 2W and 4W are used for travelling long distances.

Figure 16: Distance Travelled by Vehicles on working and non-working days



3.1.1.7 Availability of Charging and Vehicle Charging Behaviour

This section analyses the responses of the survey respondents on parking availability, charging behaviour, availability of office charging, distance from public charging stations, location of charging, and the peak time slots of charging.

a. Pattern of Night Time Parking

Slow or regular charging is a very essential requirement for EVs. This makes the availability of parking facilities very important so that we know if the charging facilities can be accessed during night time or during idle time charging.

Figure 17 below shows the %age share of responses for the preferred location of parking EV. Garage is the most opted parking facility with 42% share followed by public or on-street parking with 31% share and parking in society space with 26% share. This suggests that most of the EV 2W users have access to basic parking facilities and, therefore, home charging would not be a problem for 2W users.

Figure 17: Share of Parking of EV 2W

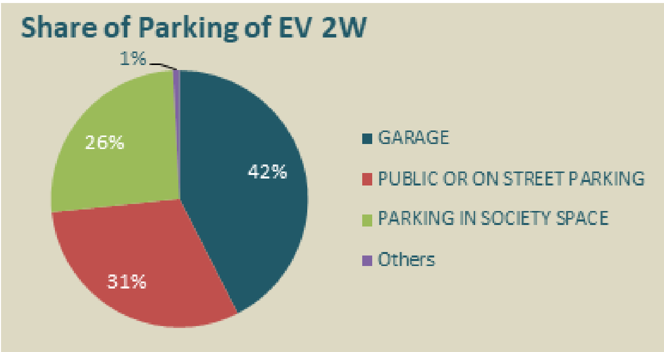
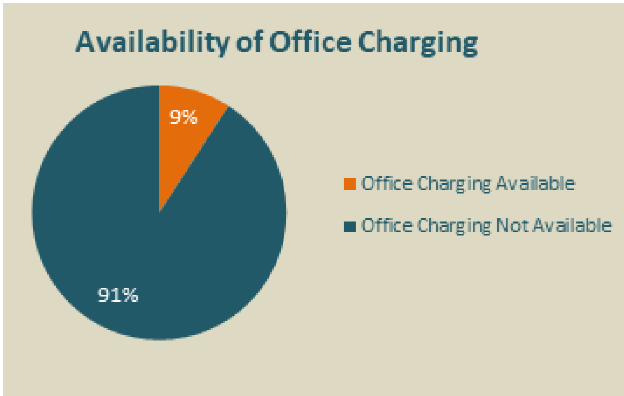


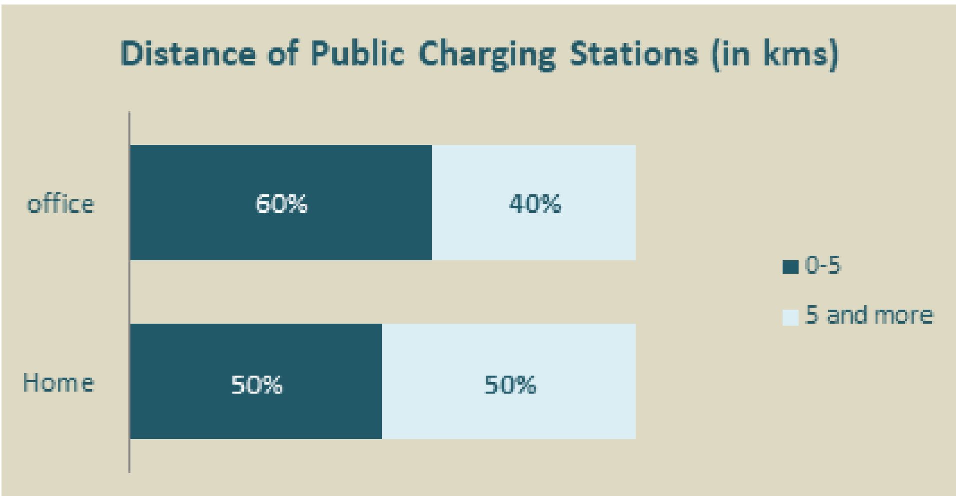
Figure 18: Availability of Office Charging



From Figure 18 above, only 9% of the respondents have charging options available at the office and the rest 91% have no charging option available at their office.

Figure 19 below shows the distance of the public charging station from the respondent's office and home. Only 6% of the respondents were found to be aware of the public charging facilities near their homes and offices.

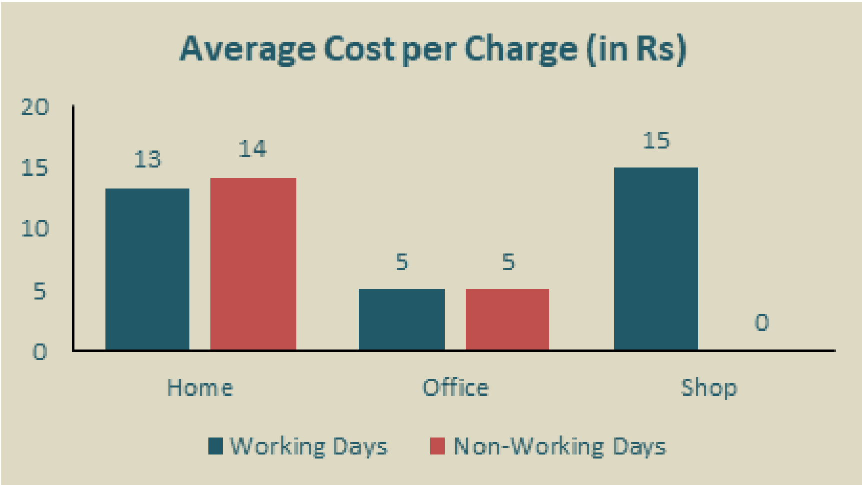
Figure 19: Distance of Public Charging Stations



From Figure 19, among the respondents who are aware of public charging facilities, 60% of the respondents have public charging stations 0-5 km from their offices and 50% have public charging stations at the same distance from their homes. Similarly, 40% have public charging stations over 5 km from their offices and 50% have public charging stations the same distance from their homes.

As discussed earlier, only 6% of the respondents were aware of public charging facilities. Thus, when asked about the waiting time in public charging stations, the respondents replied that they have never visited a public charging station and had no idea of the waiting time. None of the respondents interviewed visited the public charging stations.

Figure 20: Average Cost per Charge



The average cost of charging for office, as shown in Figure 20, is INR 5 charged for both working and non-working days. Average home charging costs on working and non-working days are Rs.16 and INR 14 per charge respectively and shop charging costs INR 15 per charge for working days. However, as none of the respondents were found to be using public charging, its cost is not estimated from the survey.

Figure 21: Location of Charging

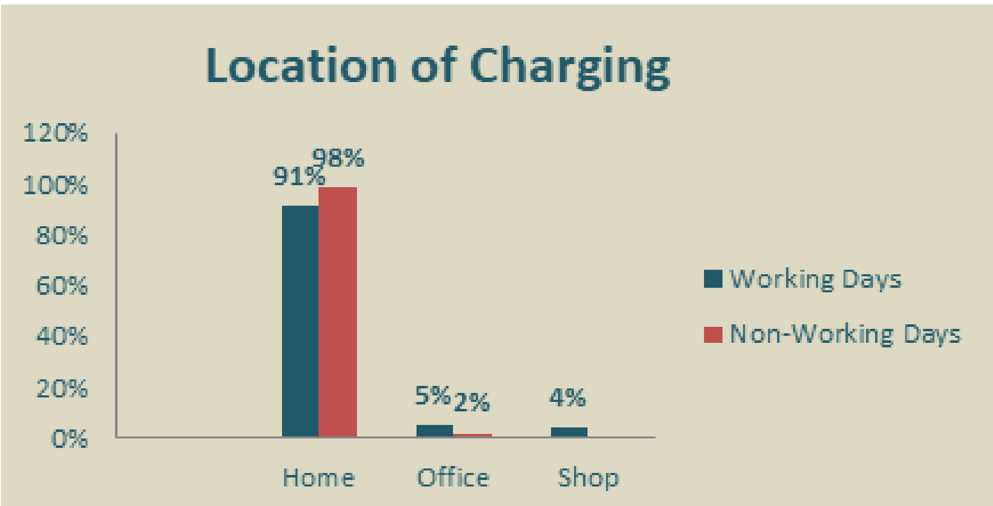


Figure 21 shows that more than 90% of the respondents charge at their homes on both working and non-working days and that office charging and shop charging are almost negligible. This reflects a strong preference for home charging among owners of EV 2Ws. The respondents were asked the frequency of charging or the number of times they charged their EV 2W per week.

The responses to this survey question are shown in Figure 22 below. The frequency distribution of the responses is skewed towards higher values with the highest 39% of the respondents saying that they charge their EV 7 times a week (once a day). This is followed by 17% and 16% of the respondents charging 5 times and 6 times a week, respectively. However, it also means that 55% of the respondents charge their EV 2W less once a day. A small %age of respondents mentioned that they charge 12 times and 14 times a week. This is consistent with the earlier finding that respondents use their EV 2W to travel short distances on working and non-working days

Figure 22: Frequency of Charging per week

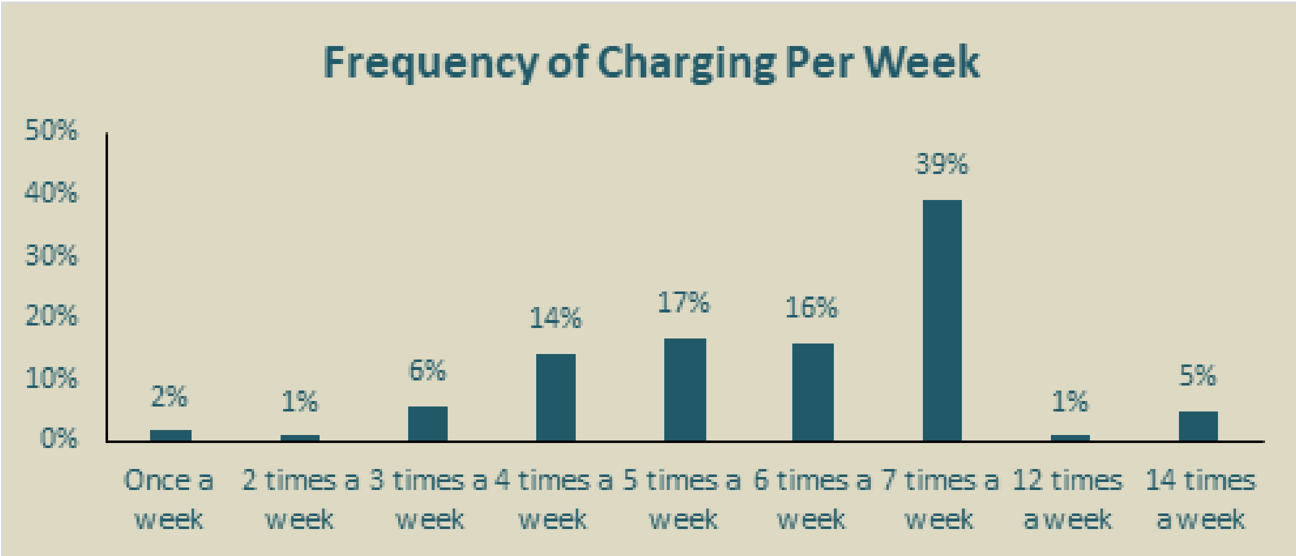
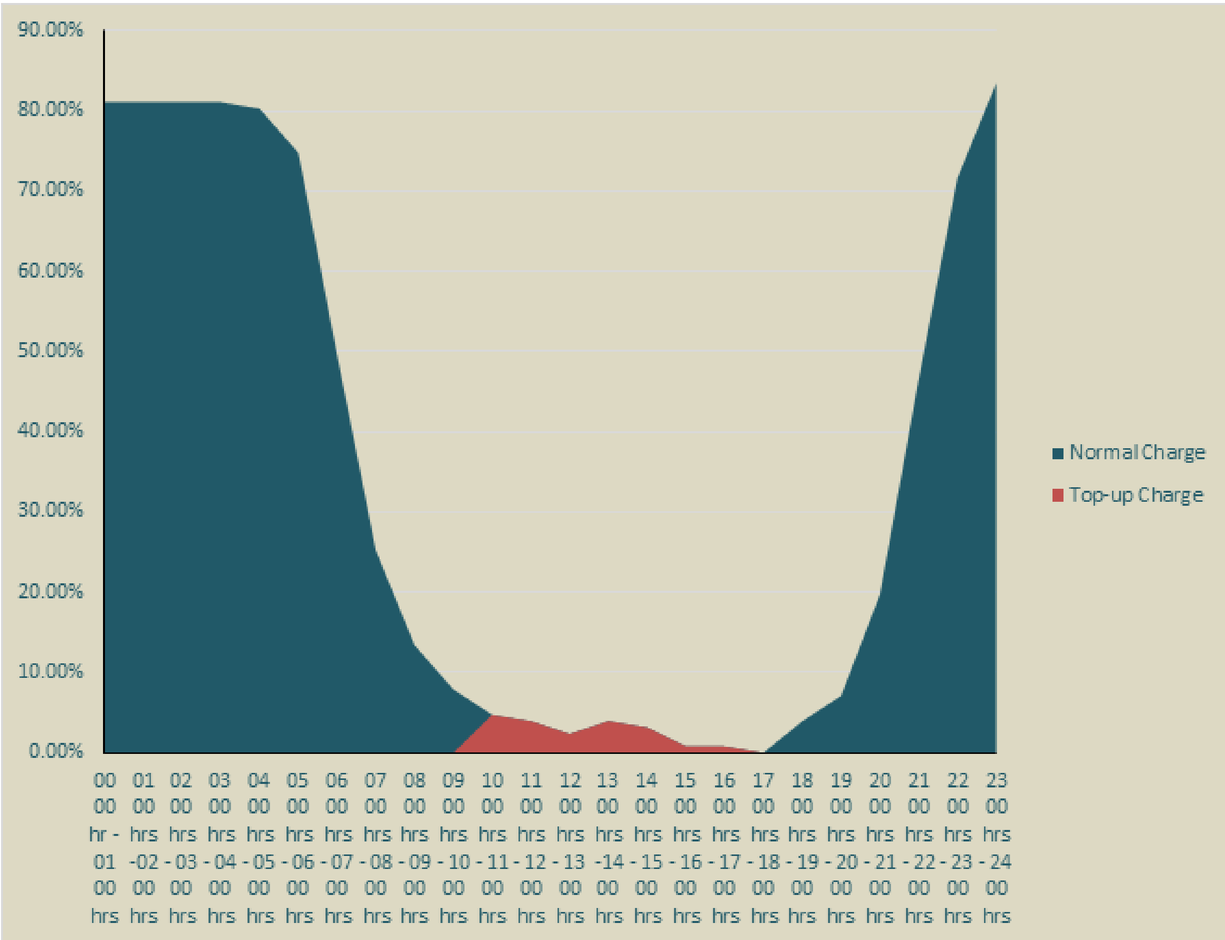


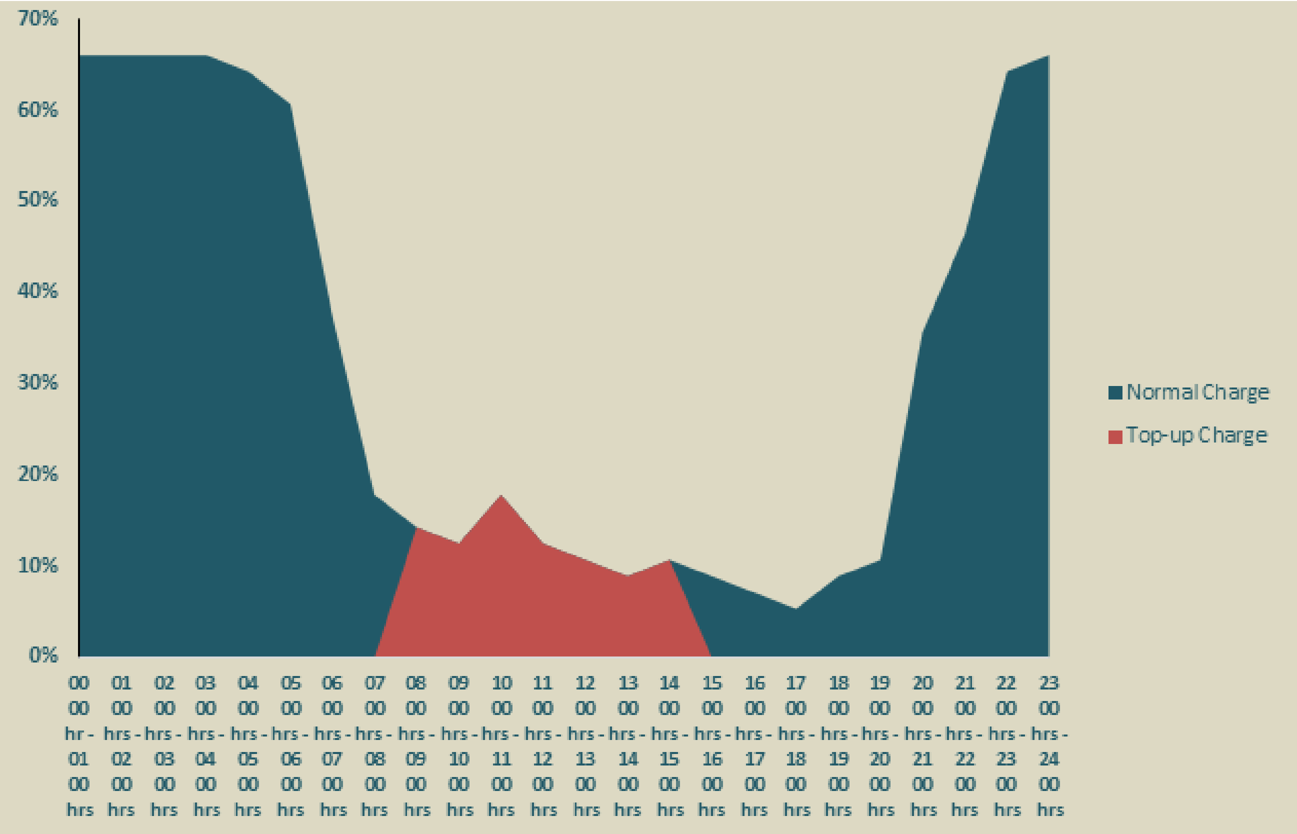
Figure 23: Charging Behaviour on Weekday



The charging pattern for EV 2W is through two modes: regular charging and top-up charging. The regular charging time on weekdays and weekends is from 7 pm to 8 am, as can be observed from Figures 23 and 24. Generally, top-up charging is not relevant for electric 2W vehicles. On average, it takes 7-8 hours to completely charge an electric 2W vehicle. Therefore, for the sake of analysis, charging is assumed to be a top-up if it takes less than the average normal charging of 7-8 hours.

It has been observed that only 9% of the total respondents opt for top-up charging on weekdays. The analysis of survey responses showed that of the total respondents, 4% opted for top-up charging on weekdays at 8 am to 12 pm, 2% opted for charging at 10 am to 2 pm and 3% opted for charging at 1 pm to 5 pm. Similarly, on weekends, 16% of the respondents opted for top-up charging. The time slot for top-up charging on weekends is 8 am to 11 am opted by 7%, 9 am to 11 am opted by 2%, 10 am to 1 pm opted by 5% and 11 am to 2 pm opted by 2% of the respondents.

Figure 24: Charging Behaviour on Non-Working Days



The average Plug-in SOC during the full charge for EV 2W in a working day is 24%. Similarly, for non-working days, it is 34%. As can be observed from Figure 23 and 24 the frequency distribution is skewed towards lower values on working days and towards higher values on non-working days.

Table 3: Charging Pattern in weekdays and weekends

SOC - Plug-in Weekday	Average SOC (in %)	Average Battery Charged (in %)	Average Time Taken (in hrs.)	Proportion of Respondents
10-19	12	87	9:57	32%
20-29	20	79	8:41	31%
30-39	30	68	7:46	17%

SOC - Plug-in Weekday	Average SOC (in %)	Average Battery Charged (in %)	Average Time Taken (in hrs.)	Proportion of Respondents
40-49	40	57	8:05	13%
50-59	50	44	3:06	4%
60-69	60	33	3:40	3%
Average	24%	74%	8:38	100%
Weekend				
10-19	11	89	9:17	21%
20-29	20	78	10:05	11%
30-39	30	70	7:25	13%
40-49	40	58	8:51	25%
50-59	50	49	6:04	27%
60-69	60	40	3:30	4%
Average	34%	65	7:57	100%

Table 3 shows the average plug-in SOC, average battery charged, the average time taken and the proportion of respondents who plugged in their vehicles for charging on weekdays and weekends. Of the total responses, 32% of the respondents have SOC in 10-19% range followed by 31% having SOC in the range of 20-29% in a working day. On non-working days, 27% of the respondents have SOC in 50-59% range followed by 25% having SOC in the range of 40-49% while plugging in to charge their vehicles.

The survey covered various kinds of electric two-wheeler models being used in Delhi. The top three models used by the respondents are Hero Flash, Hero Electric Optima, and Hero Electric Maxi with a share of 41%, 21%, and 10% respectively.

The 2W vehicle can be divided into three categories: moped, scooter, and motorcycle. Table 4 below provides a summary of responses from the survey on each EV 2W model's actual range on the ground and the %age share of respondents using the model. Revolt provides the highest range (km/charge) in the motorcycle segment of EV 2W and Veeta provides the highest range in the scooter segment.

Table 4: Model and Segment Wise Range

	Scooter Model	% of Respondents Using Model	Average Range (km/charge)
Average Range	Moped		NA
Average Range	Scooter		54
1	Hero Electric Cruz	9%	58
2	Hero Electric Optima	21%	54
3	Hero Flash	41%	51
4	Hero Nyx	3%	60

	Scooter Model	% of Respondents Using Model	Average Range (km/charge)
5	Hero Electric Maxi	10%	48
6	Hero Electric Okinawa	2%	55
7	Hero Wave	1%	60
8	Veeta	1%	70
9	Lohia Royal	1%	50
10	Gowel ZX	1%	55
11	Avon 207	2%	48
12	YO Xplor	2%	45
Average Range	Motorcycle Model		104
1	Revolt	8%	104

As can be observed from Table 4, the average range of scooters from the survey is 54 km per charge and motorcycle is 104 km per charge. No mopeds are being used by the respondents in the survey.

3.1.1.8 Vehicle Servicing Pattern

After-sales services are essential for the usage of EVs by consumers. Therefore, availability and kind of servicing provided can be crucial to people's purchase decision. Capacity building of repair workers and up-gradation of repair shops may be necessary. The after-sales servicing requirements of the respondents in the survey and the survey responses on the cost per service by vehicle type, the average number of services availed, and after-sales services are discussed below.

The respondents were asked about the age, number of services, and the average cost per service of owned vehicles. As shown in Table 5 below, the average cost per service (in INR) for electric two-wheelers, and conventional two and four-wheelers are 751, 935, and 2,524 respectively.

Table 5: Average Number of Services Availed by Vehicle Type and Cost per Service

Average No. of Services Availed				Cost per Service (in INR)
Age of Vehicle	< 1 year	1-3 years	> 3 years	
EV 2W	1	2	2	751
Conv. 2W	NA	2	3	935
Conv. 4W	NA	1	2	2524

As shown in Table 5, the average number of services availed for EVs purchased in less than a year is 1. For conventional 2W and 4W, there are no services availed for vehicles purchased in less than a year. For vehicles older than a year, the average number of services availed for EVs and conventional vehicles is the same at 2. However, the number of services availed increases for conventional 2W vehicles with the increase in the age of the vehicle, while for EV 2W they remain the same at 2.

a. After Sales Services – Currently Availing

Some of the after-sales services availed by the survey respondents are regular servicing of the vehicle to check if the key components are still working and oiling up the vehicle for long-lasting and smoother working after a certain distance has been travelled by the vehicle. After-sales services also include repairing services to repair or replace the components of the vehicle. This includes motor control, battery and brake repairing services. However, battery replacement services are not available in the market for EV 2W.

b. After Sales Services – Willing to Avail

The respondents were asked about all the services that they are willing to avail themselves of for EV 2W. The survey respondents wanted to avail the regular servicing of the vehicle, battery replacement service, and regular check-ups of various components of the vehicles such as brake, motor and battery along with road side assistance service for EV 2W.

3.1.1.9 Consumer Opinion and Preferences

The respondents were asked to rate the factors considered important while purchasing a 2W EV and the factors which impact EV usage in a Likert scale (1-Not Important; 2-Somewhat Important; 3- Neutral; 4- Important; 5-Very Important). More than 90% of the respondents considered all the factors listed in Table 6 for purchasing an EV as important or very important. The factors which are considered very important by at least 90% of the respondents are: capital cost, range, operating and maintenance cost, government policies, high petrol price, and emission/ environment factors.

Table 6: Consumer Opinion and Preferences

Importance of Factors Considered While Purchasing 2W EV					
Likert	Not Imp	Somewhat Imp	Neutral	Imp	Very Imp
Capital Cost	0%	0%	0%	10%	90%
Range	0%	0%	2%	5%	93%
Charging Time	0%	2%	2%	9%	88%
Operating & Maintenance Cost	0%	0%	1%	5%	94%
Availability of Variants	0%	1%	3%	24%	73%
Availability of Public Charging	2%	0%	5%	20%	73%
Performance of EW vis-à-vis Conventional	0%	0%	4%	17%	79%
High Resale Value	2%	0%	6%	32%	61%
Government Policies	1%	0%	0%	3%	97%
High Petrol Price	0%	0%	1%	9%	90%
Emission/Environment Factors	0%	0%	1%	4%	95%

Satisfaction of Respondents from Various Factors					
	Not Satisfied	Somewhat Satisfied	Neutral	Satisfied	Very Satisfied
Range	5%	9%	8%	34%	44%
Charging Cost	1%	1%	3%	2%	94%
Charging Time	4%	9%	6%	30%	51%
Availability of Charging Infra	56%	2%	33%	3%	7%
Waiting Time at Public Charging Stations	0%	89%	2%	7%	3%
Quality of After Sales Service	1%	4%	4%	13%	78%
Satisfaction of Consumers					
Satisfaction Level	1%	1%	10%	40%	48%

The factors considered to be less important are – availability of variants, availability of public charging, performance of EV vis-à-vis conventional, and high resale values which suggests that all these factors are not given much importance before purchasing an EV.

Similarly, the respondents were asked to rate the factors which impact EV usage on a Likert scale (1-Not Satisfied; 2-Somewhat Satisfied; 3- Neutral; 4- Satisfied; 5-Very Satisfied). In terms of satisfaction experienced by the respondents from using their EV 2W, survey responses shown in Table 6 indicate that, compared to other factors, respondents are less satisfied with the existing range, charging time, availability of charging infrastructure, waiting time at the public charging station and, therefore, there is scope for improvement in them to increase usage of EV2W.

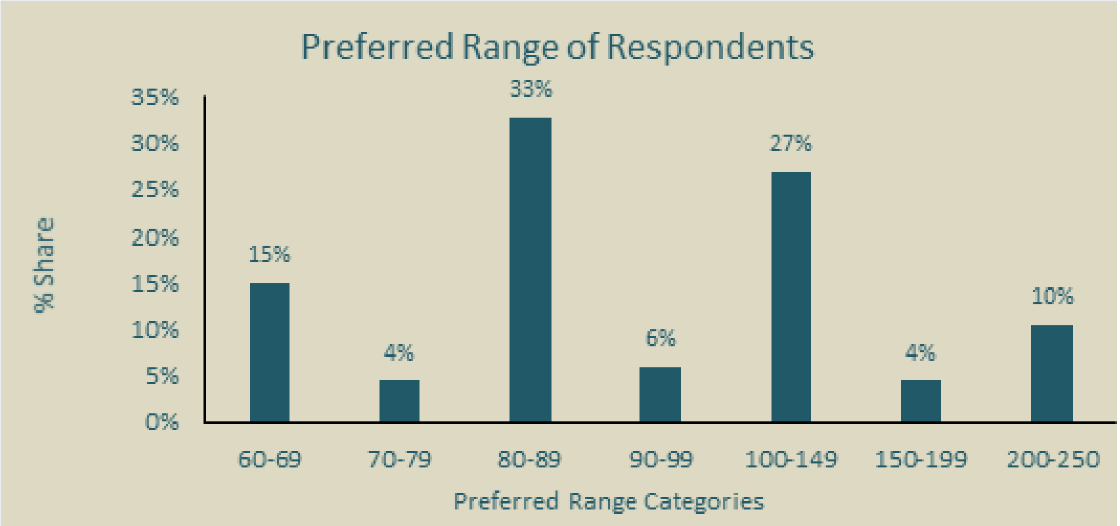
3.1.1.10 Suggestions for Improvement of EV usage

To understand consumer opinion on EV 2W usage better, the survey questionnaire was designed to be semi-structured. Options were provided for the respondents to provide their opinions and suggestions in general and on the factors listed in Table 6 above.

Public charging infrastructure has been a key focus of the Government of Delhi and India to promote EVs. However, the survey responses do not show that public charging is used by EV 2W owners. None of the respondents covered in the survey used public charging for their EV 2W and only 6% have an idea about public charging stations. When asked for the reasons for liking/disliking public charging stations, the respondents replied either with 'have not visited/used yet' or 'don't know about public charging'.

The survey sought to understand the consumer preferences of existing users of EV 2W and take suggestions on improvement based on their preferences. Some of the key areas of improvement as suggested by the consumers in the survey include an increased range of EV 2W, improved charging infrastructure, affordable cost of charging, availability of fast charging, better quality of after-sales service, and more charging options to be available at public charging stations. 62% of the respondents suggested improvement in the range (km/charge) of electric two-wheeler vehicles.

Figure 25: Preferred Range of Respondents



As shown in Figure 25, of the total respondents who suggested improvements in range, 39% preferred a range of 80-100 km/charge followed by 27% preferring a 100-149 km/charge category.

Table 7: Preferred Waiting Time of Respondents

Waiting Time (hours)	% Share of Respondents
1	36%
2	58%
3	6%

As can be observed from Table 7, among the respondents who made suggestions on preferred waiting time, 58% prefer a waiting time of 2 hours followed by 36% preferring 1 hour. Other suggestions by respondents include the availability of charging infra in every 2-3 km, every 10 km, every petrol pump, and every major commercial place. Respondents also prefer that service centers should be available all around which would improve the service quality of EV 2W. Respondents in the survey stated that increasing the range will make it possible for using EV to travel longer distances. Availability of fast charging will reduce the waiting time and improved charging infrastructure will increase the usage of EVs. Overall, 88% of the users of EV 2W are satisfied with the performance of the vehicle and only a small and limited number of consumers is dissatisfied with its performance.

3.1.2 Summary Findings and Policy Recommendations

We have shown that two-wheelers have a very important place in the transport sector in a middle-income country. If we have to address air pollution, noise pollution, and climate mitigation, what policies are needed to attract them and shift them to EVs? By surveying 122 owners who have already decided to purchase EVs we get the perspectives of their requirements and their attributes such as income, profession, driving habits, parking, and charging.

Socio-economic profile

1. Most early adopters of EV 2W in Delhi belong to the lower household expenditure groups, are graduates or senior secondary educated, and in the young and working-age group of 25-40 years.

2. Air pollution is the driving factor for those who have been the early adopters of EVs in Delhi.

3. Most early adopters of EV 2W in Delhi belong to lower household expenditure groups in the range of INR 7,000 – INR 40,000 per month with an average expenditure of INR 18,506 per month.

4. Private salaried individuals among first-time buyers and business owners among second- or third-time buyers are among the biggest early adopters of EV 2Ws in Delhi. While many of the early adopters of EV 2W were first-time buyers, nearly one-third of them had previously owned a 2W or 4W.

Travel pattern

1. Most early adopters of EV 2W use it for travelling short distances on both working and non-working days. More than 50% of respondents across professional categories use EV 2W for regular commute and, apart from it, for short travel also.

2. Most purchasers of EV 2Ws in Delhi have replaced their conventional vehicles with EV 2W for their work-related travel. The survey found that among the EV 2W owners, 55% of respondents who own a conventional 2W and 82% of respondents who own a conventional 4W do not use their conventional vehicles on working days.

3. In general, 2W users are characterised by short distance travel of 1- 30 km per day and hence an electric 2W perfectly suits their requirement.

4. The estimated Average daily vehicle kilometers travelled (VKT) in Delhi using EV 2W by the respondents in the survey is 22 km on working days and 11 km on non-working days.

5. The daily VKT using conventional 2W and 4W of the respondents who have purchased EV 2W was estimated to be 29 km and 41 km on working days and 22 km and 51 km on non-working days.

6. Private salaried and self-employed use their EV 2W on all working and non-working days while government employees and business owners use it for 6 out of 7 days.

Charging and parking

1. Most EV 2W owners have access to basic parking facilities at home and hence 90% of the respondents reported charging from home. Only 9% of the respondents reported having charging options at the office and 94% of respondents were not aware of public charging facilities near their home or office.

2. Among those who are aware of public charging stations, only 60% of respondents and 50% of respondents have a public charging station within 5 km of their home and office respectively.

3. None of the respondents visited a public charging station and was unaware of the waiting time there, implying that there is a need for more awareness and better infrastructure.

4. Amongst the respondents in the survey, 39% charge their EV 2W once a day, and 55% charge less than once a day.

5. Regular charging requires around 7 to 8 hours and takes place in the time slot of 7 pm to 8 am. Only 9% of the respondents were found to have done top-up charging on a weekday and only 16% did top-up charging during weekends.

6. During regular charging at the time of plug-in, 63% of respondents have 10% - 30% SOC on working days and 52% respondents have 40% - 60% SOC on non-working days.

7. The average range of electric scooters in the survey was 54 km/charge and for motorcycles was 104 km/charge.

Consumer preference

1. More than 90% of respondents considered capital cost, range, operation and maintenance cost, government policies, high petrol prices, and environmental impact as factors they consider very important while purchasing their EV 2W.
2. Factors that respondents considered less important in their decision to purchase EV 2W are the availability of variants, availability of public charging, performance vis-a-vis conventional 2W, and high resale value.
3. Most respondents were satisfied with their EV 2Ws. However, based on their usage of EV 2W, respondents expressed less satisfaction with the existing range, charging time, availability of charging infrastructure and waiting time at public charging stations.
4. Improvements in range, charging infrastructure, affordable cost of charging, availability of fast charging, and after-sales service quality were suggested by 62% of the respondents.
5. Nearly 39% of those who suggested improvements in the range preferred a range between 80-100 km. Of respondents who suggested a lower waiting time, 36% preferred it to be 1 hour
6. Other suggestions included public charging stations every 2-3 km or within every 10 km or at every petrol pump and every major commercial place.
7. Respondents preferred free regular servicing in the first year and improved service quality with service canters all around

3.2 EV- Four-Wheeler (Private)

On August 7, 2020, the Government of Delhi had announced the Delhi EV Policy 2020, focusing on increasing the adoption of EVs in the city by incentivizing the purchase and use of EVs. The policy aims to register 500,000 EVs in the city by 2024. Around 6000 EVs have been bought since this policy's announcement, which comprises 2W, rickshaws, taxis, and even private cars[2].

This section of the survey deals with private owners of electric 4W. The survey could consider only 21 electric private cars owners for the interview as only these few were available after many searches through car dealers and the internet. Many owners who had purchased electric cars in the past had either sold them or were not available at their said address and contact number. This reflects the fact that there have been very few private purchasers of EV 4W in Delhi.

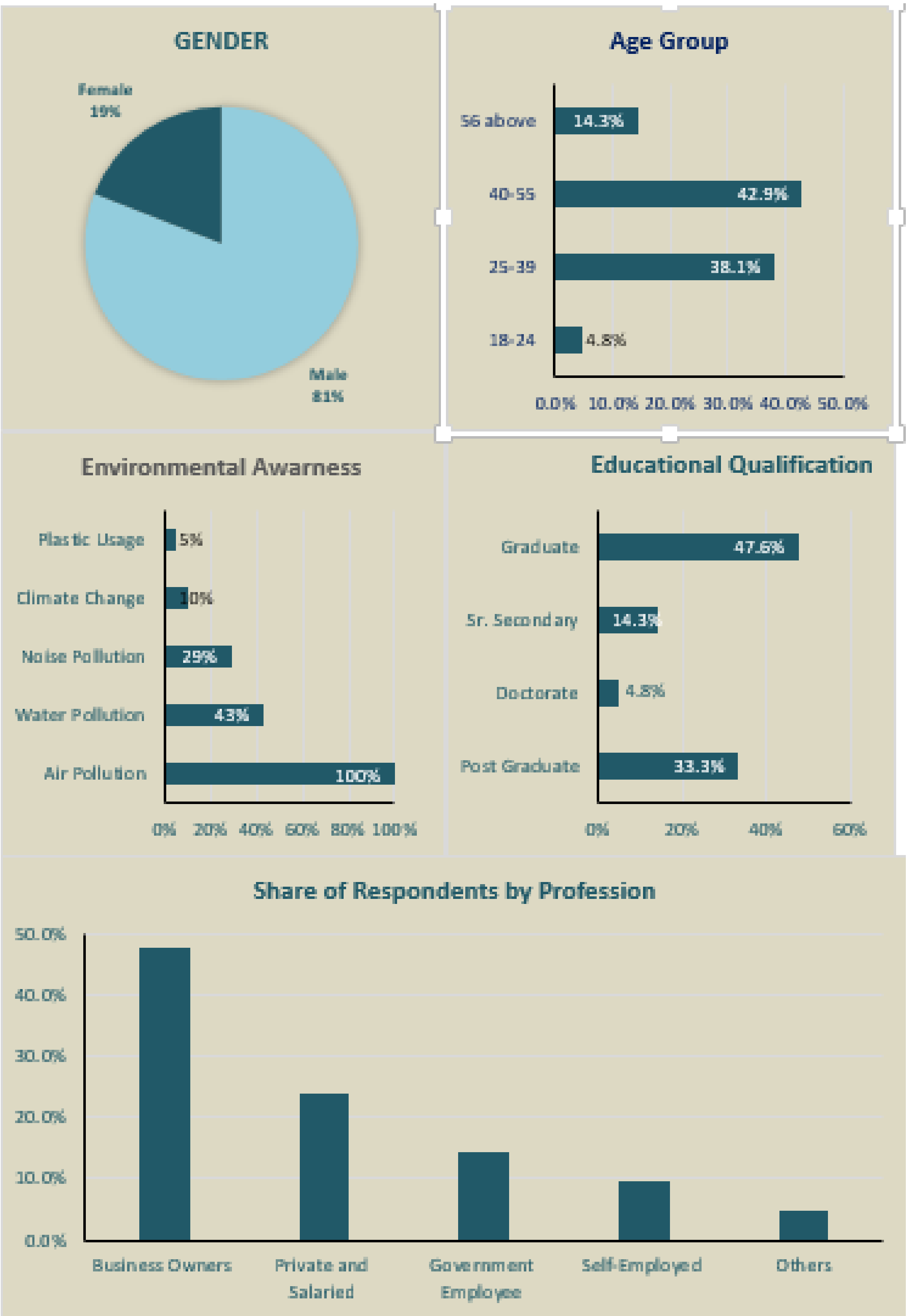
3.2.1 Survey Results

3.2.1.1 Demographic Profile

This section presents the distribution of respondents according to gender, age, profession, education qualification, income, and awareness of climate change and EVs. In the total responses to the survey, 19% of respondents were female with an age group of more than 35 years. The analysis of survey respondents shows that only 4.8% of the respondents belong to the 18-24 years' age group, and a maximum number of respondents belongs to the 25 to 55 year age group. Figure 26 shows the gender, age group, environmental awareness, and educational qualification of the respondents.

[2]https://www.hindustantimes.com/cities/delhi-news/delhi-govt-to-change-its-fleet-of-cars-to-electric-vehicles-in-6-month-scm-101612424462719.html

Figure 26: Demographic Profile of Respondents

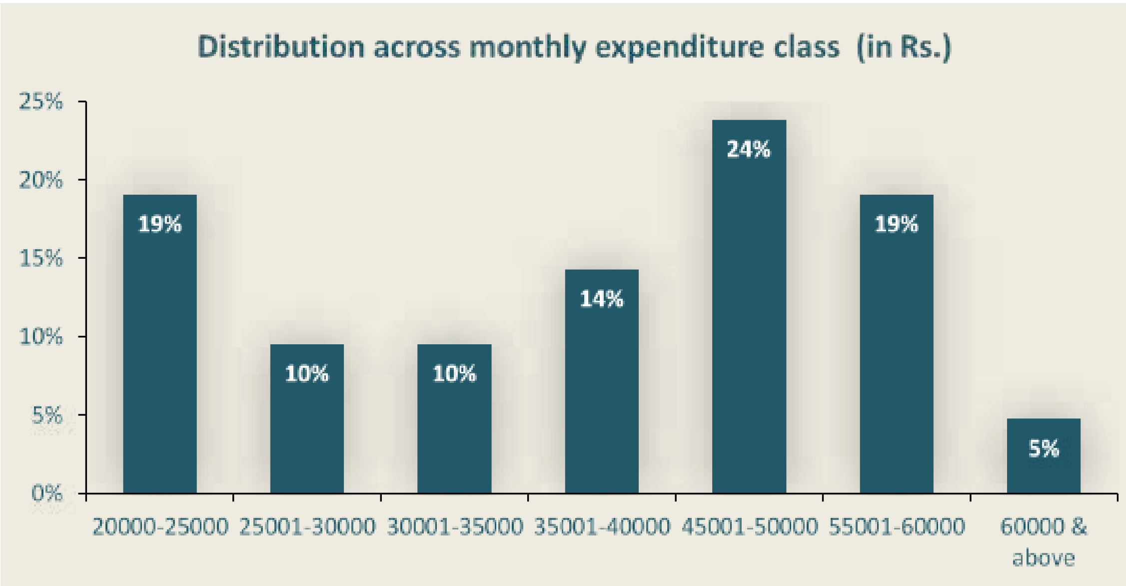


3.2.1.2 Environmental Awareness

In terms of awareness of environmental issues, almost all the respondents were found to be aware of air pollution as an environmental issue; 43% are aware of water pollution, 29% are aware of noise pollution, 10% are aware of climate change, and only 5% are aware of plastic usage. This represents that people are aware of the environmental benefits of EV 4Ws, and air pollution is the driving factor for their purchase. In terms of the educational background of the respondents, 48% of the respondents are graduates, followed by 33% postgraduates.

The survey respondents were also asked about their professional background: nearly 50% are business owners, followed by 23.8% of respondents who are salaried individuals. The rest are government employees, self-employed, and housewives. The respondents were asked about their household consumption expenditure, and the responses showed that almost 50% of the respondents spend 30K to 50K per month. Figure 27 shows the average monthly household expenditure and descriptive analysis of our respondents.

Figure 27: Average Monthly Household Expenditure (In INR)



Expenditure distribution characteristics (in INR)	
Mean	44,286
Median	40,000
Mode	50,000

3.2.1.3 Vehicle Ownership

The survey respondents were asked questions on the type, technology, fuel type, and the number of other vehicles they owned apart from electric 4W. Analysis of the responses shows that 81% of the respondents own another vehicle along with an electric 4W. In the total number of other vehicles owned by people other than EV, 58% are diesel 4W, 31% are petrol 4W, and 12% are petrol 2W. This implies that an electric 4W is likely to be purchased by people who already own a conventional vehicle. Deeper observation shows that in the Delhi NCR region, people owning a diesel 4W is more likely to purchase an electric 4W than those owning a petrol 4W or 2W. Figure 28 shows the number of vehicles owned by a respondent family and the fuel type of other vehicle ownership by respondents.

Figure 29 below shows the profession-wise %age of respondents owning one or more than one vehicle. As can be seen among all professional groups of respondents, all self-employed, 20% of private salaried and 10% of business owners own only one vehicle. The rest of the respondents in professional groups own more than one vehicle. Except for self-employed, most people in other groups have more than one vehicle. This reconfirms that people who already own a conventional vehicle are more likely to purchase an EV in their second or third purchase.

Figure 28: No. of Vehicles Owned by Family & Additional Vehicle Ownership- By Fuel Type

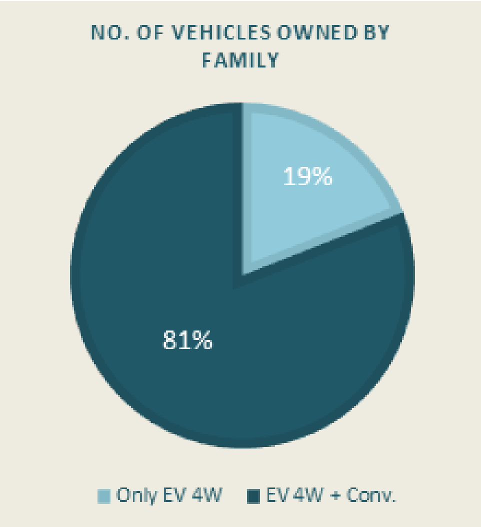
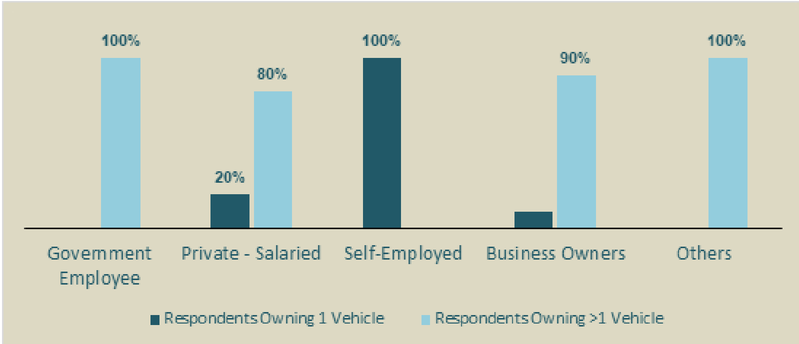


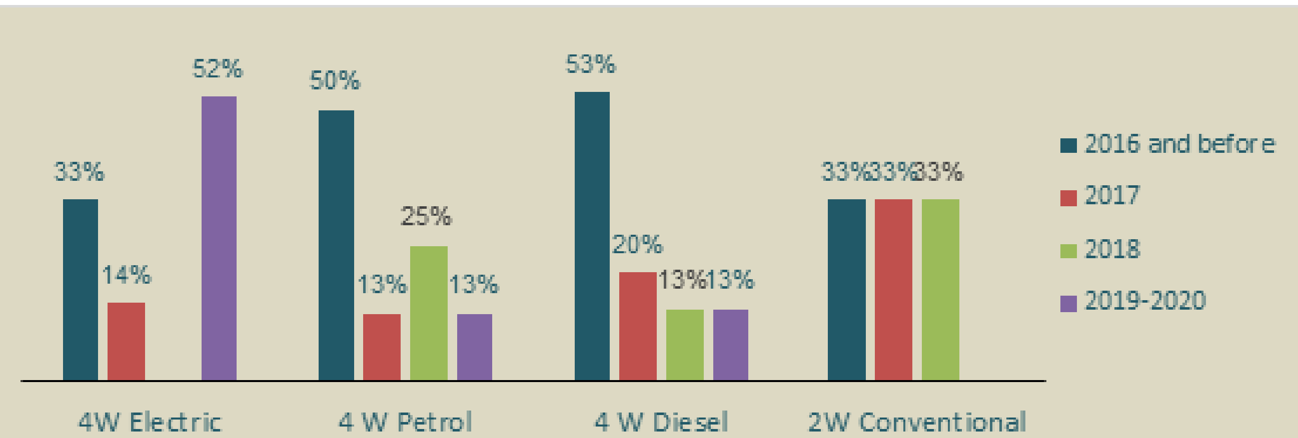
Figure 29: No. of Vehicles Owned – By Type of Profession



The Survey covered various EV models available in the market. Tata Nexon EV with a share of 38% and Mahindra E20 with a share of 52% are the most owned models among respondents in the EV 4W. The respondents' other models are MG ZS EV and Mahindra e-Verito, with a share of 5% each.

After the Delhi EV policy 2020 announcement, EVs' adoption has picked up pace. The survey also shows that 52% of the electric cars were bought in 2019-20, and 33% have been bought in 2016 and before. At the same time, most of the conventional 4W were purchased in 2016 and before. Figure 30 shows the year of purchase of vehicles among the respondents.

Figure 30: Year of Purchase of all surveyed vehicles



3.2.1.4 Vehicle Usage Pattern

In this section, the travel pattern of the respondents and the usage pattern of their EV and conventional vehicles are analysed to see how EV 4W fits into their requirements and to what extent it can substitute their previous conventional vehicles.

3.2.1.5 The pattern of use and travel by profession

Table 8 below shows professional group-wise the number of days of usage of EV 4W in the total number of working and non-working days. In general, working days are Monday – Friday. However, for business owners and self-employed, Saturdays and Sundays are also considered working days.

Table 8: Frequency of Usage of Electric car on working and non-working days

Average Frequency of usage of EV 4W by profession - In Working Days					
	Government Employee	Private and Salaried	Self-Employed	Business Owners	Others
Total No. of Working Days	5	5	7	6	7
Frequency of Usage	5	5	7	5	3
Average Frequency of usage of EV 4W by profession - In Non-Working Days					
Total No. of Non-Working Days	2	2	0	1	0
Frequency of Usage	1	2	0	1	0

As can be seen, EV 4W is being used frequently by all professional groups on all working days except for business owners who don't use it on one of the working days. All groups are also using EV 4W on all non-working days except for government employees who use it on only one of the two non-working days. One of the most important travel requirements is regular office commuting which depends on the kind of profession a person is engaged in. The survey responses were analysed for profession-wise purposes for which EV 4W was used. The results presented in Figure 31 below show that regular office commute and short trips are the two major reasons the respondents generally use EV 4W. However, there are some marked differences with professional groups in the purpose for which they use their EV 4W. All respondents in the self-employed category reported that they use their EV 4W for office commuting only, while all respondents in the other categories use their 4W EV for short trips only. In the case of business owners, 90% of respondents said they use their EV 4W for office commute and 10% for short trips, while two-thirds of government employees said they use EV 4W for office commute and one-third said they use it for short trips only. Interestingly, 20% of respondents from the private salaried group use it for holiday and leisure, 60% use EV 4W for office commute, and 20% use it for short trips. The preference for using EV 4W exclusively for regular office commute and short trips probably reflects consumer preference to use EV for fixed or short distances only due to range anxiety. More discussion on range anxiety will be presented in the consumer preference section. Figure 31 below shows the purpose of using electric cars by Profession.

To further understand the transportation requirement of the respondents, the survey asked the respondents the distance traveled in a working and non-working day in an electric car and conventional vehicle. As shown in Figure 32 below, a significant proportion of respondents answered zero for distance traveled using their conventional 2W and 4W on working and non-working days. This implies that 86% of the respondents do not use their conventional 2W on working and non-working days. Similarly, 38% of respondents who own a conventional 4W also do not use it on their working and non-working days. The proportion of respondents using their EV 4W are significantly higher on working days compared to non-working days. Thus, it can be concluded that most people who purchased EV 4W in Delhi have almost replaced their conventional 2W and minimised their use of conventional 4W with it for their travel needs. We can also observe that they use conventional 4Ws for traveling longer distances both on working and non-working days. The respondents use EV 4W for both short and medium-distance travels on both working and non-working days. The responses also showed that any survey respondents do not use public transport (Buses and Metro) on working days and non-working days. This shows that owners of private 4W vehicles seldom use public transport in Delhi.

Figure 31: Purpose of Using 4W EV - By Profession

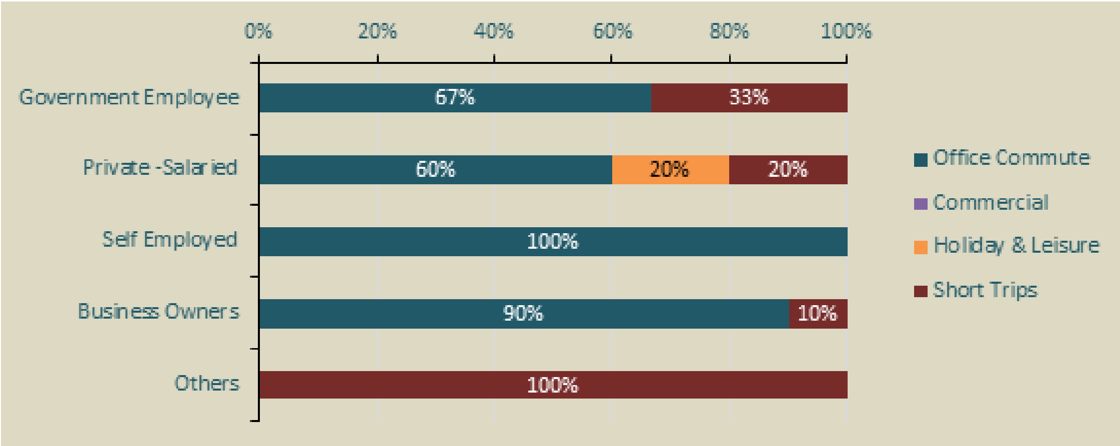
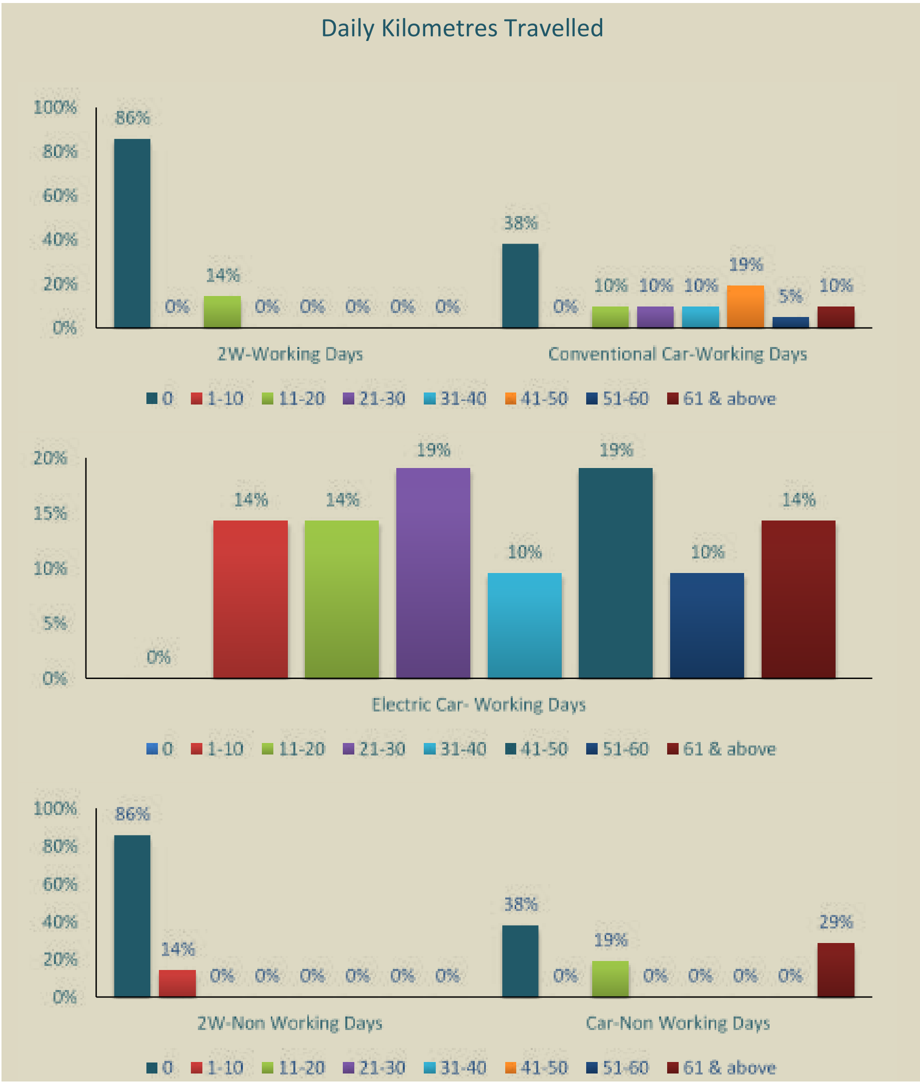


Figure 32: Daily KMs Travelled by Vehicle Type



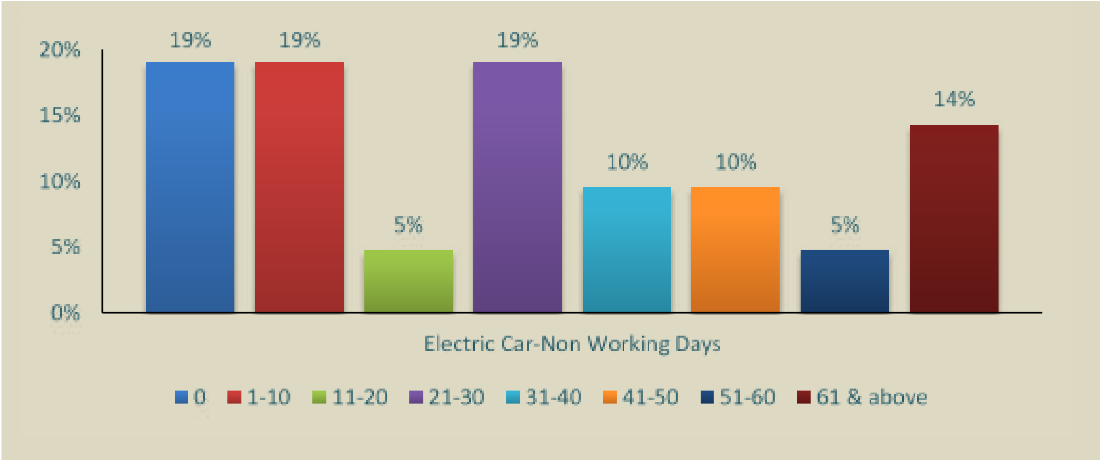


Table 9: Descriptive Statistics of Avg. Vehicles KMs Travelled in Working & Non-Working Days

	Electric 4W	Conventional 2W	Conventional Car
Mean (Working)	41	15	51
Sample Variance (Working)	779	21	1,197
Mean (Non-working)	44	7	59
Sample Variance Non-Working)	1,571	5	3,716

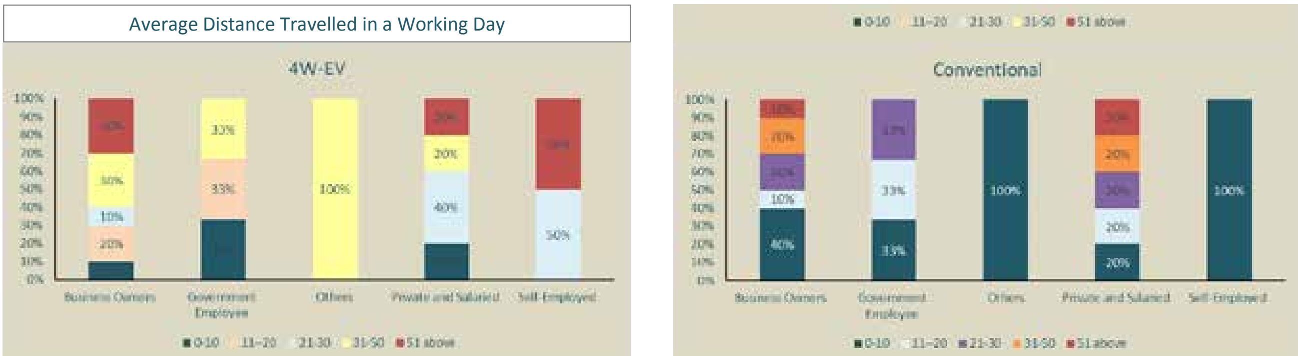
From Table 9, it can be stated that on a working day, the average kilometers travelled by respondents using a conventional car is 51km followed by Electric 4W (41 km) and conventional two-wheelers (15 km). Similarly, on a non-working day, conventional cars are being used for long-distance travel (59 km), Electric 4W (44 km) for slightly lower distance travel, and 2W (7 km) are being seldom used but for short-distance travel only. The average vehicle kilometer travelled values are calculated, ignoring zero and no responses.

The responses were also analysed professionally group-wise and shown in Figure 33. We denote 0-10 km as short distance, 11-20 km as medium distance, 21-30 km as moderate distance, and 30-50 km and above as long distance. Figure-33 shows that a large number of respondents, close to 50%, in all professional groups, except the group 'others', use their EV 4W to travel short, medium and moderate distances. Nearly two-thirds of government employees said that they use their EV 4W to travel short and medium distances, while 60% of respondents among private salaried and 40 % of business owners said that they use their EV 4W for short and medium distances.

In the survey sample, self-employed owners do not have any additional conventional vehicles; hence they use their EV for all purposes. Among respondents in the self-employed group, 50% said that they use it for medium distance travel. However, 100% of respondents in the category 'others' said that they use it for long-distance travel of 31-40 km. This is slightly contradictory with Figure 31, where all respondents in the 'others' category said that they use their EV 4W for short trips. The contradiction probably means the respondents use their EV 4W for travel trips of 31-40 km, which is not of the category of office commute, commercial, or holiday & leisure.

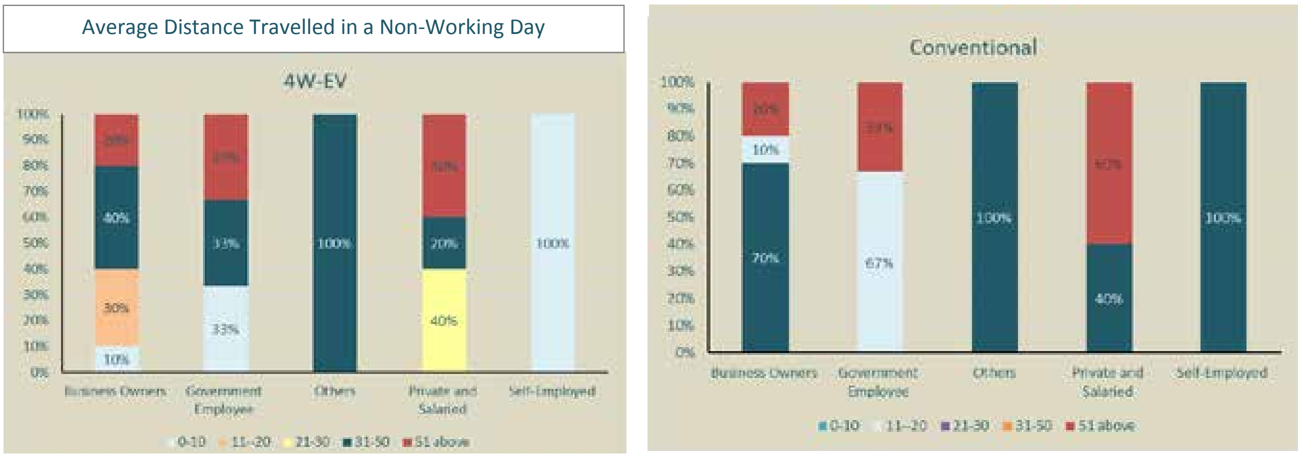
The preference of a majority of respondents to use EV 4W for short and medium-distance trips probably reflects the range anxiety of current users of EV 4W. Despite that, we see that a significant number of respondents in each professional group have replied that they use their EV 4W for long-distance travel. One-third of respondents are from government employees, 20% of private salaried, 30% of business owners, and 100% of 'others' use their EV 4W to travel more than 31-40 km. Similarly, 20% of respondents from Private salaried, 50% of self-employed, and 10% of business owners have said that they use their EV 4W for travelling more than 50 km.

Figure 33: Average Distance Travelled in a Working Day



Our observation shows the trend of using EV 4W for short and medium distances on the weekends. This is shown in Figure 34. Among all the respondents, 40% of private salaried, 40% business owners, 33% government employees, and 100% of the self-employed group use their EV to travel short, medium, and moderate distances. As was the case in working days, a significant number of respondents also report using the EV 4W for travelling a long distance of 30-40 km or above 40 km per day. Thus, it can be concluded that despite range anxiety concerns, many current users of EV 4W have substituted their conventional cars with electric cars for short and long-distance travel.

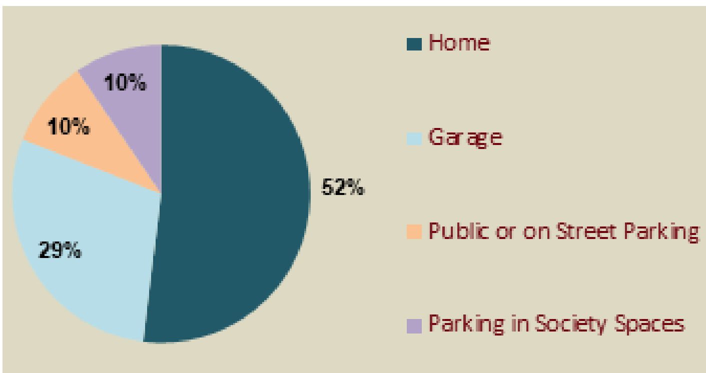
Figure 34: Average Distance Travelled in a Non-working Day



3.2.1.6 Availability of Charging and Vehicle Charging Behaviour

According to the EV policy announced by the Government of Delhi in 2020, 25% of all new vehicle registrations will be EV by 2024.[3] To support the growth of EVs in policy, it also plans to set up charging stations at every 3 km radius. This section analyses the respondents' preference for public charging infrastructure and how much they think of it as critical to using their EV 4W. Charging is a very important infrastructural requirement for EVs, and the availability of charging infrastructure when the

Figure 35: Location of Parking Vehicle



[3]https://auto.hindustantimes.com/auto/news/delhi-to-increase-ev-charging-stations-issue-tender-to-hire-operators-41603764468892.html

electric vehicle is idle (when the vehicle is parked) is essential. Therefore, the survey tried to assess the availability of parking facilities with the respondents. As most of the respondents own more than one car, they all have a dedicated spot for parking their electric car. The survey found that 81% of our respondents park their vehicle at home or in a garage, and only a few park their vehicle in public or social parking areas. Figure 35 shows the location of parking for all the electric owners.

The respondents were asked the minimum distance of the nearest public charging station from their home or office. Figure 36 below shows the proportion of respondents having a public charging station within 5 km or more than 6 km from the EV parking location. Responses showed that almost 60% of the EV owners have public charging stations within a 5 km radius of their home or office parking locations.

Figure 36: Distance of Nearby Public Charging Station

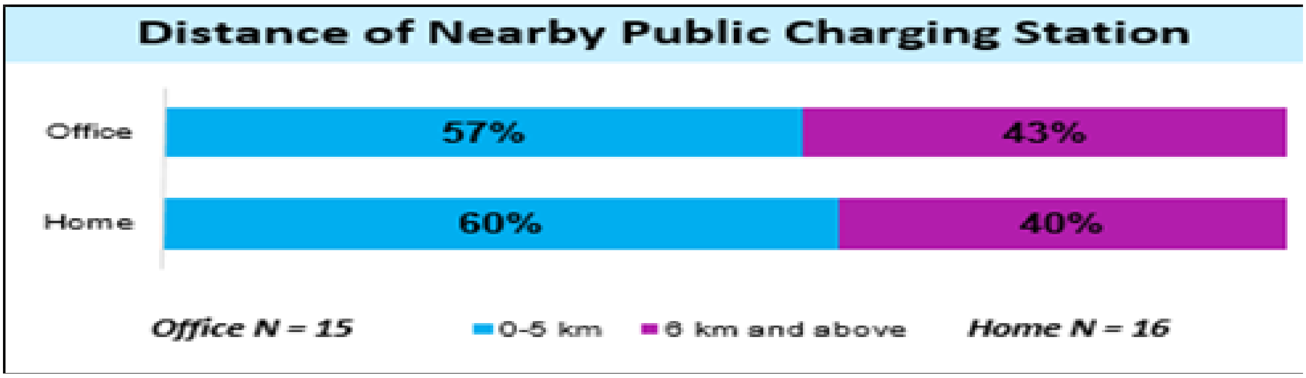


Figure 37 below shows that only 5% of respondents have a charging facility in the office and Table10 shows that on a working day, 95% of respondents opt for home charging of the EV 4W, and only 5% opt for office charging. On non-working days, only one-third of respondents charge their EV 4W, and they, too, opt for home charging. Despite more than half of the respondents having a public charging station within 0-5 km of their homes or offices, none of the respondents in our survey use public charging to charge their EV 4W. The reason for not opting for public charging could be dissatisfaction with the public charging facility or travel distance of users because additional charging is not required.

Figure 37: Availability of Charging Infrastructure at Office

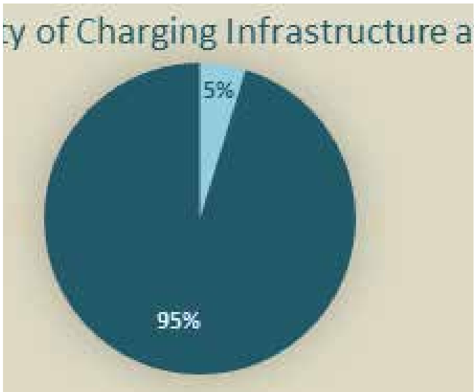


Table 10: Location of Charging in Working and Non-working Day

Location of Charging	Home	Office	Public
Working Day	95%	5%	0%
Non-working Day	100%	0%	0%

Table 11: Average Cost Per Charge (INR)

S. No.	Models	INR/KWh	Location of Charging
1	Mahindra e2o	7.8	Home
2	Mahindra e2o	3.1	Home
3	Mahindra e2o	5.5	Home

S. No.	Models	INR/KWh	Location of Charging
4	Tata Nexon EV	16.6	Home
5	Tata Nexon EV	13.8	Home
6	Mahindra e2o	15.6	Home
7	Mahindra e2o	5.9	Home

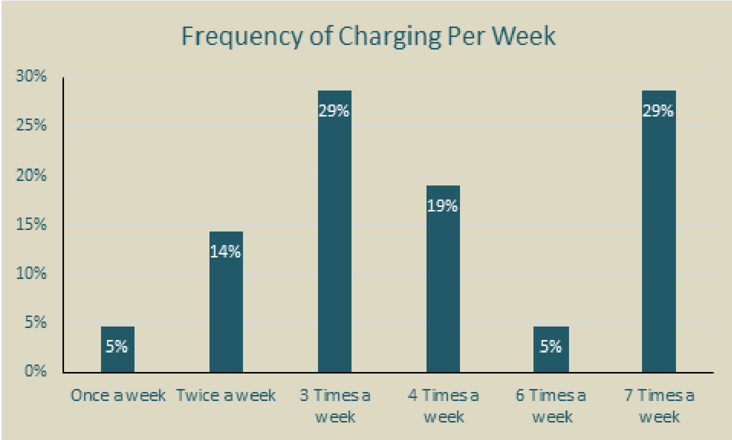
The average Plug-in SOC during the charging period for EV 4W on a working day is 34%. Similarly, for non-working days, it is 36%. Table 12 shows the average plug-in SOC, average battery charged, the average time taken, and the proportion of respondents plugged in their vehicles for charging on working and non-working days. Of the total responses, 29% of the respondents have SOC in the 40-49 % range, followed by 24% having SOC in the range of 20-29 % in a working day. On non-working days, 67% of the respondents do not charge followed while 14% have SOC in the range of 30-39 % while plugging in for charging their vehicles. This again shows that the respondents use conventional 4Ws for their non-working day long-distance travel for leisure and hence do not charge their EV 4Ws.

Table 12: Model Wise 4W EV Status of Battery Charging Capacity

SOC - Plug-in	Average SO C (in %)	Average Battery Charged (in %)	Average Time Taken (in hrs.)	Proportion of Respondents
Working days				
No Charging				5%
10-19	10	90	10	10%
20-29	20	80	10.1	24%
30-39	30	70	11.3	14%
40-49	40	60	4.01	29%
50-59	50	50	15	5%
60-69	60	40	4.83	14%
Average	35	65	9.2	100%
Non-working days				
No Charging				67%
10-19	10	90	5.0	5%
20-29				0%
30-39	32	68	7.3	14%
40-49	40	60	2.5	5%
50-59	50	40	3.0	5%
60-69	60	40	11.0	5%
Average	38	60	6	100%

In this survey also the respondents were asked the frequency of charging or the number of times they charged their EV 4W per week. The responses to this survey question are shown in Figure 38 below. Here we observe that almost one-third of the respondents charge their EV 7 times a week (equivalent to once a day), and another one-third charge it three times a week. This shows that the respondents' travel demand is such that they don't need to charge regularly or adjust their travel behaviour given the range offered by their EVs and use it for short and planned trips. Thus, they do not require to charge their EV more than once a day.

Figure 38: Frequency of Charging Per Week



The survey has tried to capture the charging pattern of the respondents for weekdays and weekends. The plug-in and plug-out time reported by the respondents and shown in Table 12 above is used to compute the %age of vehicles charging at any given hour. In this way, a 24-hour charging profile is obtained for a weekday and weekend and presented in Figures 39 and 40, respectively. The charging pattern for EV 4W is through two modes, i.e., regular charging and top-up charging. In the private EV 4W case, the respondents do not require to use top-up charging on any day. We observe from Figures 39 and 40 that the regular charging time in weekdays and weekends is from 5 pm to 7 am, considered non-working hours. On average, it takes 9-10 hours in normal charging mode and up to 2 hours in fast charging mode to completely charge an electric 4W vehicle. All respondents have their private charging point at home, which is provided and installed by their EV manufacturers. The regular, once a day, slow charging satisfies their requirements of daily travel. Hence the fast-charging option is seldom used and required by the respondents.

Figure 39: Peak Time Slots for Charging 4W EV in working day

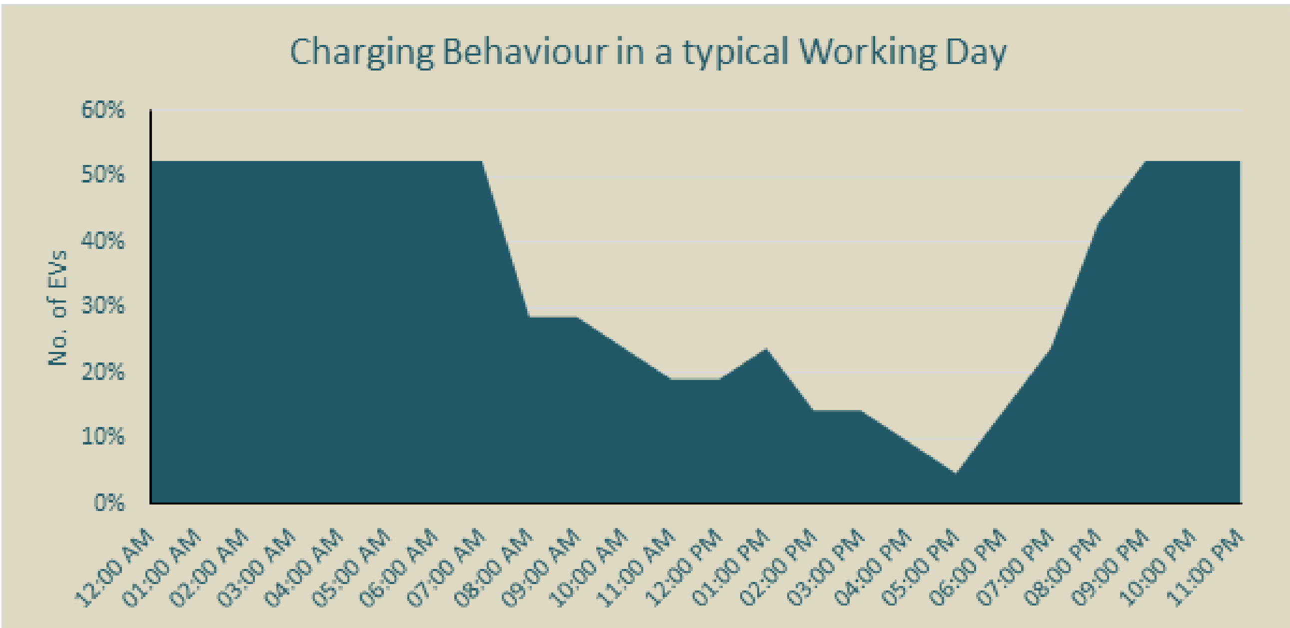
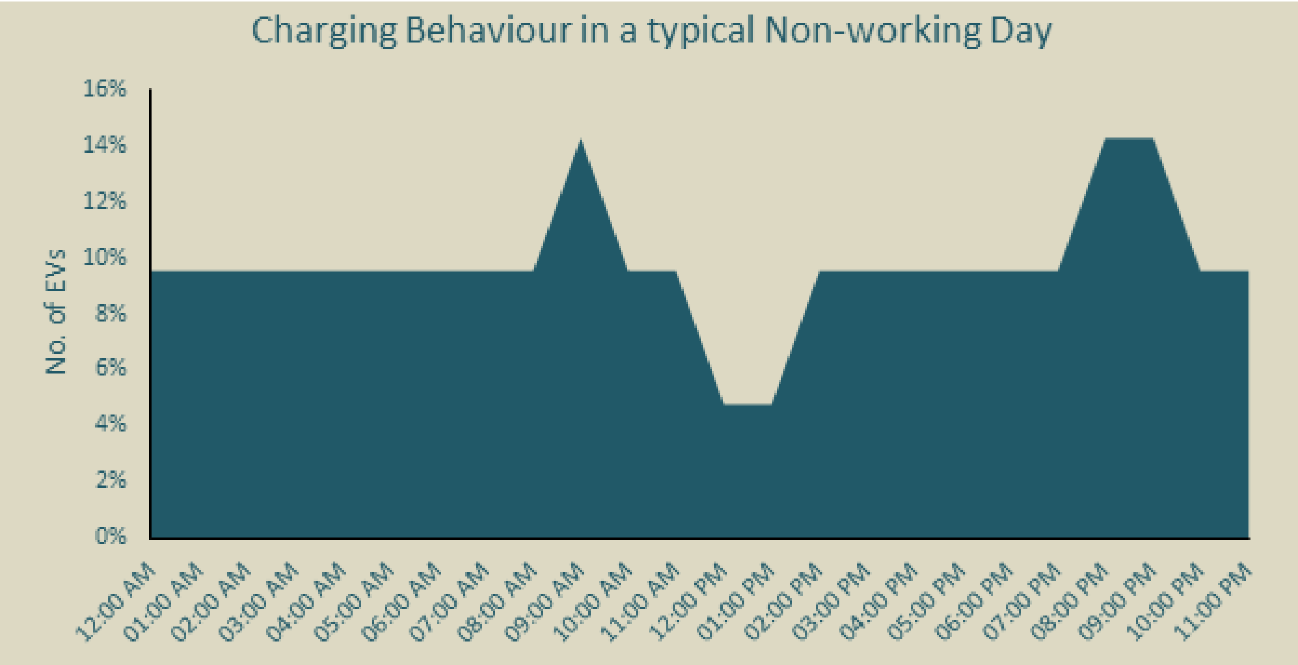


Figure 40: Peak Time Slots for Charging 4W EV in non-working day



The survey covered various kinds of electric models being used in Delhi. A summary of responses from the survey on each EV 4W model's actual range on the ground with and without AC is provided in Table 13. MG Hector ZS provides the highest range (km/charge) with and without AC, and in terms of battery charging capacity, MG Hector ZS is performing better compared to other EV variants. Overall, a hatchback's average range is 76-92 km/charge, sedan EV models have an average range between120 -130 km/charge, and electric SUVs have an average range of 280 -312 km/charge.

Table 13: Model Wise 4W EV Range (km/ Charge)

S. No	Category	Model	% of Respondents Using Model	Average Range (KM/Charge)	
				With AC	W/O AC
1	Hatchback	Mahindra e2o	52%	76	92
2	Sedan	Mahindra E Verito D2	5%	120	130
3	SUV	TATA Nexon	38%	211	244
4		MG ZS EV	5%	350	380
5	SUV			280	312
6	All EV			189	212

Vehicle Servicing Pattern

After-sales services are one of the important factors that influence consumers to buy personal cars. Therefore, availability and quality servicing provided by the manufacturer can be crucial to the consumer's decision to purchase it. As EVs are relatively new, there are fewer complaints about their maintenance, and manufacturers also provide good assistance for the buyers. The further requirements and current after-sales services being availed, the cost per service by vehicle type, the average number of services availed are discussed below. The respondents were asked about the number of services and the average cost per service of owned vehicles. Table 14 below provides the average cost per service (in INR) for electric 4Ws, conventional 2Ws and 4Ws.

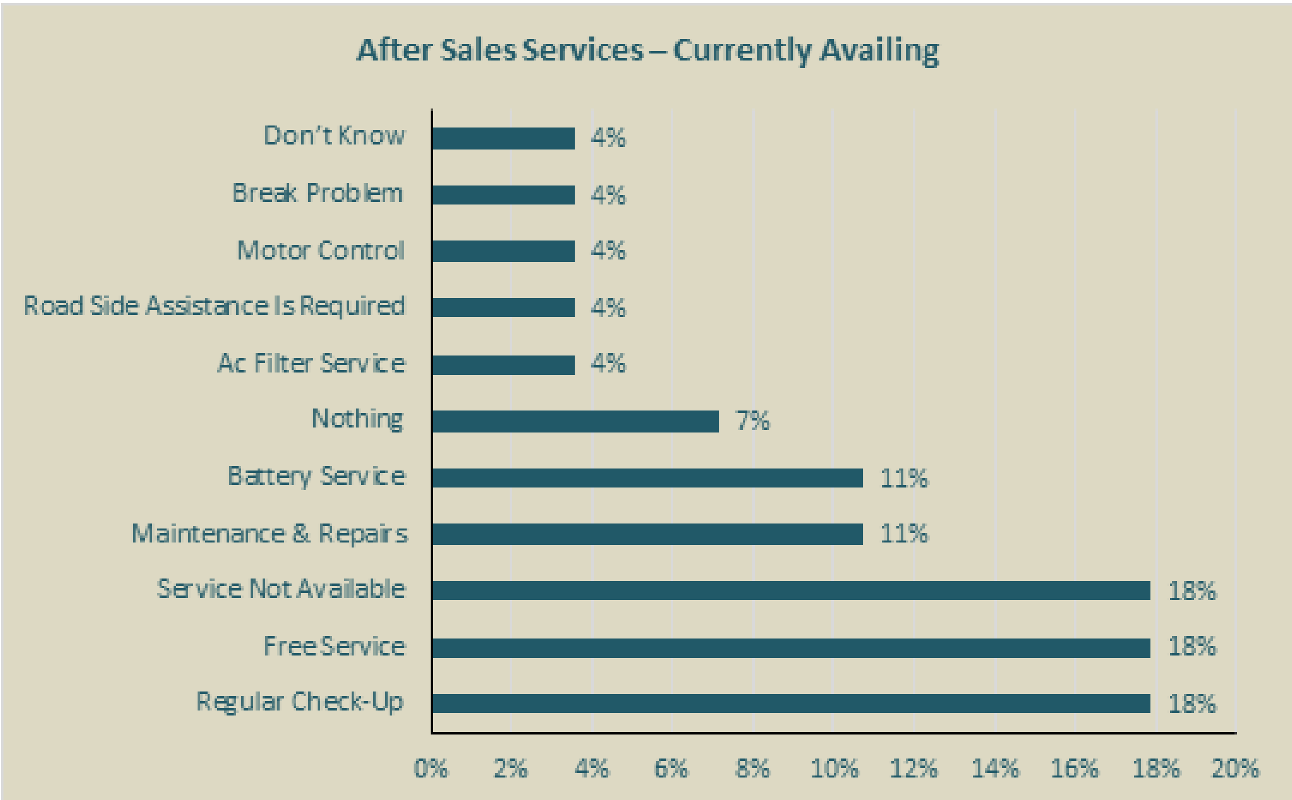
Table 14: Average Number of Services Availed by Vehicle Type and Cost per Service

Type of Vehicle	No. of Services	Cost/Service (INR)
EV 4W	2	2,606
Conv. 2W	2	3,842
Conv. 4W	2	5,670

3.2.1.7 After Sales Services – Currently Availing

Some of the most important after-sales services availed by the survey respondents are regular check-ups and free servicing. Most of the other services that the respondents are availing are battery services, AC filter clean up, motor control, etc. The after-sales services being availed by respondents of the survey are shown in Figure 41 below.

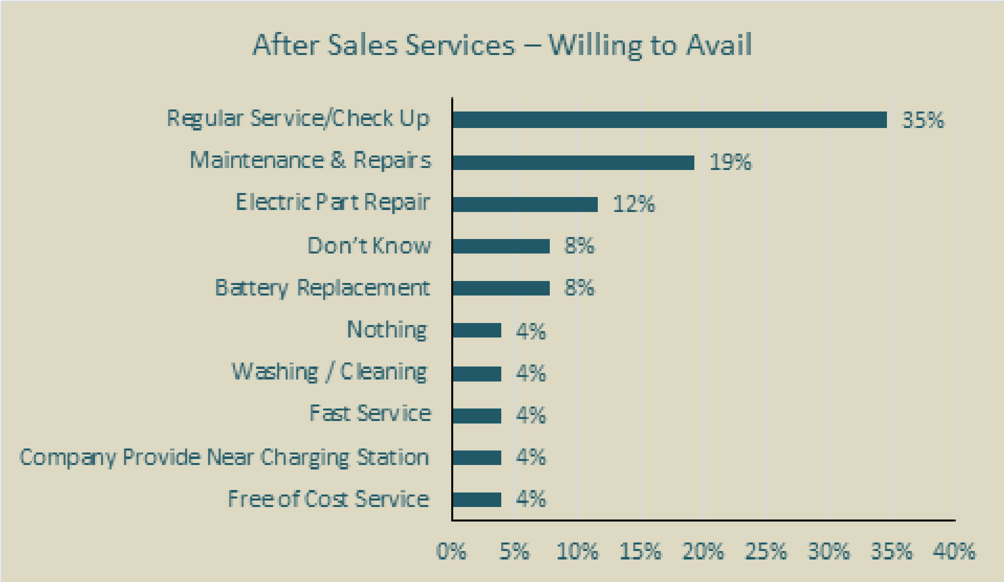
Figure 41: After Sales Service- Currently Availing



3.2.1.8 After Sales Services – Willing to Avail

The respondents were also asked about all the services that they are willing to avail themselves of for their EV 4W. Regular check-ups, electric part maintenance, and check-up were the most common services the respondents wanted to avail themselves of in regular intervals. Figure 42 below shows the services that the respondents want to avail.

Figure 42: After Sales Service- Willing to Avail



3.2.1.9 Consumer opinion and preferences

The survey sought to understand the consumer preferences of existing private users or early adopters of EV 4W. To assess the importance of factors that influence consumer decision while purchasing their EV 4W, the survey respondents were asked to rank factors that they considered important while purchasing their EV 4W. Respondents were asked to rank various factors on a scale of 1-5 (1- Very Important; 2- Important; Neutral; 4-Somewhat Important; 5-Not Important;). The %age of respondent rankings for each factor is shown in Table 14. In general, more than half of the respondents ranked each factor as very important.

All respondents ranked capital cost and operating & maintenance cost as very important. The range was ranked very important by 95% of respondents. Performance of EV vis-à-vis conventional, high petrol price, environment, and emission was ranked very important by 90% of the respondents. High resale value and government policies such a subsidy or free parking was ranked not important by 5% of respondents. Availability of public charging and high resale value was ranked as neutral or somewhat important by 47% and 33% of respondents, respectively. Availability of variants was not found to be a constraining factor in their EV purchase decisions by 19% of respondents as they ranked it neutral. Thus, capital cost, operating & maintenance cost, range, performance vis-à-vis conventional car, high fuel prices, and environment and emission are some of the important factors in the purchase decisions for EV. Availability of public charging, high resale value, government policies like subsidies and free parking, availability of variants are factors that consumers do not find critical while purchasing.

Table 15: Importance of Factors Considered while Purchasing 4W EV

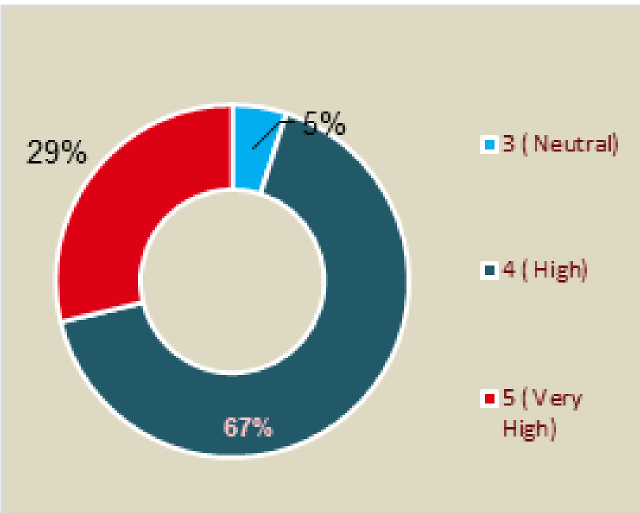
Importance of Factors Considered while Purchasing 4W EV					
Likert Scale	**Very Imp**	**Imp**	**Neutral**	**Somewhat Imp**	**Not Imp**
Capital Cost	100%	0%	0%	0%	0%
Range	95%	0%	5%	0%	0%
Charging time	81%	14%	5%	0%	0%
Operating & Maintenance Cost	100%	0%	0%	0%	0%
Availability of Variants	76%	5%	19%	0%	0%

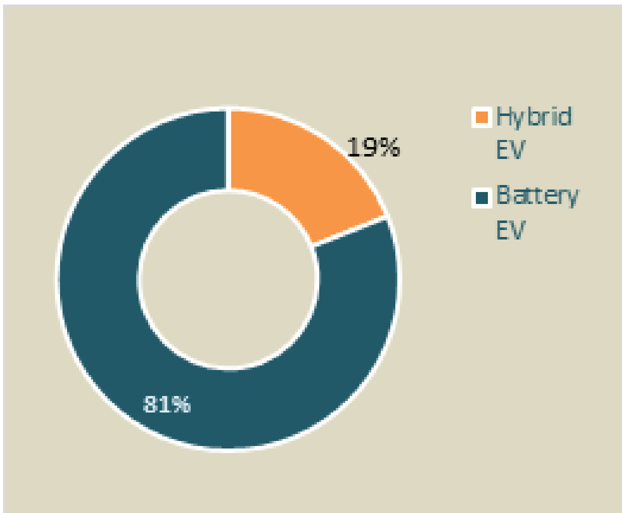
Importance of Factors Considered while Purchasing 4W EV					
Likert Scale	**Very Imp**	**Imp**	**Neutral**	**Somewhat Imp**	**Not Imp**
Availability of Public Charging	52%	0%	33%	14%	0%
Performance of EV vis-à-vis Conventional	90%	5%	5%	0%	0%
High Resale Value	62%	0%	19%	14%	0%
Govt. Policies such as subsidy or free parking etc.	71%	14%	10%	0%	0%
High Petrol Price	90%	5%	5%	0%	0%
Emission/Environment Factors	90%	5%	5%	0%	0%
Quality of after sales services	5%	10%	29%	14%	43%

Figure 43 shows all the respondents have a favorable opinion of their electric cars' performance, with 30 % of respondents ranking it very high and 67% of respondents ranking it with high ratings. The key area of improvements suggested by respondents for their vehicles are as follows:

- The range (km/charge) of EV 4W should be more.
- More number of charging infrastructure.
- Fast charging of battery.
- The quality of after-sales services should be improved.

Figure 43: Rating of Performance of EV 4W & EV Type Purchase Recommendations





A majority of 81% of the respondents preferred to recommend an all-electric model over a hybrid option.

3.2.2 Consumer Satisfaction and Suggestion for EV Usage

Since the respondents were users of EV 4W, their satisfaction with their EV 4W was also assessed. The respondents were asked to rank various factors that affected their use of EV 4W on a scale of 1-5 (1-Not Satisfied; 2-Somewhat satisfied; 3-Neutral; 4-Satisfied; 5-Very Satisfied) and provide suggestions for improvements in each factor. The %age of respondent rankings of the satisfaction levels of each factor is shown in Table 16.

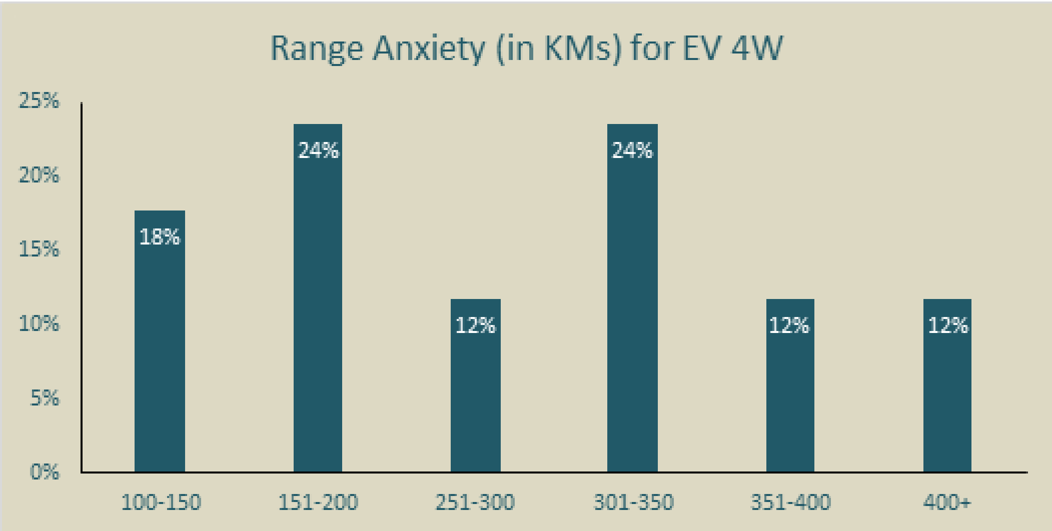
Table 16: Satisfaction of Respondents from Various Factors

Likert Scale	Not satisfied	Somewhat Satisfied	Neutral	Satisfied	Very Satisfied
Range (km/charge)	0%	5%	24%	52%	19%
Charging Cost	0%	0%	29%	0%	71%
Charging Time	0%	5%	29%	19%	48%
Availability of Charging Infra	24%	33%	33%	5%	5%
Waiting Time for Charger Availability (Public Stations)	10%	5%	81%	0%	5%
Quality of after sales services	5%	10%	29%	14%	43%

The rankings of the respondents showed that more than 50% were satisfied with the performance of the EV 4W on the count of all factors except for the availability of charging infrastructure and waiting time for charger availability. Respondents were most satisfied with charging cost, with 71% ranking it as very satisfied and 29% being neutral. Respondents also had a favorable opinion about charging time and quality of after-sales services, with 48% and 43% of respondents ranking them as very satisfied. Some respondents, in their suggestion, said that a fast charging time of 90 minutes would make EV more useful for them.

In comparison, only 19% ranked very satisfied, while 52% of the respondents ranked as satisfied in the range of their EV 4W. This implies that while consumers have a favorable opinion of the range of their current EV 4W, they would prefer more improvement. Out of the total sample, 81% of the respondents mentioned in their suggestions that a range of 350-400 km per charge would be the most preferable to meet their daily travel requirements. The suggestions by the respondents on their preferred range is shown in Figure 44 below.

Figure 44: Suggestions on preferred Range (in KMs) for EV 4W by respondents



More than 50% of respondents ranked disapprovingly of the availability of charging infrastructure. A significant 24% of respondents ranked it as not satisfied, 33 % ranked somewhat satisfied, and 33% ranked neutral. 24% of the respondents suggested the public charging infrastructure to be within 2 to 3 km range. Similarly, respondents did not rank favorably for waiting time for charger availability. At least 10% of respondents ranked it as not satisfied, 5% as somewhat satisfied, and 81% as neutral. Respondents in their suggestion said that they would prefer having a public charging station within a one-kilometer range of their regular parking spots.

Public charging infrastructure has been a key focus of the Government of Delhi and India to promote EVs. However, the survey responses do not show that public charging is preferred by EV 4W owners. None of the respondents covered in the survey used public charging for their EV 4W despite more than half of them having a public charging station within 5 km of their home or office. At the time of purchasing their EV 4W, the availability of public charging was not an important factor.

However, while using their EV 4W, the respondents found that the availability of public charging stations was a constraint. Respondents in the survey were asked what they liked and disliked about public charging stations. They stated that they liked that the stations have fast charging options and are convenient to use. But they also said that they are experiencing more waiting time and have fewer options to visit within their vicinity. This is consistent with the earlier suggestion by respondents of having a public charging station within 1 km range of their regular parking spots. They also suggested having a battery swapping facility available at every station.

3.2.3 Final recommendations

Socio-economic profile

1. The majority of the early adopters of EV 4W in Delhi are male, belong to the age group of 25-55, and are graduates or postgraduates.

2. The early adopters surveyed are aware of the environmental benefits of EV 4W, and air pollution was the primary motivating factor. Compared with air pollution, respondents were also aware of water pollution, noise pollution, and climate change with 43%, 29%, and 10% as share respectively.

3. The respondents who were early adopters of EV 4W in Delhi had an average monthly household expenditure of INR 40,000 – INR 50,000. Amongst the early adopters, 50% were business owners, and 24% were privately salaried.

4. EV 4W is likely to be purchased by people as their second or third vehicle by those who already own a conventional vehicle. Among those owning a conventional vehicle, diesel 4W owners are more likely to purchase an EV 4W than petrol 4W or 2W.

Travel pattern

1. The two major purposes for which EV 4W is used are regular office commute and short trips.

2. Most people who purchased EV 4W in Delhi have replaced their conventional 2W and minimised their use of conventional 4Ws for their travel needs. Most early adopters use conventional 4Ws for travelling longer distances only and use their EV 4Ws for short and medium-distance travels on working and non-working days.

3. The average kilometers travelled by respondents using a conventional car on a working day is 51km, followed by Electric 4W (41kms) and conventional two-wheelers (15km). Similarly, on a non-working day, conventional cars are being used for long-distance travel (59km), Electric 4W (44kms) being used for medium and slightly lower distance travel, and 2W (7kms) are being used but for short-distance travel only.

4. EV 4W is being used by the respondents on most working and non-working days.

5. Two-thirds of government employees, 60% of private salaried, 40 % business owners, and 50% of self-employed use their EV 4W for short (less than 10 km), medium (less than 20 km), and moderate (less than 30 km) distance daily travel.

6. While many respondents use their EV 4W to travel short and moderate distances, an equally significant number of respondents also use their EV 4W for long-distance travel.

7. The trend of using EV 4W for short and medium distances by the respondents is seen on the weekends, despite significant respondents using it for long-distance travel. Among the respondents, 40% of private salaried, 40% business owners, 33% government employees, and 100% of the self-employed group use their EVs to travel short, medium, and moderate distances.

8. Despite range anxiety concerns, many current users of EV 4W have substituted their conventional car with electric cars for short and long-distance travel.

9. A majority of 81% of the respondents who are early adopters of EV 4W had parking facilities at home or garage, and only 19% needed parking in streets or social spaces.

Charging and Parking

1. None of the respondents opt for public charging stations to charge their EVs, although nearly 60% of the EV owners have public charging stations within a 5 km radius from their parking locations at home or office. On a working day, 95% of respondents opt for home charging of the EV 4W, and only 5% opt for office charging, and on non-working days only one-third of respondents charge, and they too opt for home charging.

2. The current Private EV 4W owners in Delhi do not use top-up charging. The regular, once a day, slow charging satisfies their requirements of daily travel. Hence the fast charging option is seldom used and required by the respondents.

3. The survey found that amongst the EV 4W models purchased by the early adopters in Delhi, the average range of hatchback models was 76-92 km/charge, sedan EV models have an average range between 120 -130 km/charge and electric SUVs had an average range of 280 -312 km/charge.

Consumer preference

1. Capital cost, operating & maintenance cost, range, performance vis-a-vis conventional car, high fuel prices, and environment and emission impacts are some of the crucial factors in the purchase decisions for EVs.

2. Availability of Public charging, high re-sale value, government policies like subsidies and free parking, availability of variants are factors consumers do not find critical while purchasing.

3. Respondents were most satisfied with charging costs, and had a favorable opinion about charging time and quality of after-sales services. Some respondents preferred that fast charging time of within 90 minutes would make EVs more useful for them

4. Consumers had a favorable opinion of the range, but would prefer a range of 350-400 km per charge to meet their daily travel requirements.

5. Respondents of the survey disapproved the availability of charging infrastructure and waiting time for charger availability. They suggested having public charging infrastructure within 2 to 3 km range and some preferred this within one-kilometer range of their regular parking spots. Some suggested having a battery swapping facility available at every station.

6. Public charging infrastructure has been a key focus of the Government of Delhi and India to promote EVs. However, the survey responses do not show that public charging is preferred by EV 4W owners. At the time of purchasing their EV 4W, the availability of public charging was not an important factor. However, while using their EV 4W, the respondents found that the availability of public charging stations was a constraint.

3.3 EV-Prospective Consumer

In the earlier survey segment, we surveyed the individuals who are owners of EVs and current users to assess their experience with EVs. This segment deals with prospective consumers, defined as people who are considering buying a 2W or a 4W within six months of the survey to consider people who are serious about buying a vehicle soon and to avoid non-serious responses. The purpose of this survey was to identify social, economic, technological, and transport behaviour-related factors that influence the decision to buy or not buy an EV. The respondents were chosen through random sampling. The survey revealed insights about the current ownership of vehicles, commuting experience, preferences regarding their new vehicles, and perspectives on EVs**.** The survey for the prospective consumers covered 140 respondents across Delhi. Our analysis is presented separately for 2W and 4W. Among the respondents surveyed, 48% wanted to buy a 4W and 52% wanted to buy a 2W. The responses show that more than 50% preferred Electric Vehicle for 2W and 4W for their next purchase (Sample Size EV Intenders = 74; Conventional Intenders = 66). In the analysis, the respondents who said yes to purchasing EVs are called EV intenders, and those who said no to purchase an EV and preferred a conventional vehicle are called conventional intenders. The results of the survey are discussed in the following sections.

Figure 45: Respondent choice for mode and technology of vehicle

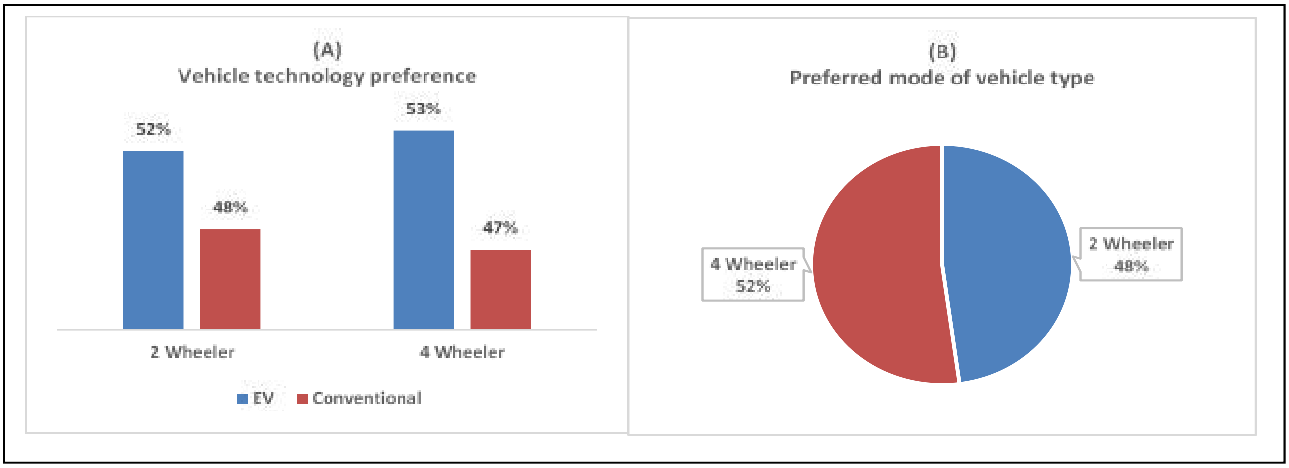
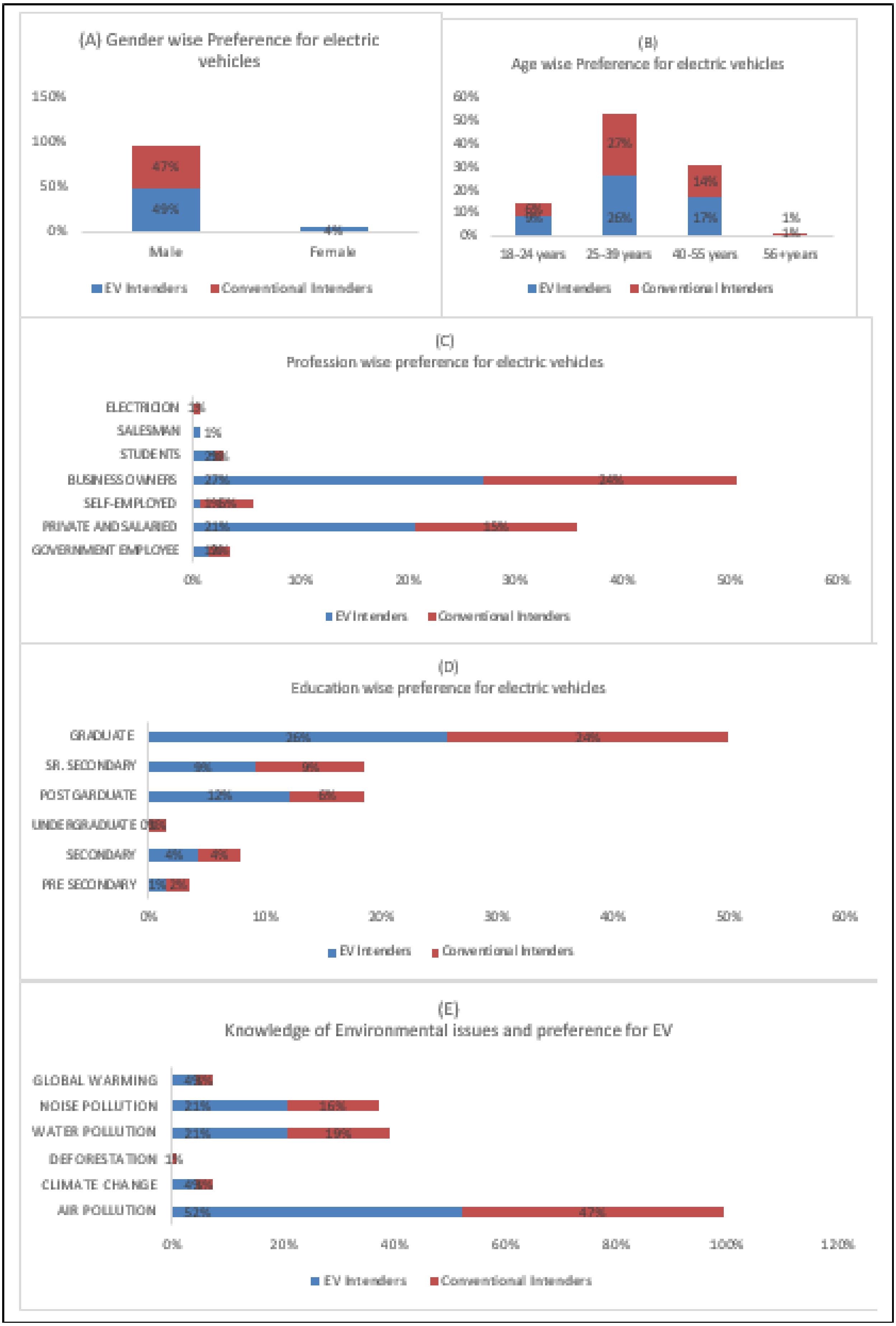


Figure-45(A) shows ***that the proportion of people who said they want to buy an EV is slightly*** above 50%-- both 2Ws and 4Ws. The proportion of people preferring EVs appears to be high. This may reflect excitement among consumers for EVs or could also be reflective of the underlying conditions in the early part of 2020 when the survey was done and since then the sales of vehicles of all categories has declined due to the slowdown in the Indian economy and due to Covid pandemic related lockdowns**.**

3.3.1 Demographic Profile

In this section, 4W buyers and 2W buyers are not separately assessed and only their preference for or against EV has been assessed. Figure 46 presents the demographic profile of the respondents and tries to identify if individuals of a particular demographic background are more likely to prefer EVs. This may help to design the advertising strategies that target individuals of a particular background to increase the market share of EVs. The analysis of survey responses showed that 96% of respondents were male. The proportion of respondents who preferred EVs and those who preferred conventional are roughly the same for all the male respondents, but all female respondents preferred EVs. This may be indicative of women preferring to use EVs for their mobility needs due to its easy to use (gearless), dignified and comfortable riding experience. A little more than half of the respondents were business owners and 36% of respondents were salaried people employed at private companies. It has been observed that respondents belonging to all the professions preferred EV over conventional vehicles, except self-employed people and government employees. 88% of self-employed and 60% of government employees

Figure 46: Demographic Profile of the Prospective Consumers

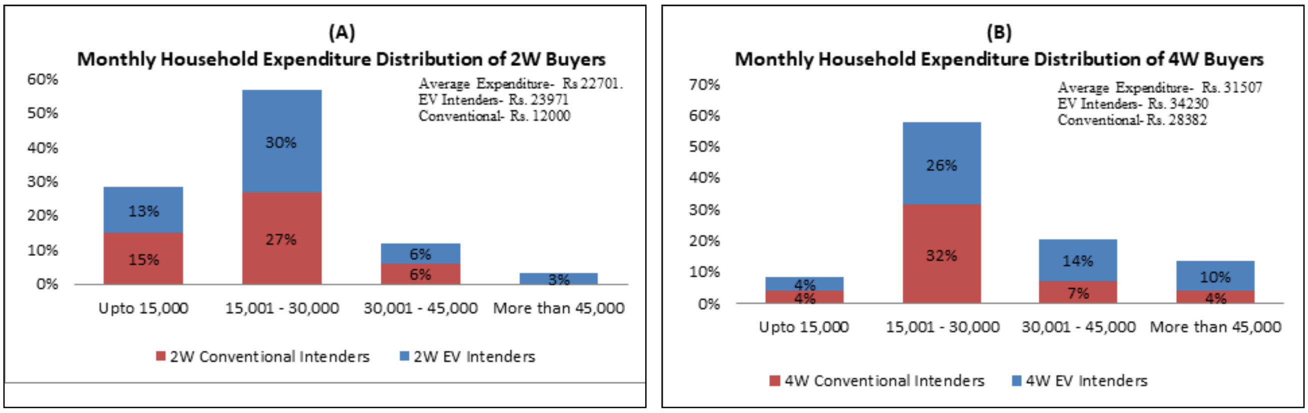


preferred conventional vehicles. The proportion of EV intenders and conventional intenders under each category for age and profession seems roughly similar and so does not seem to be a factor for preference for EVs. A majority of 54% of the respondents were of the age of 25 to 40 years and 31% of respondents were in the age group of 40-55 years. Around 70% of the respondents were graduates or higher educational level degree holders, which is considerably higher than the 23% average of Delhi in Census 2011[4]. As shown in Figure 46, the proportion of respondents wanting to buy a vehicle (2W or conventional) increases with education. The proportion of EV intenders and conventional intenders is similar for lower education levels, but for postgraduates and graduates higher proportion of respondents seem to prefer EVs. This probably indicates that educated people opt more for EVs. The average number of people per family was 4.9, with 83% of the families having 4 to 6 members each. Almost all the respondents were aware of air pollution as an environmental issue, 37% listed noise pollution, and only 7 % listed climate change. In the case of respondents who were aware of local environmental issues like air, water, and noise pollution, the proportion of EV intenders was slightly higher than the proportion of conventional intenders, while for global environmental issues like climate change and global warming, the proportions were roughly similar. Thus, overall, this indicates that awareness of any of the environmental issues may not be affecting their preference for EVs. The major attributes of EVs that the respondents were aware of are their environmental benefits, battery-based technology, noise-less operation, and low running costs.

The average monthly family expenditure of respondents is analysed separately for 2Ws and 4Ws as income may be a determinant of the choice for purchasing a 2W or 4W as well as an EV or a conventional vehicle. Expenditure was used as a proxy for income because of the unwillingness of people to reveal their income. Figure 47 below shows the average monthly family expenditure distribution for 2W and 4W buyers covered in the survey.

Figure 47 shows that for 2W and 4Ws, around 57% and 58% of respondents were in the average monthly family expenditure range of 15,000 to 30,000 rupees respectively, with a sample mean monthly expenditure of INR 22,701 and INR 31,507 respectively. The proportion of respondents preferring EVs is lower for lower expenditure groups but increases with expenditure levels. The average family expenditure for 2W EV intenders was INR 23971/ month and for 2W conventional intenders was INR 12000/month. Similarly, the average monthly expenditure of 4W EV intenders was INR 34,230/month and conventional intenders were INR 28,382/month. Thus, with an increase in income or household expenditure, preference for EVs increases.

Figure 47: Monthly Household Expenditure and Preference for EVs



3.3.2 Ownership of Vehicle

Figure 48 depicts the variation in preference for EV purchase on account of the number and type of vehicles owned by the respondents in the sample survey. A significant diversity is observed in the ownership of vehicles among the respondents, with 52% owning more than one vehicle, 41 % having one vehicle per family, and 6%

[4]Only 8.15% of Indians are graduates, Census data show - The Hindu

having no vehicle at all. Among the total respondents who own at least one vehicle, 64% own 2W and 36% own 4W. As shown in Figure 48, among those who wanted to buy 2W, more than 80% of those who had more than 1 vehicle wanted to buy an electric 2W, this was 40% for those who had 1 vehicle and 60% for those who had no previous vehicles. In general, the proportion of people wanting to buy EVs is much higher among 2W buyers than 4W buyers. Among those who want to buy a 4W, 60% of those who own more than one vehicle previously want to buy an EV, this is 40% for those who have one vehicle, and first-time buyers who want to buy a 4W opt for conventional 4W only. In general, among the respondents who own a vehicle, 60% seems inclined to buy an EV 2W or 4W. However, more than 80% of respondents who previously owned a 4W and want to buy a 2W prefer to buy an EV 2W. Thus, people owning more than one vehicle, were more likely to buy an EV, than people with only one vehicle or no vehicle at all. **This indicates that purchasers see EV as an additional vehicle rather than the primary vehicle for the household.** Business owners are likely to own more than one vehicle per family, followed by the private-salaried people. Figure 49 shows that for each profession, roughly 60 to 75% of the respondents own a 2W. Thus overall, as a previous vehicle, most respondents owned 2Ws than 4Ws.

The majority of the respondents purchased their conventional vehicles in or before 2016, as shown in Figure 50. **Furthermore, it also shows that respondents whose current vehicles were older were more likely to buy an EV.** While all the conventional 2Ws owned by the respondents in the survey are petrol-based, four wheelers owned by the respondents were also predominantly petrol-based, as shown in Figure 51.

Figure 48: EV Purchase Preference of Respondents by Number and Type of Vehicles already Owned

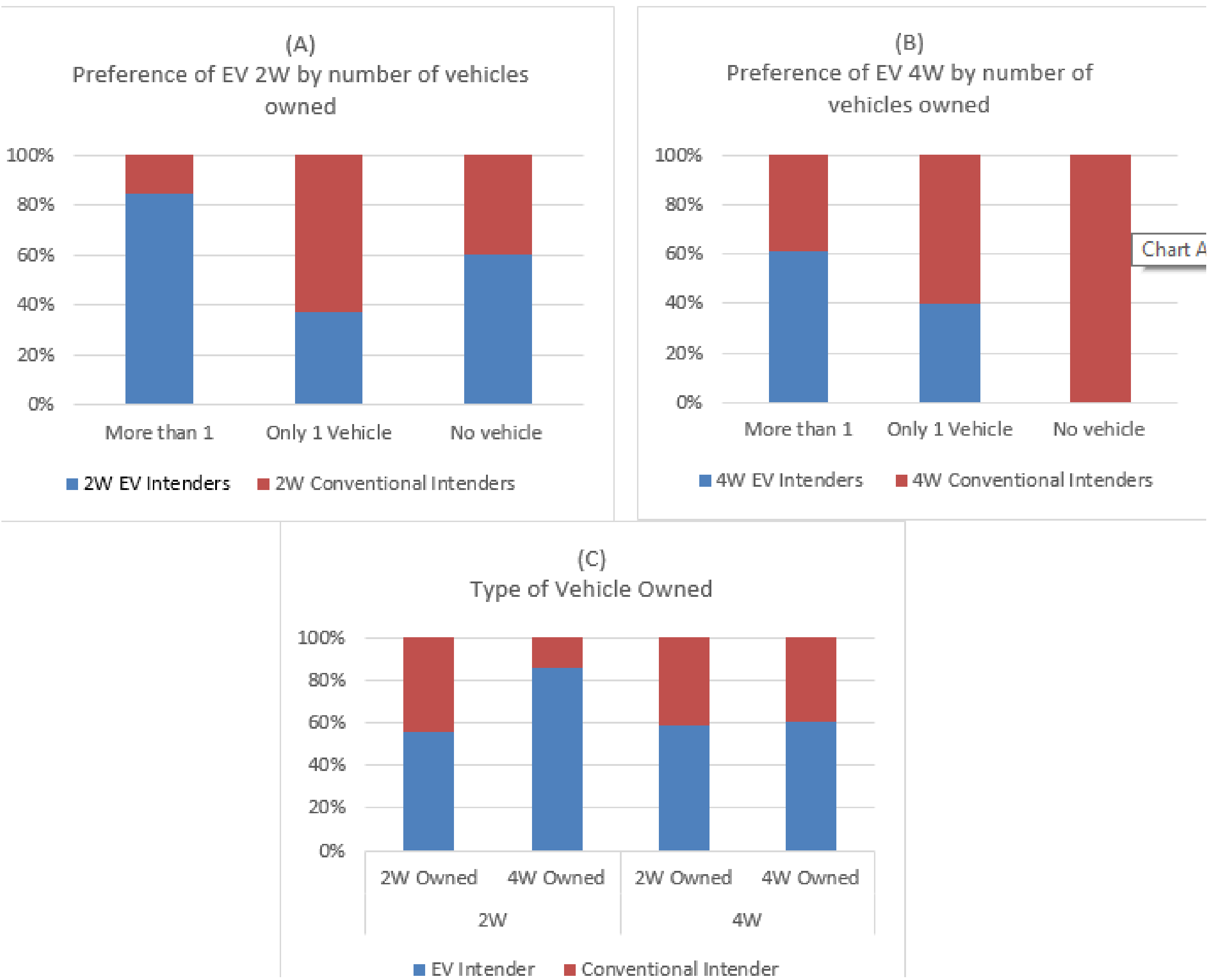


Figure 49: Type of vehicle Owned by Profession

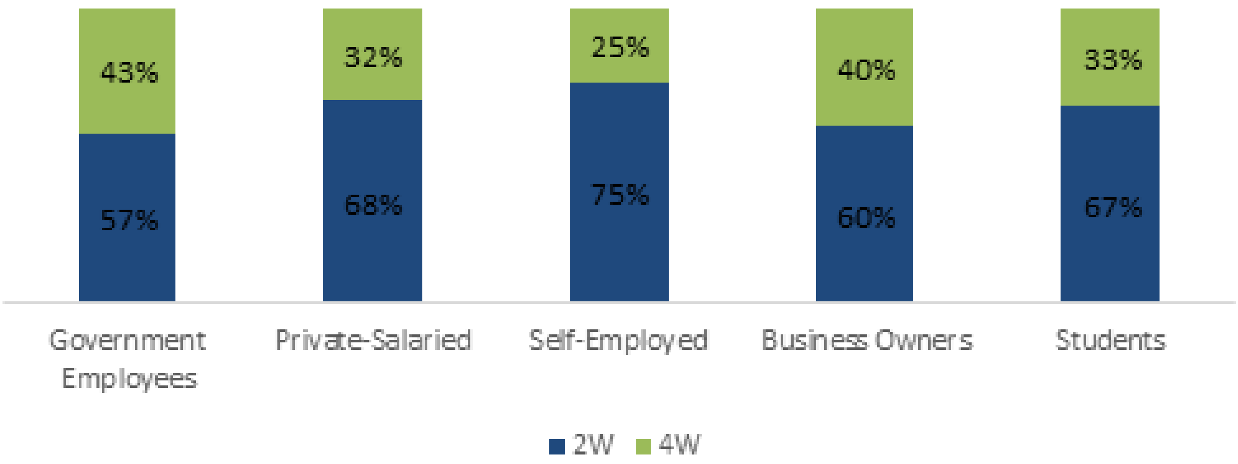


Figure 50: Year of Purchase of Current Vehicle by Type

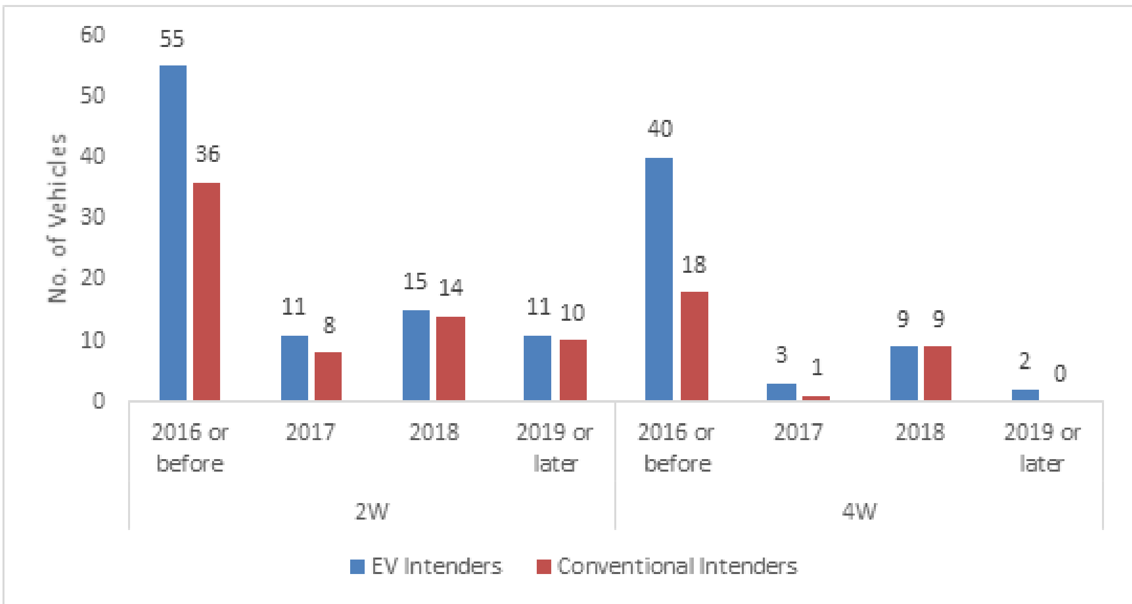
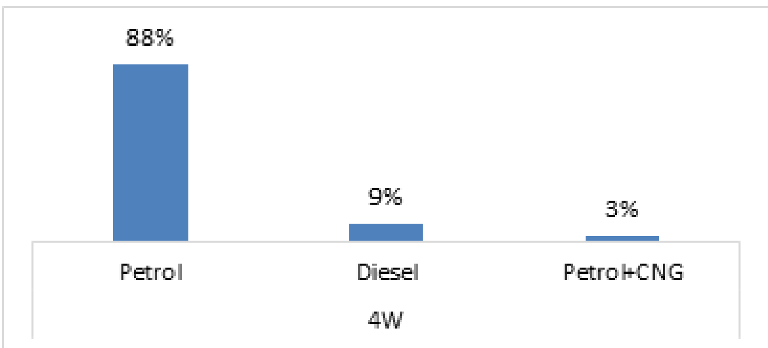


Figure 51: Type of 4Ws Owned by Fuel



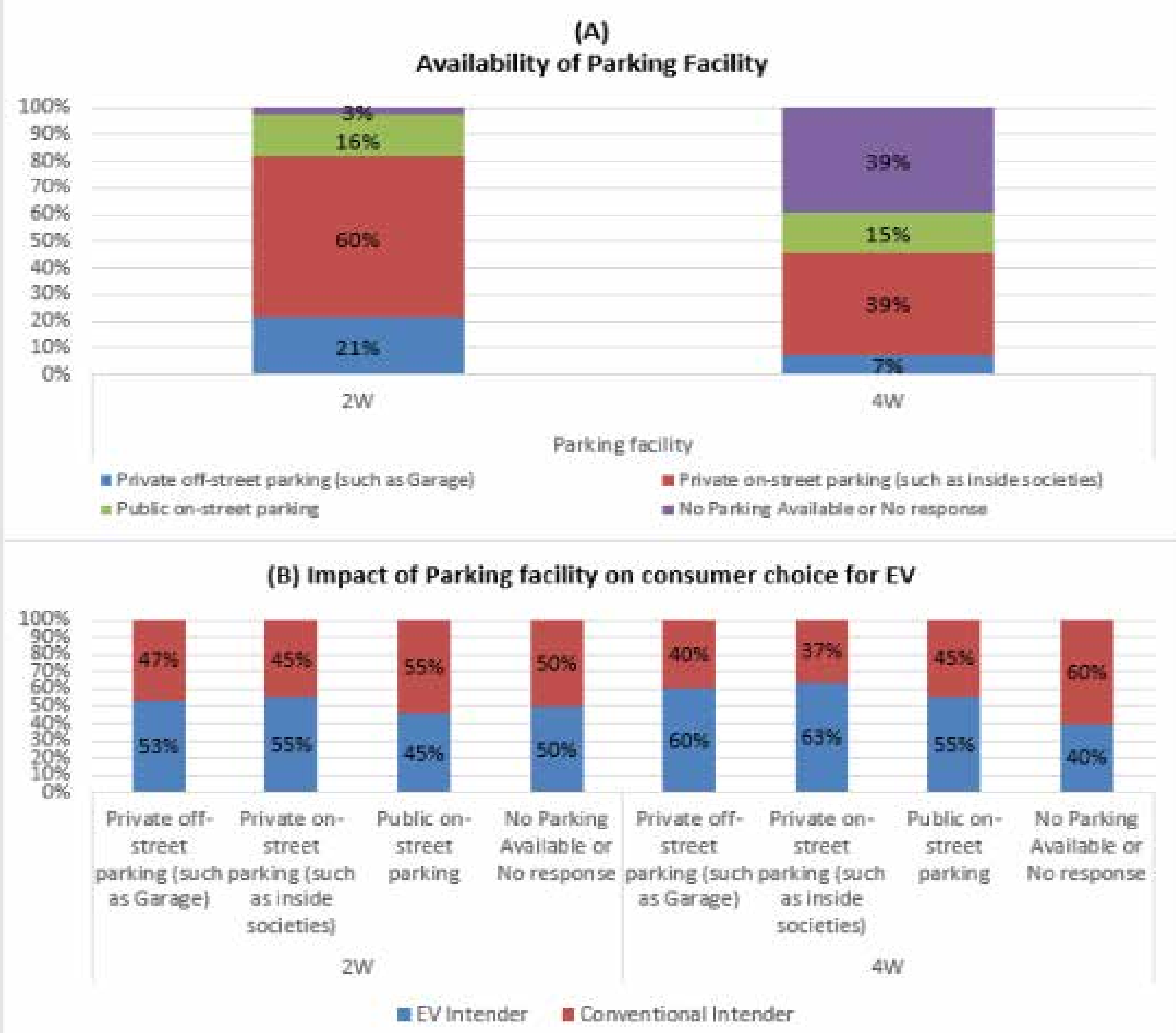
3.3.3 Parking Facility

The smooth functioning of electric 2W and 4W requires slow charging once a day as it keeps batteries last longer. This makes the existence of a parking facility for EVs (especially 4Ws), an essential infrastructure requirement.

To assess the importance of the availability of a parking facility for charging while making their EV purchase decision, the survey asked the respondents who wished to purchase 2Ws or 4Ws, of their current parking facility and EV charging options in the office.

Results from the analysis of the responses to the question on availability of parking facility presented in Figure 52. It shows that private on-street parking (such as parking spaces inside societies) was the most common parking facility available. A significant share of people (16% for 2W buyers and 15% for 4W buyers) did not have dedicated parking spaces and used public on-street parking. In the case of respondents who were prospective buyers of 4Ws, a large proportion of around 40% did not have any parking facility available or did not respond to the question. If the proportion of respondents wanting to buy EV is analysed for different types of parking facilities, it is found that for both 2W and 4W the proportion of respondents opting for EV is roughly the same amongst respondents with private on-street parking and private off-street parking. However, the proportion of respondents wanting to buy EVs in case of both 2W and 4W reduces for respondents with public on-street parking facility. In the case of respondents with no parking facility, the number of people wanting to buy EV does not seem to be affected in the case of 2W, but in the case of 4W, the proportion of respondents opting for EVs is significantly reduced. This shows that the lack of parking facilities could be a huge hindrance to the future adoption of EVs in Delhi, particularly for EV 4Ws. The people with no parking spaces were likely to prefer conventional vehicles to 4Ws.

Figure 52: Availability of parking facility for vehicles



3.3.4 Travel Patterns of Respondents and Usage of Vehicles

This section discusses the travel behaviour of the respondent prospective buyers of EV 2W and 4W. The survey tries to analyse and identify if transport requirements or transport choices are a factor in determining individual choices for purchasing EV. For this purpose, the survey asked the respondents to state the purpose and frequency of using various modes of public transport and private transport (own 2W and 4W). The respondents were also asked to mention, for one week, their expenditures for travelling on various modes of public transport and the mileage and kilometres travelled using their 2W or 4W on weekdays and weekends. The analysis of the responses is presented below.

A. Own Vehicles

The usage of private vehicles by the respondents in the survey was much higher than public transport[5]. Figure-53 depicts the frequency of usage per week of 2Ws matches closely with the average number of working days for all professions. However, this was not the case for the 4Ws, implying that 2Ws were the preferred choice for the respondents for regular commuting during working days. The transport purpose or nature of travel for which owned vehicle is used is analysed in more detail in the sections below.

Figure 53: Average No. of Working Days and Frequency of Usage of Vehicles in a Week

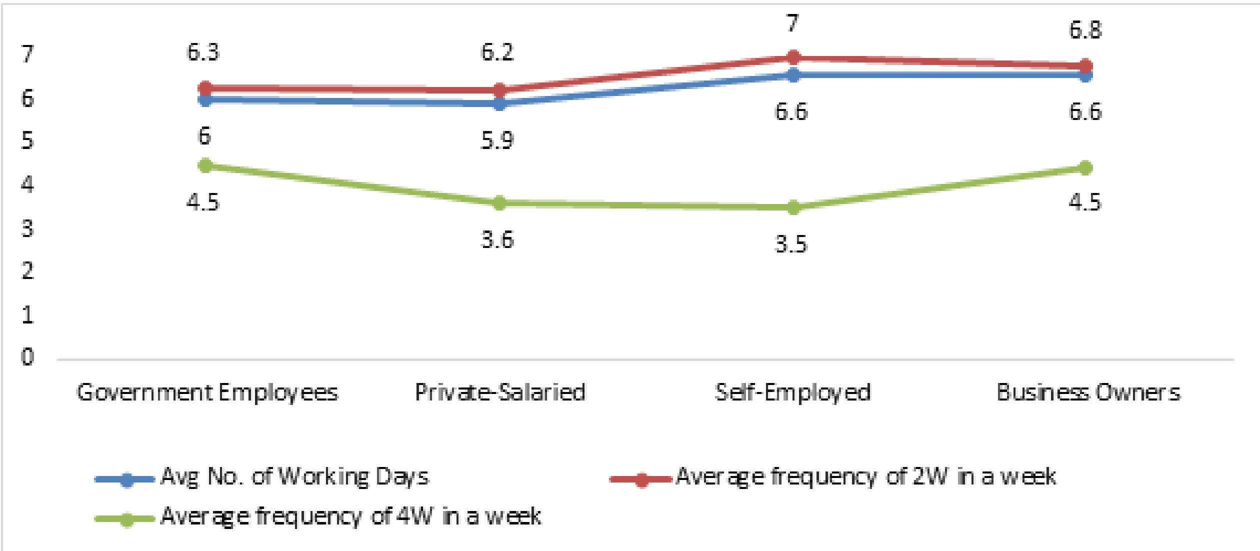


Figure-54 shows the purpose for which respondents, who prefer or do not prefer EV, use their currently owned 2W and 4W. It tries to analyse if the kind of purpose for which a consumer uses his vehicle has an impact on his choice of EV. Figure 54 confirms that "Regular commute" to the workplace is the purpose for which most owners use their vehicles. 2W is a more preferred mode of regular commuting. The analysis of the responses shows that at least 60% of the respondents who are already owners of 2W use it for "Regular Commute to the workplace" irrespective of whether they intend to buy an EV or conventional vehicle. 4Ws were also used for regular commute, but significant proportions of respondents said that they use the 4W for "Short trips" and "Long trips" also.

However, if the purpose for which vehicle is used is compared between those who want to buy EV and those who do not, then EV 2W intenders have a higher proportion of people using it for "short trips" and trips like

[5]This may be because this is a vehicle-based survey among prospective consumers who, as shown in the previous section, mostly owned their vehicles. They were mostly the head of their respective families and thus had preferential access to those vehicles.

going to "college/Schools" compared to respondents who want to buy a conventional 2W. Individuals from a professional background like students have a strong preference for EV and those from professional backgrounds like "Salesman" have all chosen EV 2W only. ***Similarly, for 4W buyers also, the respondents who preferred an EV had a higher proportion of people saying they use it for*** short trips. Individuals who are "Students" strictly prefer EV 4W. This confirms that people who have non-regular short-distance travel requirements are more likely to opt for purchasing an EV. Professional groups like salesmen and students can be targeted to boost EV sales. To assess this more quantitatively, the respondents were asked to mention the vehicle kilometres travelled using their owned 2W and 4W, and the responses were analysed separately for EV intenders and Conventional intenders. These are presented in Table 17 and Figure 55 and Figure 56.

Figure 54: Purpose of Using Vehicle by Profession

Table-17 gives the average distance travelled per day by the respondents using their existing 2Ws and 4Ws on weekends and weekdays. The average distances have been calculated by using the respondent's answers to distance travelled using their 2W and/or 4W on the last working and non-working day and the frequency (number of days per week) of use of 2W and/or 4W.

Table 17: Mean Distance Travelled by2Ws and 4Ws on Weekends and Weekdays(Km)

2W Intenders	Electric		Conventional		Total		Electric	Conventional
	2W	4W	2W	4W	2W	4W	Total	
Working Day	33	45	31	53	32	46	34	32
Non-Working Day	24	42	22		23	42	27	22
4W intenders	**Electric**		**Conventional**		**Total**		**Electric**	**Conventional**
	2W	**4W**	**2W**	**4W**	**2W**	**4W**	**Total**	
Working Day	29	33	20	33	25	33	31	25
Non-Working day	15	55	10	45	13	51	31	28

Overall, Table-17 also shows that the average distance travelled per day using their current vehicles by EV intenders is slightly higher than that by conventional intenders for both 2W and 4W on both working and non-working days. This seems to be contradicting the earlier conclusion that EV intenders had more short-distance travel requirements compared to conventional intenders. The contradiction is explained through Figures 55 and 56 which gives the proportion of respondents under different ranges of distance travelled using their current vehicles for various professional groups on working and non-working days. The figure is plotted based on sample responses to the question of kilometre distance travelled using their current 2W and/or 4W on the last working day and non-working day.

Figure 55:

Table 17 above shows that the average distance travelled per day by 2W intenders is higher on working days than non-working days. In the case of 4W EV intenders, the average distance travelled per day is the same on working and non-working days. But for 4W conventional intenders, the average distance travelled per day is lower for working days than on non-working days. This is consistent with the earlier discussion that more than two-thirds of respondents who intend to buy 2W use their vehicle for a regular commute to the workplace which will reflect on higher average distance travelled on working days and, in the case of respondents who wanted to buy 4W, many also used their vehicles for short and long-distance travel which reflects on higher average distance travelled on non-working days. The average distance travelled per day for 2Ws on working days was around 29 km, and on non-working days is 9 km. Similarly, the average distance travelled per day of 4Ws on working days was 34 km and 50 km on non-working days. These are sample average values of kilometres travelled and hence many respondents would have longer as well shorter travel distance compared to the average. Therefore, short distance travel would constitute distances below the sample averages. Thus, for 2W users, short distance travel would be in the range of 1-30 km and similarly, for 4W users, a short distance trip would be slightly higher up to the range of 30-50 km.

Figure 56: Travel Pattern of 4W Vehicles in a Week (by profession)

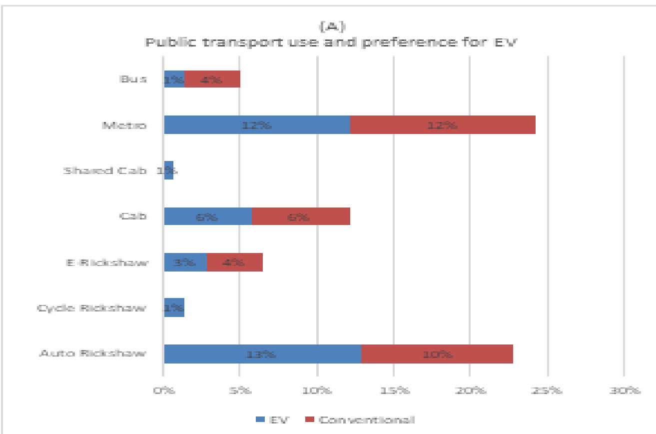
As shown in Figure 55 for 2W intenders, the professional groups of "Government employees", "Self-employed" and "Electrician" that do not opt for EV 2Ws at all have a lower or negligible proportion of people with short distance travel requirements in the range of 1-30 km per day on working days. Among EV 2W intenders of the "Private Salaried" and "Business owners" professions, close to 30% of respondents have short distance travel requirements of 1-30 km during working days compared to less than 20% for conventional 2W intenders. In the four-wheeler category too, the trend of a higher proportion of EV intenders having short distance travel requirements on working days holds as shown in Figure 56. Among EV intenders, 38% and 28% of respondents in the professional group "Self-employed" and "Private Salaried" have a travel distance of 1-30 km on working days compared to only

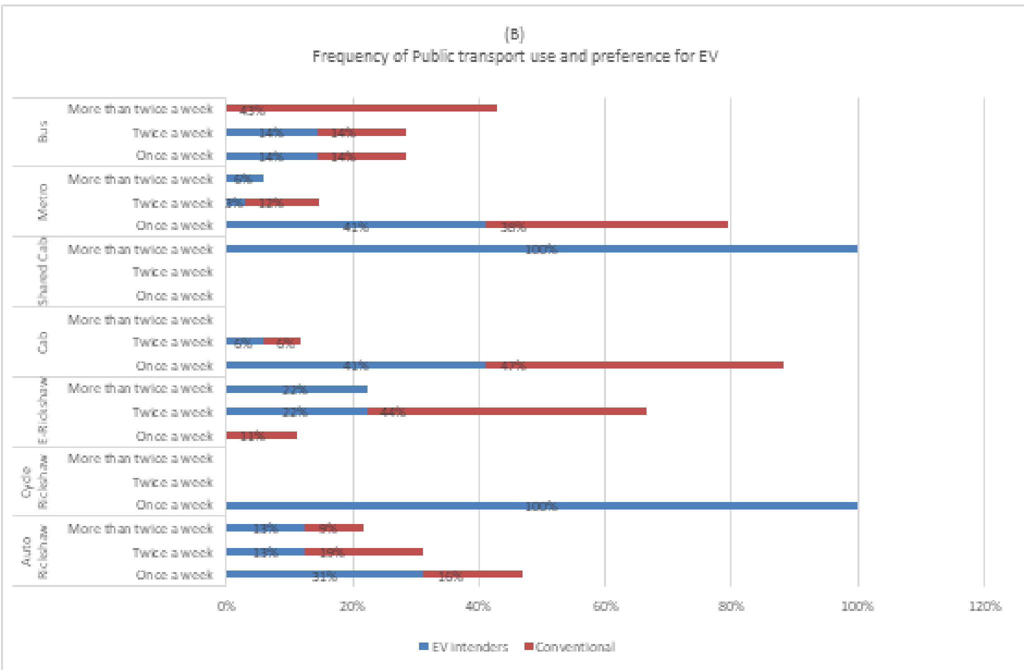
26% and 22% for conventional 2W intenders. Similarly, among EV intenders in the professional group "Business Owners", 27% had a travel distance of 1-30 km per day, and 35% had a travel distance of 30-50 km on working days compared to 31% and 33% in the case of 2W intenders. The exception to the trend exists as in the cases of professional groups like "Government employees" and "Students" who want to buy EVs but have more long-distance travel requirements. The respondents in the professional group "Students" do not prefer conventional 4W at all and use their EV 2Ws and 4Ws for long distances as well short distances and hence can be considered as enthusiastic buyers of EVs.

3.3.5 Public Transport

As discussed earlier, usage of public transport (including cabs), is lower than the usage of private vehicles. As in the case of own vehicle use, respondents were also asked about the frequency, purpose, and expenditure on mode-wise public transport. Figure-57 below shows two graphs, 57A shows the proportion of respondents who availed various modes of public transport and 57B shows the proportion of people who used it once, twice, and more than twice among respondents who used each mode. As shown, the most used public transport modes were the metro, cabs, and auto rickshaws.

Figure 57: Travel Pattern of Respondents through Public Transport (including cabs)



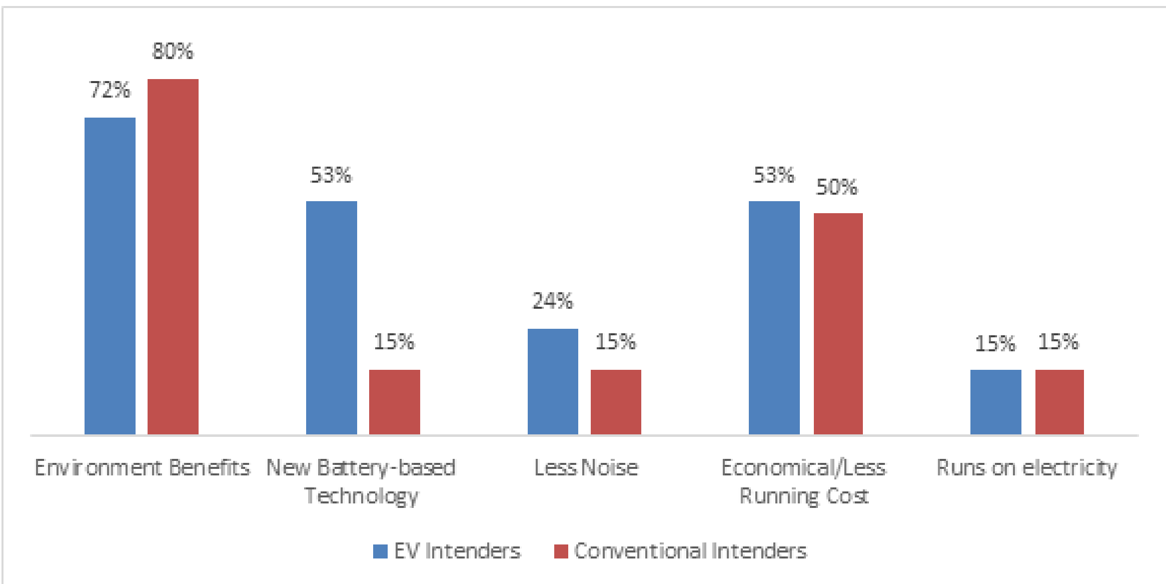


The analysis in the earlier section showed that respondents who preferred EV had short-distance travel requirements. The majority of the respondents in the survey are 2W and/or 4W owners, but still many of the respondents have reported using public transport as well. Figure 57 is used to assess if the EV intenders were the ones who used public transport the most. The proportion of respondents accessing metro and cab transport have equal shares of EV and conventional intenders while the share of EV intenders was slightly higher among the people who used auto rickshaws. If we consider the frequency of public transport usage, respondents who used bus transport once or twice a week have equal inclinations for purchase of EVs and conventional vehicles, but those who used it more than twice a week seem to be preferring conventional vehicles only. The share of EV intenders is much higher than conventional intenders for respondents who used the metro, auto-rickshaw, shared cab, and e-rickshaws more than twice a week. This indicates that respondents who are frequent users of public transport may consider buying an EV to substitute it.

Consumer Perspectives

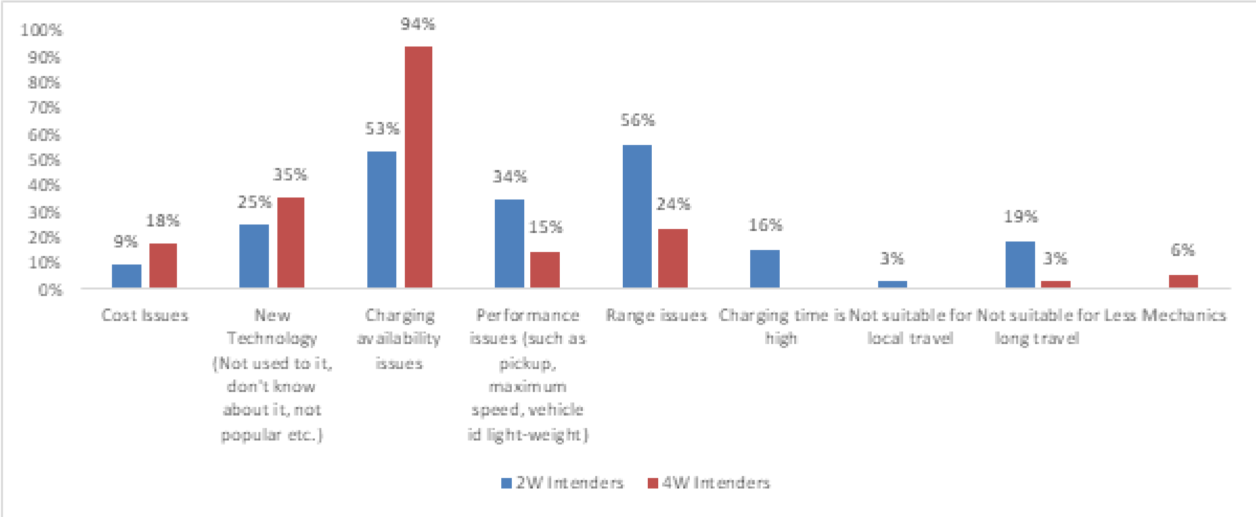
To understand the consumer choices driving EV demand, the survey sought to understand the consumer preferences on various aspects of EVs. To begin with, the respondents were asked about their awareness of various EV attributes. The responses showed variation in awareness between EV intenders and conventional intenders. While a slightly higher proportion of conventional intenders compared to EV intenders ranked the "environmental benefits" as important, a significantly high proportion of EV intenders mentioned "new battery-based technology" and "less noise" as important benefits of EV they were aware of (Figure 58). Other attributes like "economical running cost" and "runs on electricity" were attributes that almost equal proportions of EV and conventional intenders were aware of. This implies that an advertising campaign for promoting EVs should highlight features such as "new battery-based technology" and "less noise" more, in addition to other benefits, for improved impact.

Figure 58: Awareness of EV Attributes among Conventional and EV Intenders



Further, the respondents, who preferred conventional vehicles over EVs were asked for their reasons for not buying an EV though not all respondents provided the reason for not buying EVs. Figure 59 provides the top reasons mentioned by 2W and 4W respondent buyers for not buying EVs. It also provides for each reason, the proportion of respondents who mentioned it among those who gave reasons for not buying EVs. The most prominent reason for not buying EVs was "charging facility availability issues" including both home charging facility and public charging stations, which was mentioned by 93% of 4W buyers and 53% of 2W buyers. Other major reasons included "range issues" mentioned by 56% of 2W buyers and 24% of 4W buyers, "performance issues" were mentioned by 34% of 2W and 15% of 4W buyers, "New technology" related discomfort and ignorance was highlighted by 25% of 2W and 35% of 4W buyers, "Cost issues" was highlighted by 9% of 2W and 18% of 4W buyers and "Not suitable for long travel" was highlighted by 19% of 2W buyers and 3% of 4W buyers.

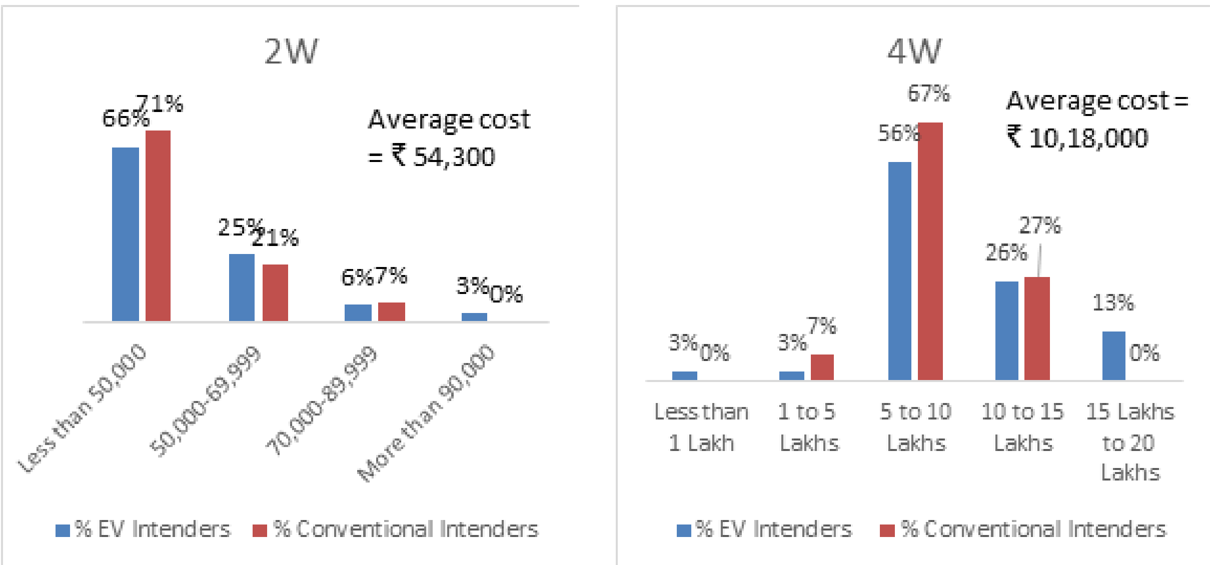
Figure 59: Reasons to not buy an EV by Conventional Vehicle Intenders



3.3.7 Capital Cost

As shown in Figure 59, cost issues were cited by 18% of 4W buyers and 9% of 2W buyers as reasons for their not buying EV. To understand the importance of the cost of EV for prospective EV buyers, the respondents were asked to mention the capital cost they are willing to pay for their EVs. This can be interpreted as a willingness to pay for EV by the prospective buyers, the responses are shown in Figure 60. It is to be noted that around 20% of the total respondents did not respond to this question.

Figure 60: Preferred Capital Cost for EVs



Among the respondents who mentioned their preferred capital costs, Figure 60 shows that the proportion of EV and conventional respondents for a given range of costs decreases with higher levels of cost. It also shows that as preferred cost increases, the proportion of EV intenders preferring it increases relative to the proportion of conventional intenders for both 2W and 4W buyers. This implies that EV intenders are enthusiasts who would be willing to pay higher prices, whereas conventional intenders aren't willing to pay high prices for EVs. In the case of 2W buyers, the majority of respondents – 66% of EV intenders and 71% of conventional intenders prefer cost to be less than INR 50,000. A cost of INR 50,000 to INR 70,000 is preferred by 25% EV intenders and 21% conventional intenders. Very few respondents preferred a cost of more than INR 70,000 and almost no conventional intender preferred a cost of more than INR 90,000. The lowest-priced EV 2W selling in Delhi currently is the Hero Electric Flash with an ex-showroom price range of INR 46,640 to INR 56,940 and a low range of 65 km per charge. While the most expensive EV 2W selling in Delhi is the Okinawa costing INR 1,08,000 with a range of 160 km per charge. The average price of EV 2W in Delhi is INR 77,850. Current prices are higher than what most respondents prefer and there is a case for 54 to 36% reduction in prices through subsidies and other measures. It can also be seen for 2W buyers that, for any level of cost, the proportion of EV intenders and conventional intenders preferring it is roughly the same implying that the capital cost of the EV 2W may not be a determinant of the choice between EVs and conventional 2Ws. This is consistent with the very low proportion of 2W conventional buyers ranking cost as a reason for not buying EVs.

In the case of 4W buyers, few respondents have suggested a preferred cost of less than INR 1 lakh and INR 1 to 5 lakh. These seem to be irrational suggestions. With an increase in costs, the proportion of respondents preferring it reduced. Most of the respondents – 56% of EV intenders and 67% of conventional intenders--have mentioned their preferred cost in the range of INR 5 lakh to 10 lakh. Interestingly, a significantly higher proportion of conventional intenders than EVs prefer a cost in this range. Only 26% of EV intenders and 21% of conventional intenders preferred a cost in the range of INR 10 lakh to 15 lakh. Further, only 13% of EV intenders and none of the conventional intenders preferred a cost is INR 15 lakh. If we consider the cost of current electric 4W models in Delhi, the cheapest model is the hatchback EV Mahindra e20 NXT at INR 6.49 lakh but would be available early 2022. This is followed by sedan EV models Tata Tigor EV at 13.3 lakh and Mahindra e-Verito at INR 10.49 lakh. The most expensive EV 4W are EV SUV models Tata Nexon EV at INR 16.7 lakh, MG ZS EV at INR 24 lakh, and Hyundai Kona Electric at INR 25.3 lakh. Overall, the current average price of EV 4Ws in Delhi for Oct 2021 is INR 17.6 lakh. Most EV 4W vehicles currently available are much above the preferred range of INR 5 - 10 lakh. Even the current average price of EV is above INR 15 lakh. There is the scope of cost reduction for EV 4W by 40% (from INR 25 lakh to 15 lakh) for SUVs and by 20-40% at least for Sedans (INR 13-17 lakh prices brought down to INR 10 lakh) as well, to significantly improve its sales.

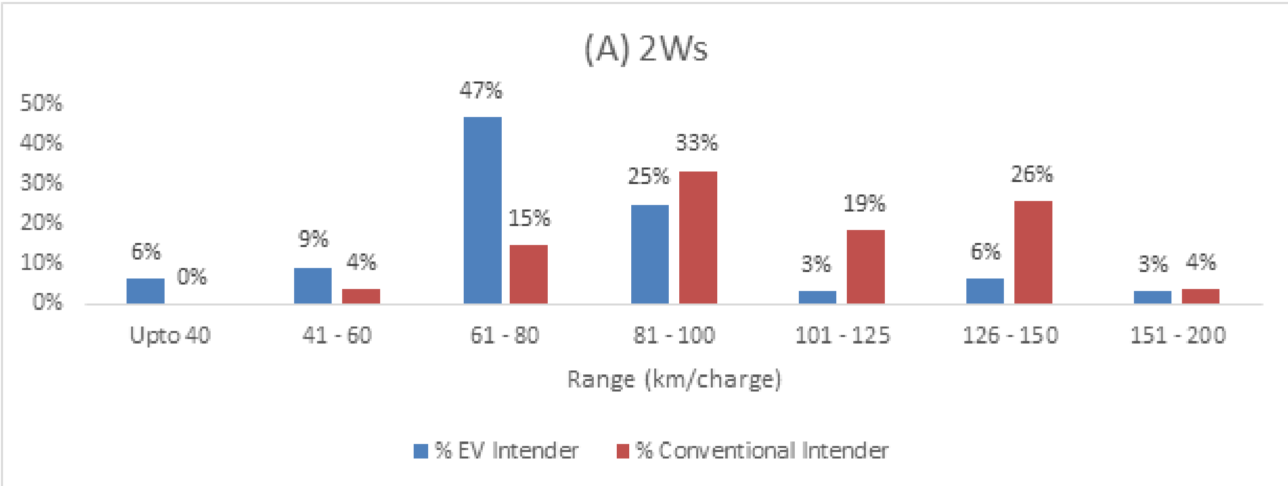
3.3.8 Range Preferred

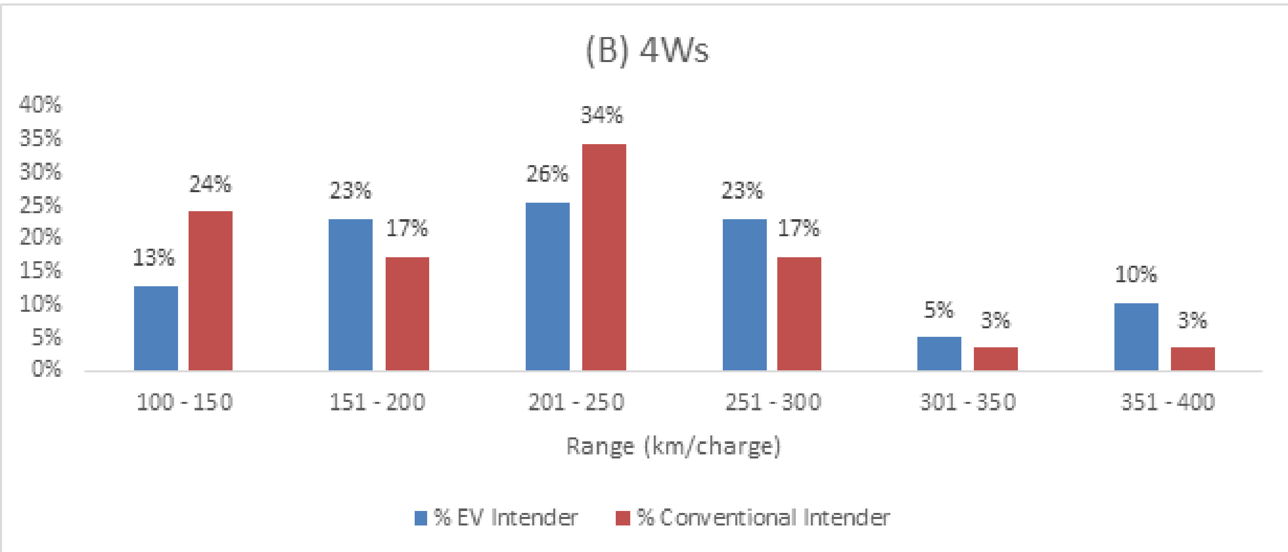
As shown in Figure 59, range issues were mentioned by 39% of the respondents who want to buy a conventional vehicle as a reason for not buying an EV. To understand the requirement for the range of the prospective buyers, respondents were asked their preferred range in their EV vehicle. Figure 61 shows the frequency distribution of a preferred range of 2Ws and 4Ws. In the case of 2Ws, the suggestions for range varied from 20 km/charge to 200 km/charge. There is a clear difference in preference for a range between electric and conventional intenders of 2W. Intenders of EV 2W are satisfied with the lower range, conventional 2W intenders prefer much higher values of the range. This is consistent with the finding in Figure 54 that EV 2W intenders are people whose transport requirement consists of regular commute to the office and short distance travel. Figure 61 shows that 87% of EV intenders of 2Ws mentioned their preferred range between 20-100 km/charge. A majority 72% would prefer a range between 60-100 km/charge. Compared to the EV intenders, 93% of conventional intenders of EV prefer a range between 60-150 km/charge. Of these, 48% of conventional intenders mentioned their preferred range between 60-100 km/charge while 45% preferred to have a range between 100-150 km/charge.

As reported in the earlier section, electric 2W scooters currently existing in the market covered in the survey of EV 2W owners had a range from 45 km/charge (YO Xplor) to 70 km/charge (Veeta) with an average range of 54 km/charge and electric motorcycles had a range of 104 km/charge (Revolt). If we compare the preferred range mentioned by respondents to the range of existing electric 2W in the market, there is scope to improve the range of scooters from an average of 54 km/charge to 100 or 150 km/charge. This is likely to strongly impact many who prefer conventional 2Ws also finding EV 2Ws attractive and economical.

In the case of 4Ws, the responses on the preferred range varied from 100 km/charge to 400 km/charge as shown in Figure 61. However, the majority of respondents -- 85% of EV intenders and 92% of conventional intenders -- had a preferred range between 100–300 km/charge. Very few respondents mentioned that they prefer a range from 300-400 km/charge. Unlike 2Ws, the frequency distribution of the responses of the preferred range for 4Ws is mostly similarly distributed over a wide interval of 100 km/charge to 300 km/charge. This is consistent with Figure 54 which showed that apart from regular office commute, respondents used 4W for "Short trips" and "Long trips" also and hence their range preference would vary based on their travel requirement of short or long distance.

Figure 61: Preferred Range of EVs by Respondents



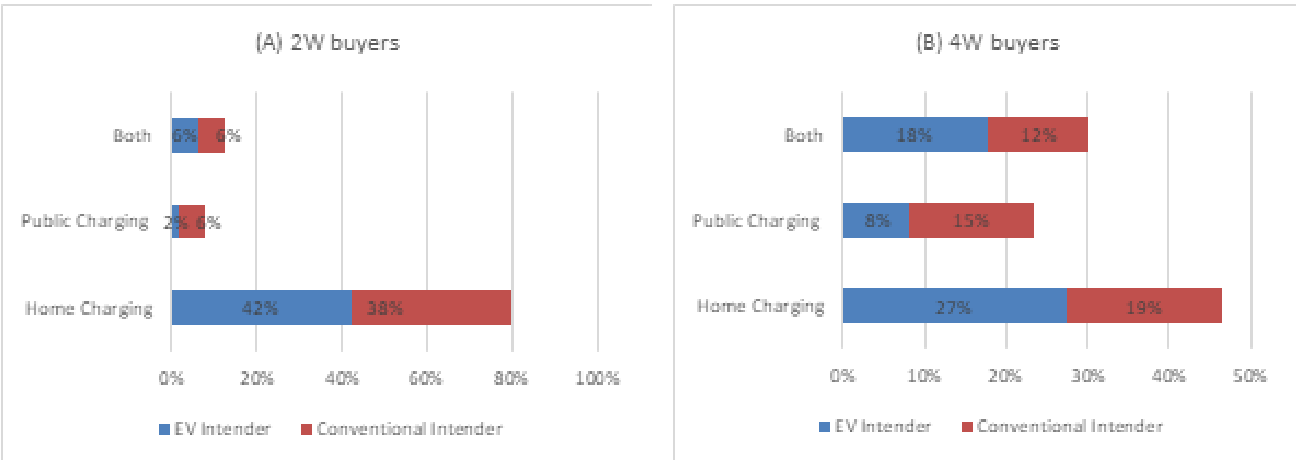


The respondents surveyed for 4W had 40% conventional sedan buyers, 40% EV sedan buyers, and 20% EV SUV buyers. Most of the respondents who preferred a range beyond 300 km/liter were EV SUV buyers, but some were sedan buyers too. The survey of current private owners of EV reported in the earlier section showed that EV Hatchbacks had a range 76 to 92 km/charge depending on if it was used with or without AC. Similarly, EV sedans had an average range between 120-130 km/charge, and EV SUVs had an average range of 280-312 km/charge. If the preferred range suggestions of the respondent 4W buyers are compared with the range of EV 4Ws that were surveyed for current private owners of EV 4W, the buyers of sedan are preferring a range much above 120 km/charge up to 300 km/charge or sometimes even up to 400 km/charge. The EV SUV buyers also are preferring a range above the current range of 300 km/charge up to 400 km/charge. Range suggestions by respondents had comparable proportions of EV intenders and conventional intenders implying that both EV intenders and conventional intenders prefer improvement in range. Thus there is tremendous scope for improvement in the range of the currently available electric 2W and 4W vehicles for increasing EV 2W and 4W sales.

3.3.9 Charging Type

Charging behaviour is an important aspect of EV that can constrain its growth. Figure 59 shows that charging availability issues as a reason to not buy EV was cited by 94% of the 4W buyers and 53% of 2W buyers who chose conventional vehicles over EV. The setting up of EV infrastructure requires knowledge of the consumers' preferred location for charging if they used an EV. In this regard, the respondents were asked their preferred location of charging. No options were provided to the respondents to keep the responses open-ended and actual responses were recorded. Figure 62 shows that 80% of 2W buyers preferred home charging with almost equal proportions of EV intenders and conventional intenders preferring it. In the case of 4 W buyers, only 46% of 4W buyers prefer home charging of which 27% are EV intenders and 19% are conventional intenders. Among 4 W buyers, 23% prefer public charging compared to only 8% among 2W buyers and 30% of 4W buyers prefer both – home and public charging compared to only 12% among 2W buyers. There is a much higher preference for public charging among 4W buyers than 2W buyers. A higher proportion of conventional intenders preferred public charging than EV intenders among 2W and 4W buyers. This shows that public charging infrastructure is not so critical to EV 2W growth but may be an important constraint for EV 4W growth. People currently wanting to buy EVs are enthusiasts and are okay with charging their vehicles at home. However, those who do not prefer EVs and want to buy conventional vehicles have a stronger preference for public charging. This implies that for popularising EV purchase further among non-enthusiasts, public charging infrastructure growth is important

Figure 62: Preferred Mode of Charging of Respondents



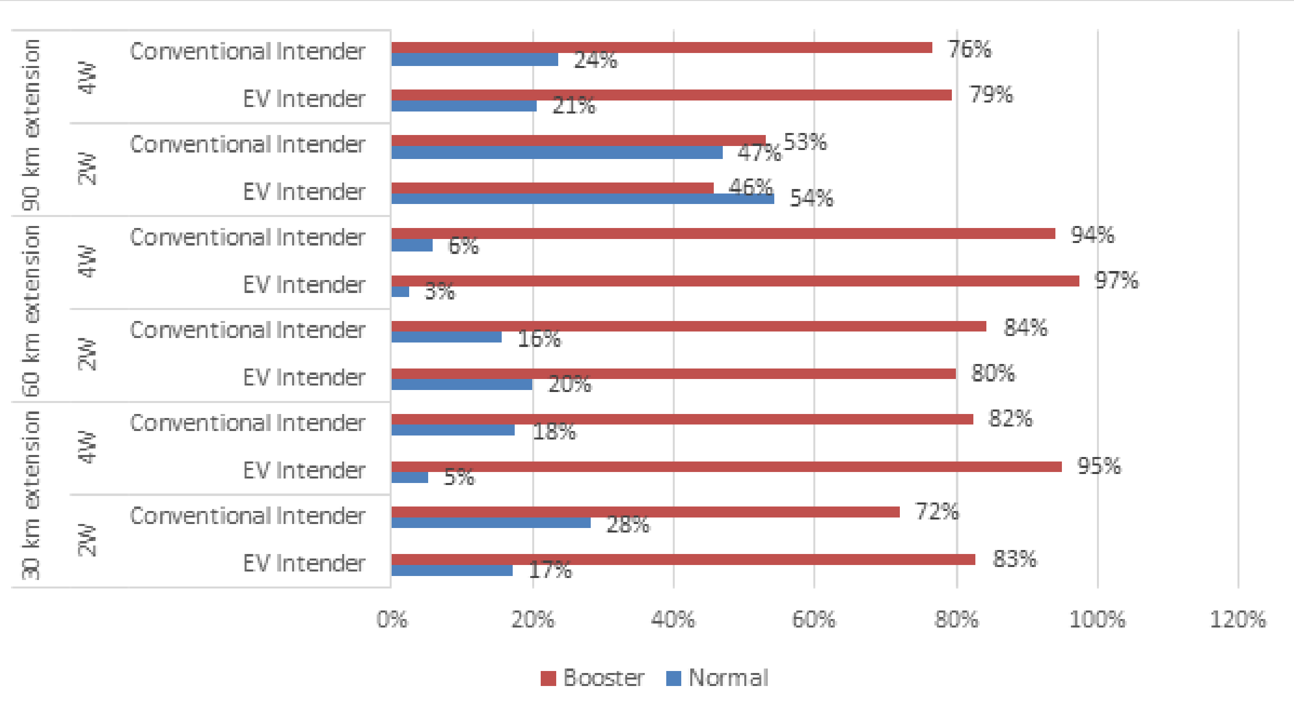
To further understand the consumer requirements and preferences about public charging facilities, the survey asked the respondents the distance of the nearest public charging station from their regular parking spot. Results showed that **less than 10% of the respondents knew about the public charging stations near them.** The respondents were further asked their preferred distance of public charging station from home or office. Around 60% of the respondents preferred to have a charging station within 1 km of their homes and offices.

The respondents also listed waiting time at public charging stations as reasons for not purchasing EVs. To ascertain respondent preferences in this regard, the survey asked the respondents their preferred waiting time at the charging station for charging their EV. The respondents were given to choose from two different charging options at public charging stations – normal charging and booster charging. For each of the two options three economic schemes, which differed in terms of time taken to charge and cost, were provided and the respondents were asked for a choice between the two charging options for each scheme to provide an extension of 30 km, 60 km, and 90 km. The choices given to the respondents are shown in Table 18 and the results are presented in Figure-63.

Table 18: Choice of Normal or Booster Public Charging Options for Different Distance Extensions, based on Cost and Time Taken

		Normal	Booster
30 km extension	Time taken	40 mins	10 mins
	Cost	INR 30	INR 60
60 km extension	Time taken	80 mins	20 mins
	Cost	INR 60	INR 120
90 km extension	Time taken	120 mins	30 mins
	Cost	INR 90	INR 180

Figure 63: Preference of type of public charging station based on distance extension, cost, and time taken



The results of the choices by the respondents show that in general proportion of respondents preferring booster charging is much higher than those preferring normal charging irrespective of the preference for EV and all schemes except in the case when 2W buyers are asked to choose between normal and booster charge for a 90 km extension. In this case, the proportion of respondents preferring normal and booster charge is similar implying that if the charging requirement is for long-distance travel then booster charge is not much preferred for 2Ws. Also, compared to 2W buyers, a higher proportion of 4W buyers prefer booster charges across all three schemes. This shows that irrespective of costs, 4W buyers and users would require booster charging to support their travel requirements. Comparing the responses for the three schemes for conventional and EV intenders in Figure 63 shows that for a 30 km extension, the proportion of respondents preferring booster charging reduces for both 2W and 4W conventional intenders. In the case of 60 km and 90 km extension, the proportion of respondents preferring booster charging increase slightly for conventional 2W buyers and decreases slightly for conventional 4W buyers. This shows that while booster charging is strongly preferred by EV and conventional intenders but if charging is required for short-distance travel then conventional intenders or EV non-enthusiasts wouldn't prefer booster charging facilities they had been purchased and been using an EV.

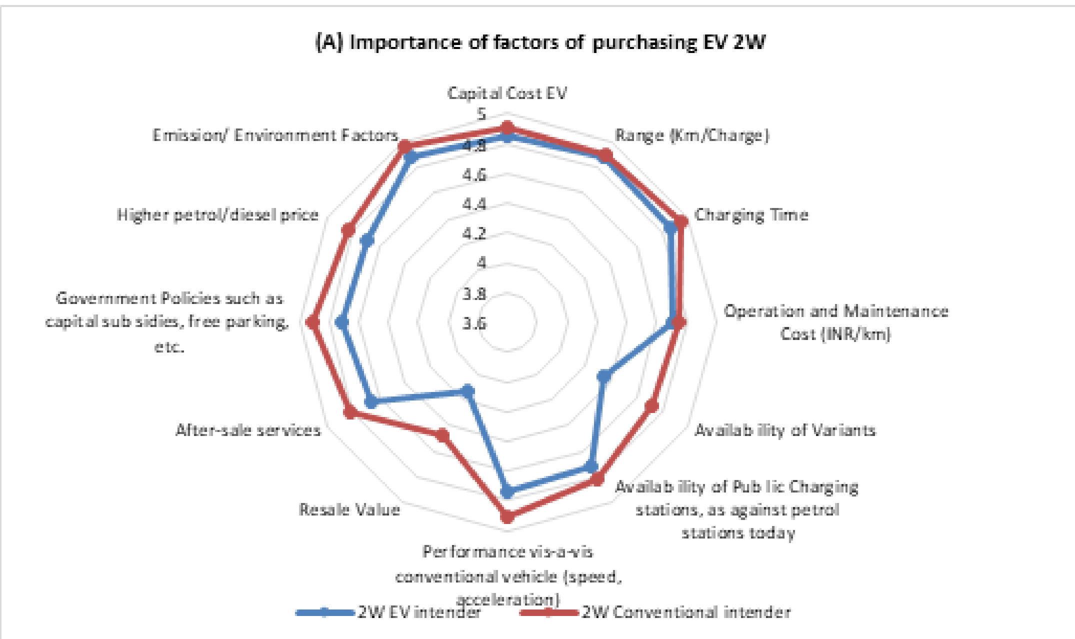
3.3.10 Importance of different EV Attributes and Policies

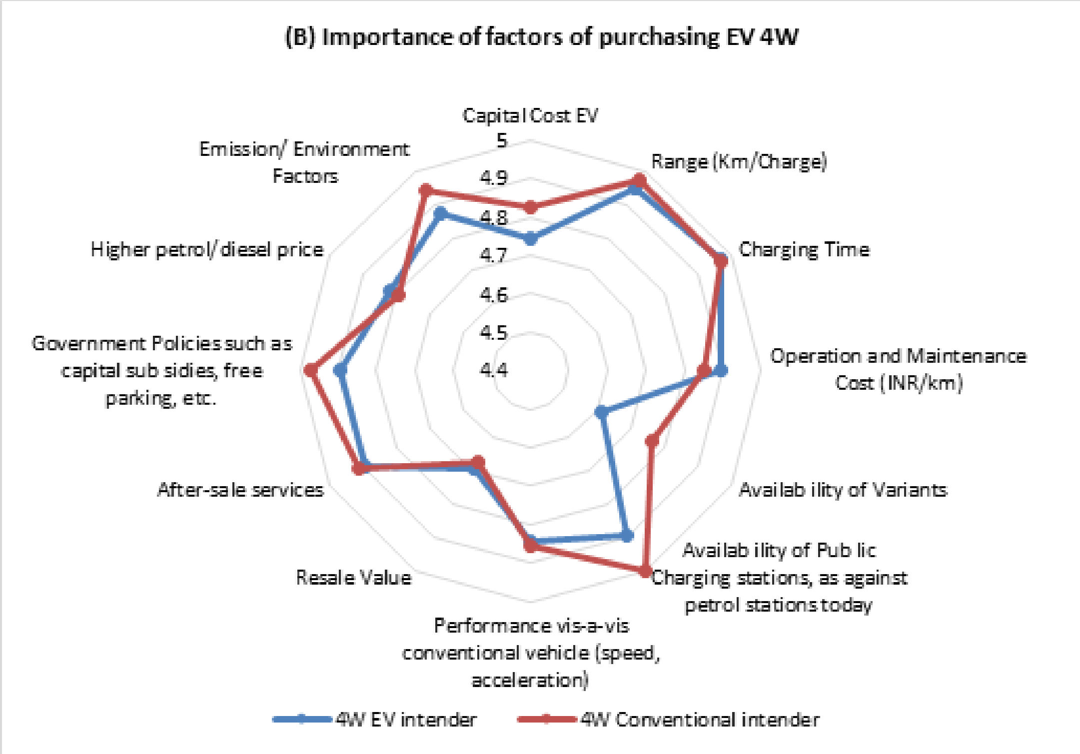
To get an overall understanding of the relative importance of factors that affect a consumer's decision to purchase an EV, the survey asked respondents to rate twelve factors on a scale of 1-5 (1-Not Important; 2-Somewhat Important; Neutral; 4- Important; 5-Very Important) according to their importance in influencing their choice of purchasing an EV. The factors were identified based on a literature survey and ongoing debate in the field of EVs.

The results of the rankings by respondents are shown in Figure 64 separately for 2Ws and 4Ws. The responses of EV intenders and conventional intenders are also separately analysed to see if EV intenders differ in their choices from conventional intenders. In general, prospective consumers or buyers of both 2Ws and 4Ws have assigned very high ranks (4 or 5) to all the factors. This implies that all factors are important and are considered by the consumer while deciding about purchasing an electric vehicle. The minimum average rank by 2W buyers is 4.14 and 4.61 by 4W buyers. Range, emissions, environmental factors, charging time, and capital cost was ranked the highest by both EV 2W and conventional 2W intenders, and resale value, availability of variants, and after-sales services were ranked the lowest. Higher petrol and diesel price was ranked lower by EV intenders while conventional 2W intenders ranked operation & maintenance cost lower than even after-sales services.

Similarly, range and charging time were ranked highest followed by operations and maintenance cost, availability of public charging, after-sales services, and government policies by EV 4W intenders while the availability of variants, resale value, and capital cost were ranked the lowest. Conventional 4W intenders ranked availability of public charging, range, charging time, and government policies as the highest but government policies were ranked the same as charging time unlike in the case of EV intenders. This was followed by emissions/ environmental factors, after-sales services and operations and maintenance costs. They also ranked performance vis-a-vis conventional equally with operations & maintenance cost. The lowest-ranked factors by conventional 4W intenders were availability of variants and resale value and higher petrol and diesel price.

Figure 64: Importance of Different EV Attributes by Respondents





Range, environment, capital cost and charging time come out to be the most crucial factors for 2W buyers that influence their decision to buy an EV 2W. It was seen earlier that knowledge of environmental issues did not impact choice for EVs. Factors like resale value and availability of variants, while important, are not so crucial. For 4W buyers also, range and charging time, availability of public charging, and government policies are the most crucial factors that influence their decision to purchase EV 4W while the availability of variants, resale value though important are not as crucial. Capital cost is also not so crucial for EV 4W intenders and high petrol and diesel prices also are not crucial for conventional intenders.

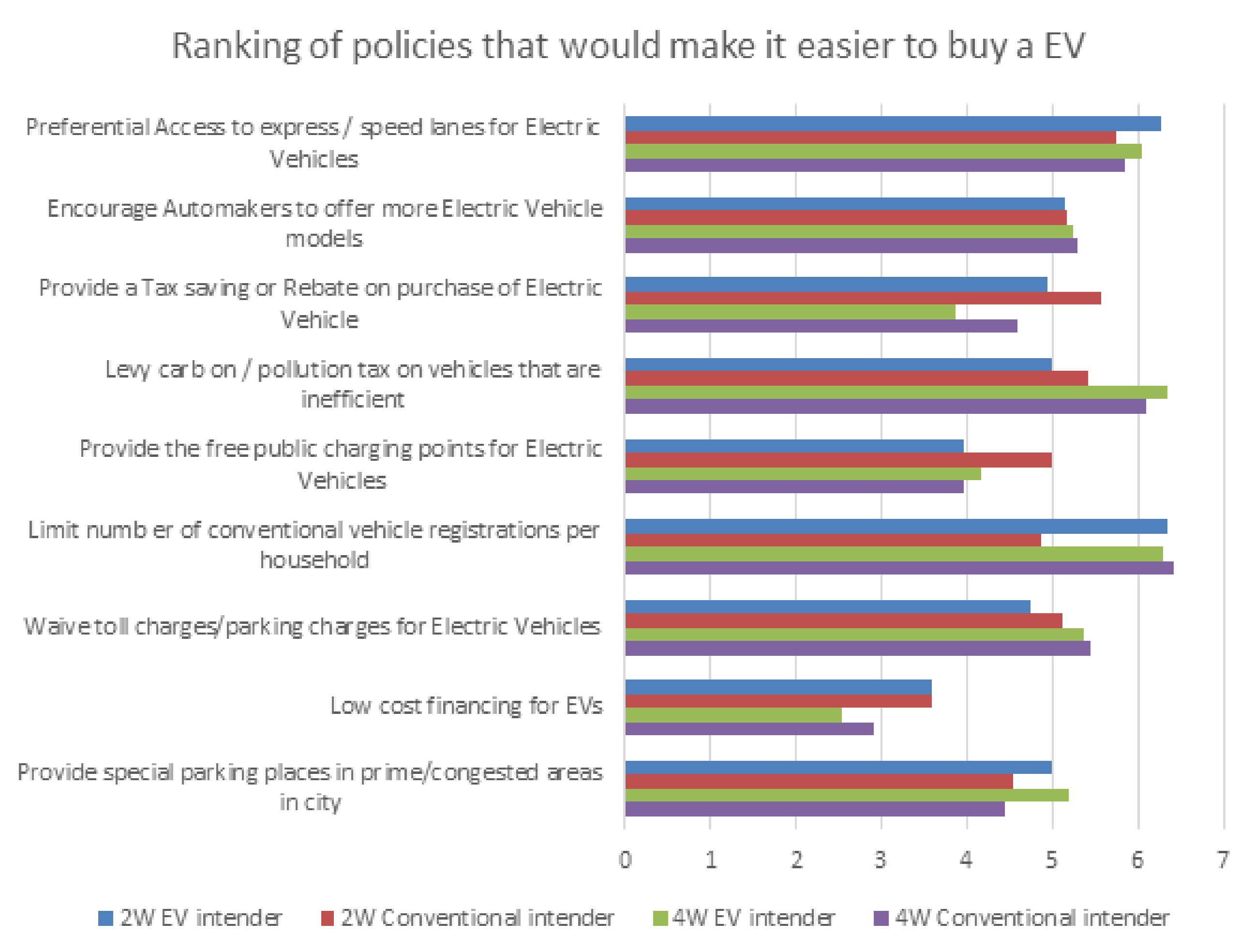
After understanding the factors that consumers prioritise while purchasing EVs, the survey also sought to understand the policies needed to pursue consumers to buy EVs. In this regard, the survey asked respondents to rank a set of policies from highest to lowest on a scale of 1 to 9 so that would make it easier for them to own an EV. The policies and their average ranks by 2W and 4W EV and conventional intenders are given in Figure-65. As shown in the figure, policies received an average rank of around 6 or below. Since the policies are ranked on a scale of 1 to 9, we assume a rank of around 4.5 amounts to respondents being neutral and below 4 means respondents do not find the policy very important.

Figure 65 shows that none of the policies were ranked very high by the respondents. However considerable diversity in rankings is observed for various policies.

Preferential access to an electric vehicle, pollution tax on inefficient vehicles, and limiting the number of conventional vehicle registration are policies that received the highest average rank by respondents as policies that can make it easier to buy EV.

Preferential access for EVs was preferred more by EV 2W and 4W intenders compared to conventional 2W and 4W intenders. In fact, EV 2W intenders prefer this policy slightly more than EV 4W intenders. This implies dedicated corridors and preferential access on the road encourage buyers to opt for EV.

Figure 65: Average Rank of Policies Facilitating Consumer EV Purchase



Levying carbon/pollution tax on inefficient fossil fuel vehicles was ranked higher by 4W buyers than compared to 2W buyers. The average rank by 2W buyers was around 5 and hence can be considered neutral. Among 4W buyers, EV intenders ranked it higher than compared to conventional. In the case of 2W buyers, EV intenders ranked it lower than conventional intenders. This implies that 4W buyers in general, and 4W EV intenders, in particular, prefer this policy while 2W buyers are more neutral about it.

Limiting registrations of conventional vehicles per household was ranked high (above 6) by EV 2W, EV 4W, and conventional 4W intenders. However conventional 2W intenders ranked it comparatively low at 4.8, meaning they are neutral about it and do not find it important.

In the case of the two policies, waiving toll charges/parking charges for EVs and encouraging automakers to provide more electric vehicle models, 4W buyers have ranked it higher than 2W buyers and within 2W and 4W buyers, conventional intenders have ranked it higher than EV intenders. This trend is more pronounced in the case of the policy of waiving toll charges/parking charges for EVs. The average rankings for both these policies are above or close to 5 and hence can be considered as important. The policy is likely to influence conventional intenders to change their decision in favour of EVs.

A related policy that respondents have found important is providing special parking places in prime/congested areas in the city. The policy is ranked higher than 5 by EV 2W and 4W intenders but is marked lower at 4.5 or below by 2w and 4W conventional intenders. This may be a reflection of the parking requirement of the consumers for charging EVs. This further highlights the importance of parking facilities for promoting EV growth.

Providing tax saving or rebates on the purchase of an EV was ranked higher (5 and close to 5) by 2W buyers than by 4W buyers (4.5 and below). With 2W and 4W buyers, the conventional intenders ranked it much higher than EV intenders. This shows that the policy is especially relevant for 2W buyers and can be important in pursuing conventional intenders to change their decision in favour of EV.

Providing free public charging points for EVs was given a high rank of 5 by conventional 2W buyers. However, 2W EV intender and 4W conventional and EV intenders gave it a low average rank of 4. This shows that 2W conventional buyers prefer free public charging facilities for them to adopt EV instead of conventional 2Ws.

Low-cost financing of EVs got a very low average rank much below 4 and hence the respondents do not think it to be important or helpful in making it easier to purchase an EV.

Thus, to summarise, preferential access to express/speed lanes for EV and limiting the registration of conventional vehicles per household are policies ranked most highly by respondents as policies that would make it easier to buy an EV. Limiting registration of conventional vehicles is a forceful intervention that may have limitations in terms of implementation, but preferential access to express and speed lanes for EV is a market measure that can be effective. Waiving toll charges/parking charges of EVs, providing tax savings or rebates in the purchase of an EV, providing free public charging points, and encouraging automakers to provide more models are some of the policies that are important for encouraging buyers who prefer conventional vehicles to opt for an electric vehicle instead. Providing special parking places in prime/congested areas in the city is a policy that would be particularly helpful to EV buyers. Leaving CO_2 or pollution tax on inefficient vehicles was a policy that 4W buyers found important to pursue them to buy EVs. Providing tax savings or rebates in the purchase of EVs and providing free public charging points are policies that 2W buyers found to be important to pursue than buying EVs.

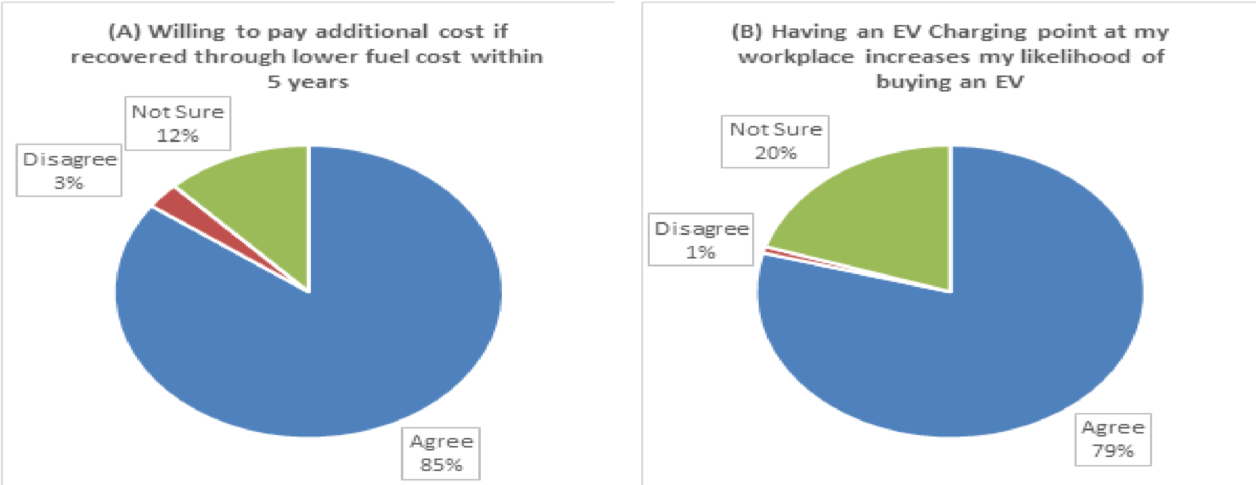
As is clear from the discussions so far, and the general debate about EV in the literature, cost and charging infrastructure are two very critical issues. In the earlier sections, it has been shown that respondents prefer a reduction in cost for EVs. However, EVs have other benefits in terms of lower maintenance and operating costs which might offset the high capital costs. Given the lack of awareness about EVs evident in the discussions so far, it needs to be judged if the consumers change their preference for EV if they are made aware of the other cost reduction advantages of EVs. We have already assessed the respondent's preference for charging location and public charging in general. The office charging facility has not been assessed so far as this facility is rare and none of the respondents reported it. However, since regular commute to work is the dominant purpose for which vehicles are used, the existence of an office charging facility can make a difference to the consumer's preference. For this purpose, the respondents were specifically asked about their choice of EVs and about cost and charging infrastructure through the following two questions:

a. Are the respondents willing to pay more for an EV if they can recover the additional cost through lower fuel costs within five years?

b. Does having a plug-in EV charger at the workplace increase their likelihood of buying an EV as their next purchase?

The results of the responses to the above questions are given in Figure 66. A significantly high proportion of respondents agreed and expressed their willingness/likelihood to pay a higher cost if recovered in five years and purchase an EV if charging points exist at the workplace. This highlights the importance of an awareness campaign to highlight the economic benefits of EVs and increasingly persuading offices and commercial enterprises to have EV charging points.

Figure 66: Preferences towards EV in two scenarios



Finally, to understand if consumers may be arriving at the decisions due to lack of awareness and understanding of EVs, the respondents were asked to indicate their preferred choice of a vehicle based on vehicle type, capital cost, operating cost, equated monthly instalments (EMI) for a loan period of seven years, range or mileage. The choices shown to the respondents are given in Tables 19 and 20.

Table 19: Choice of 4W based on capital cost, operating cost, EMI, Range or Mileage (Assuming diesel price of INR 66/Litre, electricity price INR 6/kWh, the annual run of 12,000 km

Vehicle Type	Capital Cost (INR Lakhs)	Operating Cost (INR/km)	Annual Operating Cost (INR Lakhs)	Lowest EMI for loan period of 7 years (INR/month)	Range or Milege	Please tick your preferred choice
Convention al Diesel Sedan—5 seater	10	3	0.36	16,000	22 kmpl	
EV Sedan—5 seater	13.3	0.70	0.08	21,280	140 km/ charge	
Conventional diesel SUV—5 seater	15	3.3	0.40	25,600	20kmpl	
EV SUV—5 seater	23.5	0.53	0.06	37,600	452 km/ charge	

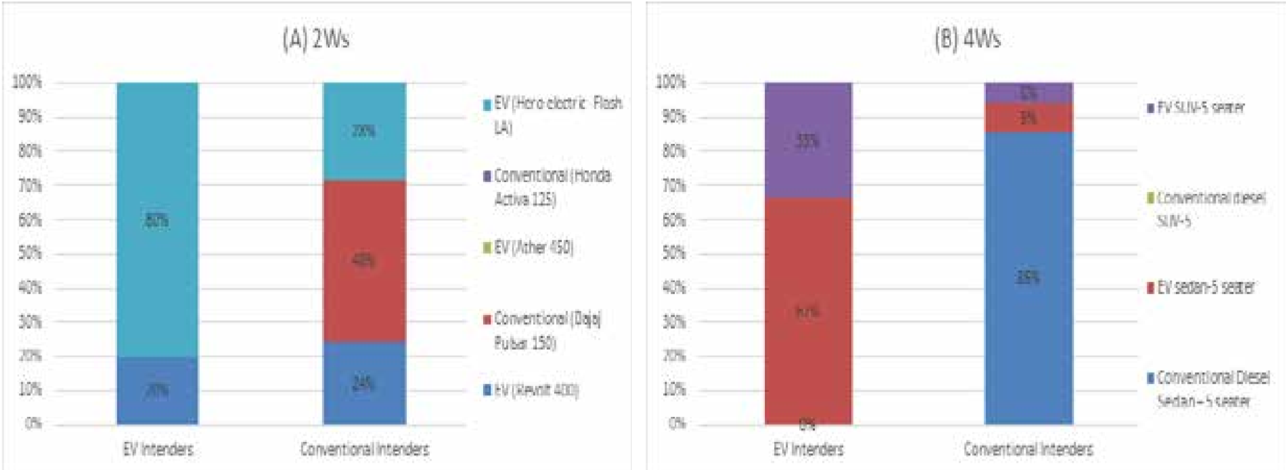
**4W hatchbacks are not included as there were no EV hatchback variants available in the market during the time of the survey.*

Table 20: Choice of 2W based on capital cost, operating cost, EMI, Range or Mileage (assuming diesel price of INR 73/litre, electricity price INR 6/kWh, the annual run of 12,000 km

Vehicle Type	Capital Cost (INR Lakhs)	Operating Cost (INR/km)	Annual Operating Cost (INR Thousands)	Lowest EMI for loan period of 4 years (INR/month)	Range or Milege	Please tick your preferred choice
EV (Revolt 400)	1.38	0.13	1.56	3,615	150 km/charge	
Conventional (Bajaj Pulsar 150)	0.79	1.12	13.44	2,070	65 kmpl	
EV (Ather 450)	1.25	0.19	2.28	3,275	75 km/charge	
Conventional (Honda Activa 125)	0.66	1.23	14.76	1,730	59 kmpl	
EV (Hero electric Flash LA)	0.42	0.14	1.68	1,100	50 km/charge	

Results of the choices of the respondents to options presented in Table 19 and Table 20 are shown in Figure 67. Responses showed that among 4W buyers, 20% wanted to purchase EV SUV 5-seater, 39% wanted to buy EV sedan 5-seater and 41% wanted to buy conventional diesel sedan 5 seaters. Among 2W buyers, 53% wanted to buy EV Hero electric Flash LA, 9% wanted to buy Honda Activa 125, 18% wanted to buy conventional Bajaj Pulsar 150 and 20% wanted to buy EV Revolt 400. No buyers were found to want an EV Ather 450. There were no respondents either who wanted to purchase conventional or EV hatchbacks or conventional diesel SUVs.

Figure 67: Preferred Vehicle Choice based on Choice Cards



After showing the choice table, around 73% of the respondents preferred EV 2Ws over conventional 2Ws, as against 52% depicted. In the case of 2Ws, 28% of conventional intenders now preferred an EV moped (like Hero-electric Flash-LA), and 24% of conventional intenders now preferred an EV bike (like Revolt 400). Similarly, 9% of convention intenders now preferred an EV sedan and 6% of conventional intenders now preferred EV SUVs. Further, each respondent was also given the option to state the reason for their choice. Figure 68 below shows the frequency distribution of reasons given by conventional intenders of EV 2W and 4W to opt for EV 2W and 4W models respectively. The reasons listed are as stated by the respondents and not presented to them to choose from.

Figure 68: Frequency Distribution of the Stated Seasons for Conventional Intenders to Choose EV Model

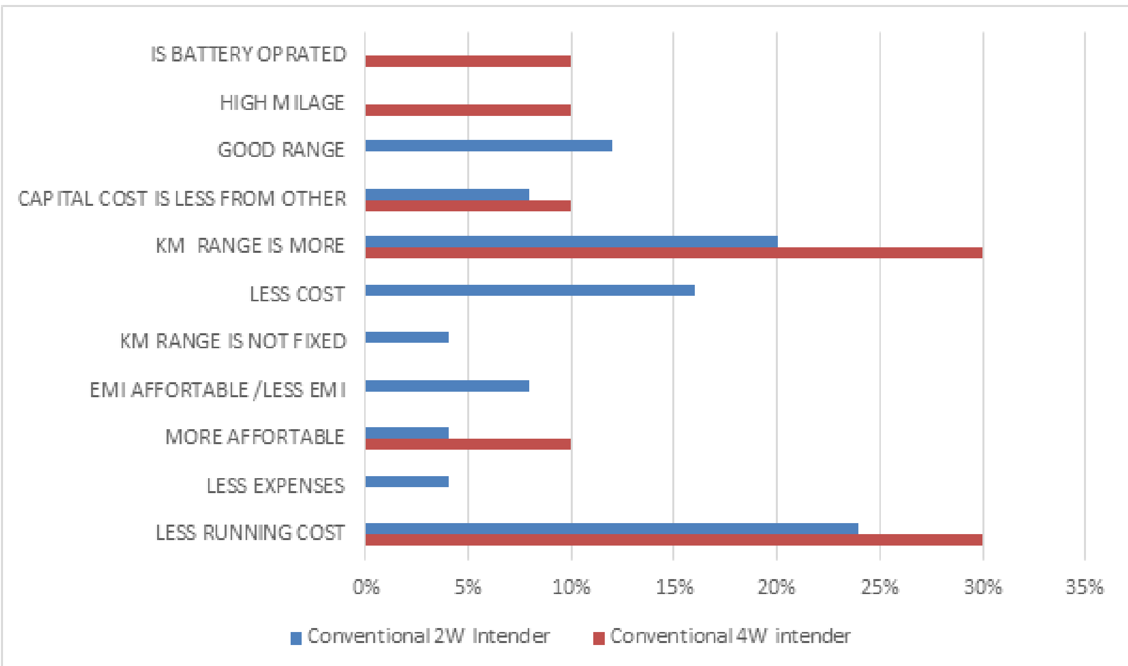
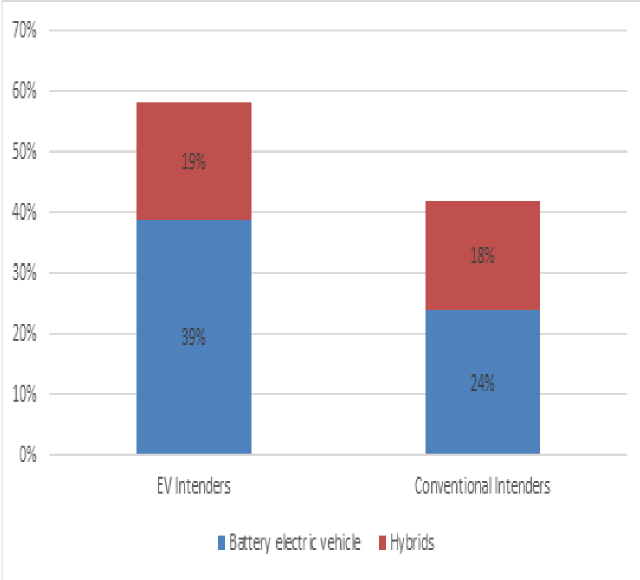


Figure 68 above shows the two most mentioned reasons by the respondents who were conventional intenders but changed their preference to EV when shown vehicular details presented in Tables 3 and 4: 1) kilometer range is more and 2) less running cost. Almost 60% of conventional 4W intenders and nearly 45% of conventional 2W intenders who changed their preference to EVs stated these reasons. Other reasons stated by conventional 4W intenders to change their preference to EV include: battery operated, high mileage, and the capital cost is less from other and more affordable options. Similarly, other reasons mentioned by conventional 2W intenders include: good range, less cost, and affordable EMIs. **This shows that there is a lack of awareness regarding EVs among the consumers, and given proper awareness, more people could shift to EVs as against a conventional vehicle.**

Figure 69: Consumer Preference for BEV and Hybrid Vehicles



The discussions so far showed that cost concerns and range issues are some of the common issues which deter consumers from opting for EVs. A possible solution to this could be the use of hybrid vehicles which can help EV owners to use them for long-distance too with alternative fuel options. To assess consumer preference in this regard, the survey asked the respondents if they prefer a battery EV or a hybrid vehicle. The summary of the responses provided in Figure 69 below shows that of the respondents who mentioned their choice, 58% were EV intenders of which 39% preferred a battery EV and 19% preferred a hybrid vehicle. Similarly, 42% were conventional intenders out of which 24% preferred battery EVs and 18% preferred hybrid. Clearly, battery EV is the most preferred, but a higher proportion of conventional intenders prefer a hybrid vehicle over a battery EV than EV intenders.

3.3.11 Statistical Analysis

In the discussions so far, the responses of the prospective consumers were analysed through tabulations, cross-tabulations, and comparative analyses between the responses of EV intenders and conventional intenders to understand the factors that influence consumers' choice of vehicle to be an EV. To establish the contribution of the factors identified so far in a more concrete way and to quantify the impact of these factors, a binary choice logit model is estimated for 2W and 4W respondents separately. The dependent variable is that the new vehicle purchase is EV or not an EV (conventional) and the explanatory variables are dummies for categorical variables like education, profession, the purpose of vehicle use, parking facility available and continuous variables like Natural log of monthly household consumption expenditure, Vehicle mode type 4W, Own4W_WeeklyUseFrequency, Own 4W VKM working day, Own 4W VKM non-working day, Preferred Capital Cost, Prefered Range, Normal Charging Option 30 Km Ext, Normal Charging Option 60 Km Ext, Normal Charging Option 90 Km Ext, Preferred Charging Station Distance from home, and Time willing to wait at charging station. The dummies computed for the categorical variables are shown below,

For education, Education D1 (post graduate+doctorate), Education D2 (pre-secondary, secondary and senior secondary), Education D3 (under-graduate and graduate).

For profession, Profession D1 (private salaried), Profession D2 (business owners) and Profession D3 (all others)

For purpose of vehicle use, Purpose (Regular commute to work-place), Purpose D2 (Long Trips), Purpose D3 (Short Trips)

In the case of 2W for parking, Parking D1 (Private off-street parking like garage or home basement), Parking D2 (private on street parking - inside parking), Parking D3 (public on-street parking), Parking D4 (other or no parking)

In the case of 4W for parking, Parking D1 (private off-street parking like garage), Parking D2 (private on street parking - inside parking), Parking D3 (public on-street parking), Parking D4 (other or home basement or no parking)

In the case of vehicle mode type, Vehicle mode type D1 (2W) and Vehicle mode type D2 (4W).

The names of the continuous variables are self-explanatory. The interpretation of the average marginal effect for each variable is that they indicate the increase in the probability of a consumer purchasing an EV due to one unit change in the value of the continuous variable. In the case of categorical variables, one of the dummies is excluded and the average marginal effect for the dummies included in the equation is the change in probability with respect to the excluded category, i.e., if the category changes from the excluded category to the included category.

As shown in Table 21, monthly household expenditure, education degree of under-graduate of post-graduate, professional background, availability of private on-street parking facilities, preferred range, and a normal charging option for 30 km extension impact the probability of a consumer purchasing an EV 2W. Having an undergraduate or graduate degree increases the probability of buying an EV 2W by 0.22. One unit higher income reduces the probability of buying an EV 2W by 0.32. People preferring a normal charging option for a 30 km extension at a public charging station also have a higher probability by 0.42, compared to those who have a preference for booster charging. With every one unit increase in the preferred range, the probability of buying an EV 2W decreases by 0.004. This shows that in the current sample, purchasing preferences are heavily constrained by higher range expectations and lower range availability. It also shows that people who are fine with normal charging compared to booster charging options for short-distance travel are likely to have a higher preference for EV 2Ws. This shows that public charging may not be critical, but might support greater penetration of EV 2Ws for those who have short-distance travel requirements.

Table 21: Logistic Regression for Prediction of EV 2W sales

Logistic Regression				
Dependent Variable	**New 2W vehicle sales are EV**			
Log-likelihood	-16.8622		LR chi2(17)	51.64
Number of observations	62		Prob> chi2	0
Pseudo R2	0.605		Average marginal effects	
Variable	Coef.	z	dy/dx	z
Log of monthly household consumption expenditure	-3.654	-1.76	-0.319	-2.01
Education D2 (pre-secondary, secondary and senior secondary)	-0.388	-0.27	-0.035	-0.27
Education D3 (undergraduate and graduate)	3.087	1.60	0.223	2
Profession D2 (business owners)	1.887	1.33	0.143	1.43
Profession D3 (all others)	-2.385	-1.30	-0.213	-1.54
Own 2W_Weekly Use Frequency	0.458	1.16	0.040	1.22
Parking 2W				

Logistic Regression				
Dependent Variable	New 2W vehicle sales are EV			
Parking D2 (private on street parking - inside societies)	-1.795	-1.24	-0.141	-1.48
Parking D3 (public on street parking)	1.416	0.70	0.092	0.82
Parking D4 (others or no parking available)	0.000			
Own 2W VKM working day	0.041	0.96	0.004	0.99
Own 2W VKM non-working day	0.035	0.74	0.003	0.76
Preferred Capital Cost	-0.000002	-0.64	-0.0000001	-0.64
Preferred Range	-0.042	-2.42	-0.004	-3.34
Normal Charging Option 30 Km Ext	5.312	2.22	0.415	4.8
Normal Charging Option 60 Km Ext	1.341	0.76	0.114	0.84
Normal Charging Option 90 Km Ext	-1.543	-1.04	-0.128	-1.2
Preferred Charging Station Distance from home	-0.448	-0.98	-0.039	-1.03
Time willing to wait at charging station	0.096	1.36	0.008	1.45
Constant	31.512	1.77		

Similarly as shown in Table 22, monthly household expenditure, education degree of pre-secondary, secondary and senior secondary, professional background, own vehicle VKM on non-working days, preferred cost, preferred range, normal charging options for 30 km, 60 km and 90 km, preferred distance of charging station from home and time willing to wait at charging station impact the probability of a consumer purchasing an EV 4W. Having an education degree of pre-secondary, secondary and senior secondary increases the probability of buying an EV 4W by 0.23 compared to people with postgraduate and doctorate degrees, and professional backgrounds like business owners and others, that increase the probability by 0.35 and 0.41 compared to being a private salaried person. For people who own a conventional 4W, with every one unit increase in VKM of the 4W on weekends, the probability of his buying an EV 4W reduces by 0.004. With every one unit increase in the preferred range, the probability of buying an EV 4W increases by 0.004. The impact of an increase in cost preference is minimal. People who prefer normal charging option for 30 km and 90 km extention at public charging stations have a higher probability of purchasing EV 4Ws by 0.29 and 0.34, compared to individuals who have a preference for booster charging. People who prefer a normal charging option for 60 km extention at public charging stations have a lower probability of purchasing EV 4Ws by 0.22, compared to those who have preference for booster charging.

Table 22: Logistic Regression for Prediction of EV 4W sales

Logistic regression				
Dependent Variable		New 4W vehicle sales is EV		
Log likelihood	-14.1193		LR chi2(21)	64.55
Number of observations	68		Prob> chi2	0
Pseudo R2	0.70		Average marginal effects	
Variable	Coef.	z	dy/dx	z
log of monthly household consumption expenditure	0.00014	1.45	0.000009	1.59
Education D2 (pre-secondary, secondary and senior secondary)	4.836	1.75	0.232	2.05
Education D3 (undergraduate and graduate)	-1.238	-0.44	-0.061	-0.44

Logistic regression				
Dependent Variable		**New 4W vehicle sales is EV**		
Profession D2 (business owners)	-11.566	-2.35	-0.348	-5.79
Profession D3 (all others)	-12.594	-1.99	-0.406	-3.05
Vehicle mode type D2 (4W)	2.180	0.95	0.131	1.15
Purpose				
Purpose D2 (long trips)	-0.630	-0.29	-0.041	-0.29
Purpose D3 (short trips)	-0.846	-0.50	-0.055	-0.50
Own4W_Weekly Use Frequency	-0.357	-0.86	-0.023	-0.87
Parking4W				
Parking D2 (private on street parking - inside parking)	0.526	0.13	0.034	0.13
Parking D3 (public on street parking)	7.045	1.32	0.296	1.17
Parking D4 (other or home basement or no parking)	2.803	0.68	0.165	0.63
Own 4W VKM working day	0.010	0.33	0.001	0.33
Own 4W VKM non-working day	-0.064	-1.78	-0.004	-2.04
Preferred Capital Cost	-0.000002	-2.69	-0.0000001	-3.89
Preferred Range	0.063	2.68	0.004	3.83
Normal Charging Option 30 Km Ext	4.387	1.38	0.291	1.87
Normal Charging Option 60 Km Ext	-5.438	-0.95	-0.222	-3.34
Normal Charging Option 90 Km Ext	6.541	1.66	0.338	4.81
Preferred Charging Station Distance from home	1.616	1.42	0.105	1.52
Time willing to wait at charging station	0.137	1.49	0.009	1.61
Constant	-15.053	-1.75		

The results show that people with longer travel requirements, especially on the weekends and with higher range preferences, may not want to purchase EV 4Ws. Public charging facilities with normal and booster charging can provide the required flexibility for people to consider using EV 4Ws even for longer distances. Thus improving range of EVs available in the market and setting up public charging infrastructure is essential to promote EV 4Ws.

3.3.12 Final Summary Conclusions and Recommendations for Prospective EV consumers

This survey was undertaken in Delhi from August 2020 to September 2020. The profile of the respondents and their responses have been discussed above. Delhi is a very large city with a population close to 20 million and an area of 1484 sq km. It has reasonable availability of public transport such as metro and buses. Yet, private vehicles are preferred for comfort and even to save time, up to some distances. Some highlights of the analysis which are important for assessing future adoption of EVs are presented below.

We summarise our findings as follows:

Socio-economic Profile

1. All women respondents preferred EVs over conventional for their mobility needs, possibly due to its easy to use (gearless), dignified and comfortable riding experience. Age and profession do not seem to be a factor for preference for EVs.

2. Awareness of any of the environmental issues may not affect preference for EVs but preference for EVs increases with education levels.

3. Preference for EVs increases with an increase in income or household expenditure.

4. EV is being seen as an additional vehicle rather than the primary vehicle for the household.

5. People owning more than one vehicle were more likely to buy an EV than people with only one vehicle or no vehicle at all, and people whose current vehicles are older were more likely to buy an EV.

6. Lack of parking facilities could be a hindrance to the future adoption of EVs in Delhi, particularly for EV 4Ws. People with no parking spaces are more likely to prefer conventional vehicles for 4Ws.

Travel demand and pattern

1. Regular commute to work-place is the most prevalent and common purpose for which 2Ws and 4Ws are used. More than two-thirds of the respondents use their 2Ws for a regular commute to the workplace. 4Ws were also used for regular commute, but significant proportions of respondents use their 4Ws for "short trips" and "long trips" also.

2. The average distance travelled per day for 2Ws on working days was around 29 km, and on non-working days, 9 km.

3. The average distance travelled per day of 4Ws on working days was 34 km and 50 km on non-working days.

4. People who have non-regular short-distance travel requirements are more likely to opt for purchasing EVs.

5. Professional groups like "student", "salesman" have a strong preference for EVs and can be targeted to boost sales.

6. People who are frequent users of public transport modes like metro, auto-rickshaw, shared cab and e-rickshaws are more likely to consider buying EVs to substitute it.

Public Charging

1. Public charging infrastructure is not so critical to EV 2W growth but may be an important constraint for EV 4W growth. For popularising EV purchases among people who may not be EV enthusiasts, public charging infrastructure growth is important.

2. Less than 10% of the respondents knew about the public charging stations near their regular parking spots of home or office. Around 60% of the respondents preferred to have a charging station within 1 km of their homes and offices.

3. Booster charging is strongly preferred over normal charging in general at public charging stations, and increasing and improving booster charging infrastructure in public charging facilities is important to promote the growth of EV 4Ws.

4. The preference for booster charging at public charging stations is lower only in the case of 2W buyers charging for long-distance travel and in the case of conventional intenders charging for short-distance travel.

Consumer Preference

1. Advertising campaigns for promoting EVs should highlight features such as "new battery-based technology" and "less noise" more in addition to other benefits for improved impact.

2. Availability of charging infrastructure needs to be increased and charging time reduced to increase the adoption of EVs by consumers.

3. From the technological point of view, improved performance, increased range, reduction in vehicle cost need to be prioritised.

4. Current prices are higher than what most respondents prefer and there is a case for 54% to 36% reduction in prices of 2W and by 40% for SUVs and by 20%-40% at least for sedans through subsidies and other measures.

5. Consumers prefer an improvement in the range of scooters from the average of 54 km/charge to 100 or 150 km/charge, 120 km/charge up to 300 km/charge for sedan buyers, and from the current range of 300 km/charge up to 400 km/charge for SUVs. This is likely to strongly impact many who prefer conventional vehicles, and will also find EVs attractive and economical.

6. Awareness and advertising campaigns to show the positive sides of the new battery-based technology, suitability for local travel and benefits of fewer mechanical parts need to be undertaken.

7. Range, capital cost and charging time come out to be the most crucial factors for 2W buyers that influence their decision to buy an EV 2W. Whereas factors like resale value and availability of variants, while important, are not so crucial.

8. For 4W buyers also, range and charging time, availability of public charging, and government policies are the most crucial factors that influence 4W buyers' decision to purchase EV 4Ws while the availability of variants and resale value, though important, are not as crucial.

9. Capital cost is also not so crucial for EV 4W intenders and high petrol and diesel prices also are not crucial for conventional intenders.

10. Preferential access to express/speed lanes for EVs and limiting the registration of conventional vehicles per household are ranked highly as policies that would make it easier to buy an EV.

11. Waiving toll charges/parking charges of EVs, providing tax savings or rebates in the purchase of EVs, providing free public charging points and encouraging automakers to provide more models are policies are likely to encourage buyers who prefer conventional vehicles to opt for EVs.

12. Providing special parking places in prime/congested areas in the city is a policy that would be particularly very helpful to EV buyers.

13. Levying CO2 or pollution tax on inefficient vehicles was a policy that 4W buyers found important to prompte them to buy EVs. Providing tax savings or rebate in the purchase of EVs, and providing free public charging points are policies that 2W buyers found to be important to prompt them to buy EVs.

14. Battery EV is the most preferred, but a higher proportion among conventional intenders prefers hybrid vehicles over battery EVs than EV intenders, indicating that range and performance issues matter to conventional intenders.

15. Offices and commercial enterprises need to be persuaded to have EV charging points.

16. Awareness campaign to highlight the economic benefits of EVs is necessary. There is a lack of awareness regarding EVs among the consumers, and given proper awareness, more people could shift to EVs as against a conventional vehicle.

Statistical inference

1. Logit model analysis shows that purchasing preferences for EV 2Ws are heavily constrained by higher range expectation and lower range availability.

2. Public charging may not be critical but might support greater penetration of EV 2Ws for those who have short-distance travel requirements.

3. Improving the range of EVs available in the market and setting up public charging infrastructure is essential to promote EV 4Ws.

3.4 EV-Four-Wheeler (Institutional)

On 25 Feb 2021, the Delhi government became the first in the world to mandate its entire hired car fleet to switch to electric within a deadline of six months. This decision will impact over 2,000 cars, and the government hopes to inspire cities and governments around India and the world to tackle the pollution and climate change problem.[6] This section of the survey covers electric 4Ws owned and operated by institutions. The institutions covered are various taxi agglomerates and government organisations. This EV 4W is analysed separately from private EV 4Ws as vehicle growth in this segment is not driven by private choices and preferences, but rather through government policy and commercial interests. The survey covered 108 respondents who were drivers of EV 4Ws owned by a total of nine organisations across the Delhi NCR. Table 23 below gives the organisations covered in the survey and the number of drivers of EV 4Ws corresponding to each organisation and their area of interview. The respondents were selected through random sampling.

Table 23: Sample of the survey

S No.	Organisation Name	Area	No of Samples
1	MERU	Sector 20, Gurugram	30
2	EESL	Lodhi Rd	18
3	NDMC	Sarojini Nagar	18
4	LITHIUM	Sector 8, Noida	29
5	EVERA PARGATI	Jasola	5
6	BSES RAJDHANI PVT LTD	SaritaVihar	7
7	BLU SMART	Sector 18, Gurugram	1
8	EEE-Taxi	PalamVihar Road,Gurugram	1
9	HYBRID Fleet management Pvt. Ltd.	Ansal Majestic Tower, Vikaspuri	1
	Total Samples		**108**

Survey Results

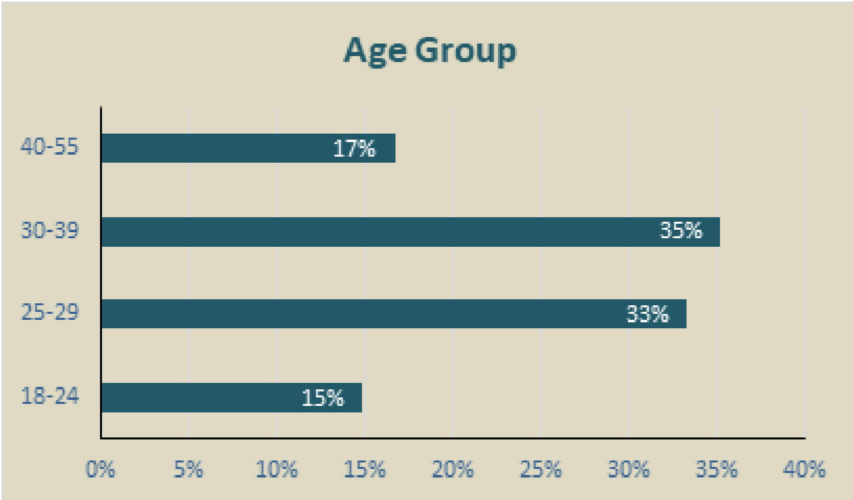
3.4.1. Demographic Profile

All respondent drivers of the survey are male, and a majority of 35% and 33% of them belong to the age group of 25-39 years, 15% belong to the age group of 18-24 years, and 17% belong to 40-55 years. There were no drivers above the age of 55 years working as institutional drivers. This is shown in Figure-70 below.

Education-wise, the survey shows that 30% of the drivers have completed senior secondary school, and 28% of drivers each were pre-secondary and secondary school educated. The Figure below gives the %age distribution of drivers interviewed in the survey by educational qualification. Figure 71 shows the level of awareness of the respondent drivers about environmental issues. Analysis of the responses shows that awareness of environmental issues is not very high, with only 63% aware of air pollution and 18% and 13% aware of noise pollution and water pollution. Figure 71 shows the driving experience of the respondents with a conventional car and an electric car. The survey shows that 73% of the respondents have at least one year of experience as an EV driver, and 23% have more than two years. The respondents who are professional drivers also reported their experience in driving the conventional car, with 34% having 1-5 years of experience and 39% having 6-10 years of experience.

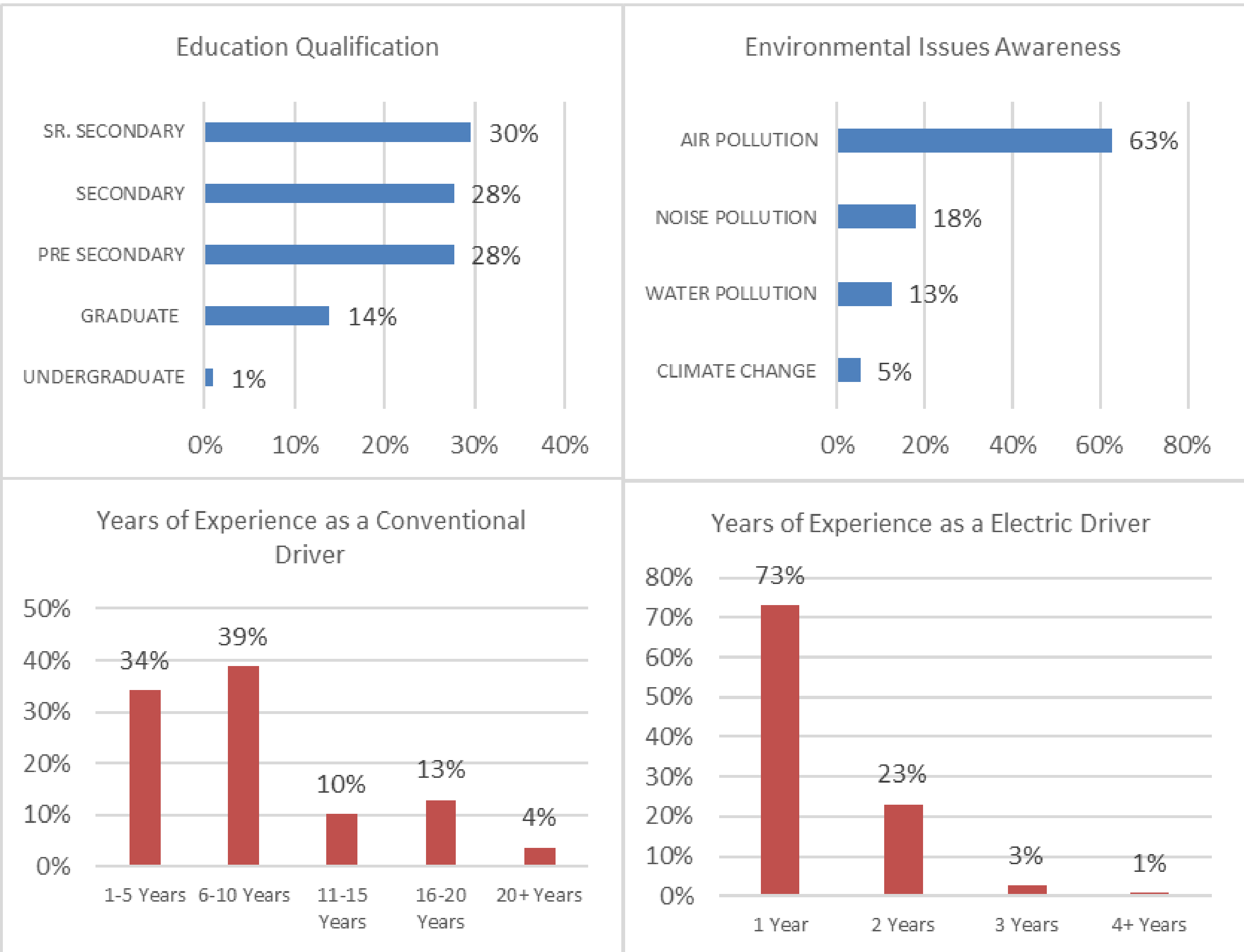
[6]https://www.livemint.com/politics/policy/delhi-govt-to-switch-its-fleet-of-cars-for-electric-vehicles-within-6-months-manish-sisodia-11614265255190.html

Figure 70: Age Profile of Respondents (in years)



Education-wise, the survey shows that 30% of the drivers have completed senior secondary school, and 28% of drivers each were pre-secondary and secondary school educated. The Figure below gives the %age distribution of drivers interviewed in the survey by educational qualification. Figure 71 shows the level of awareness of the respondent drivers about environmental issues. Analysis of the responses shows that awareness of environmental issues is not very high, with only 63% aware of air pollution and 18% and 13% aware of noise pollution and water pollution. Figure 71 shows the driving experience of the respondents with a conventional car and an electric car. The survey shows that 73% of the respondents have at least one year of experience as an EV driver, and 23% have more than two years. The respondents who are professional drivers also reported their experience in driving the conventional car, with 34% having 1-5 years of experience and 39% having 6-10 years of experience.

Figure 71: Demographic Information



Ownership of Vehicle -- Among the vehicles from the seven organisations surveyed, most were private organisation vehicles. Figure 72 shows 72% of the EVs surveyed belong to private firms.

The emphasis of each organisation in pushing Electric 4W is assessed by comparing the total number of vehicles owned by it and the share of conventional and EVs in it. Figure 73 below shows EESL has the highest share and number of EVs (97%, i.e., 315), followed by Lithium Urban Technologies (96%, i.e., 255) in its fleet. Figure 74 shows the model-wise shares of EV models considered in the survey. Among the electric car variants surveyed, Mahindra E-Verito (56%) is the most preferred EV 4W model used by fleet operators, followed by Tata Tigor (36%). Most of the fleet operators have entered the market recently, as shown in Figure 75, at least half of the electric cars have been purchased in the year 2020.

Figure 72: Type of Organisations

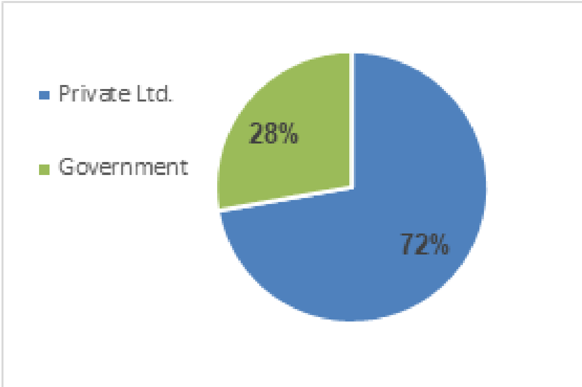


Figure 73: No. of Vehicles owned by Organisations – By Fuel Type

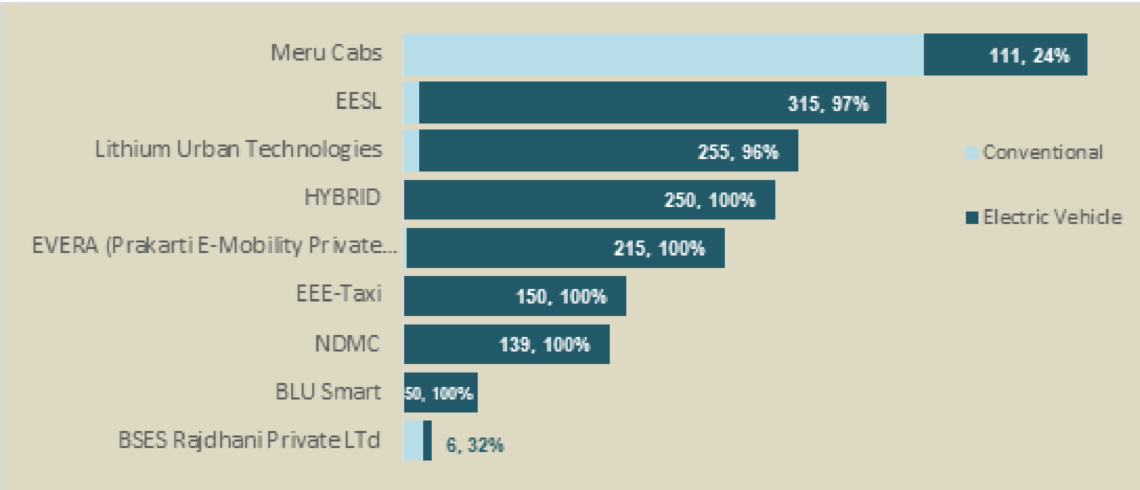


Figure 74: 4W EV Model Used by Organisation

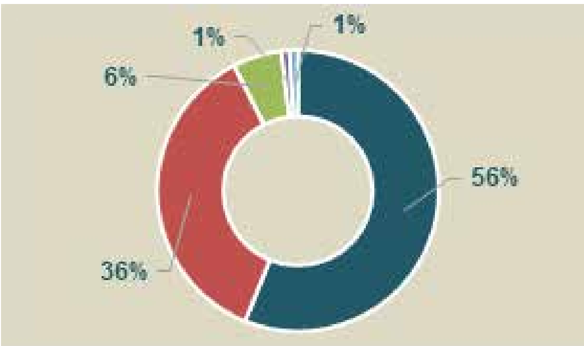
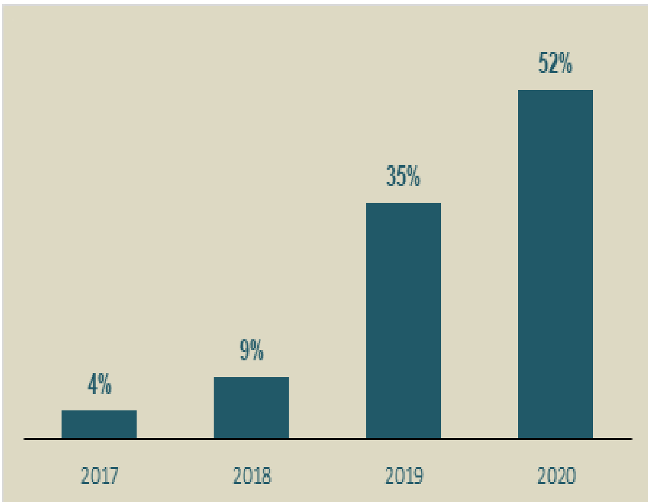


Figure 75: Year of Purchase – EV Cars



Travel & Usage Pattern of Vehicle

All respondent drivers of private fleet operators mentioned that they have only one non-working day in a week, which is Sunday, and the vehicle sits idle that day in their parking location. At the same time, respondent drivers from government organisations are working all days of the week.

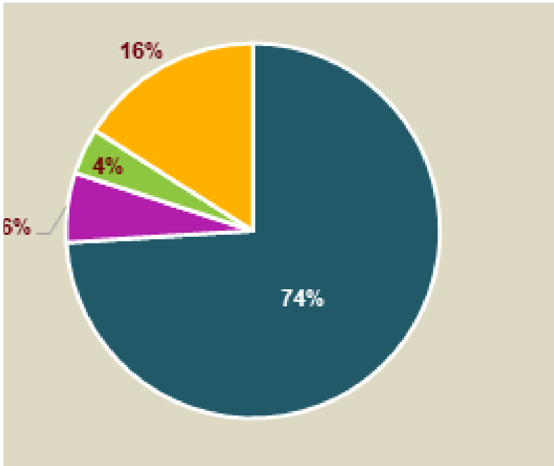
Table 24 shows that electric cars are used on all working days by government organisations and fleet operators.

Table 24: Average Frequency of Usage of EV 4W – Working Days

By Type of Organisation		
	Private	Government
Total no. of Working Days	6	7
Frequency of Usage (No. of Days)	6	7

Availability of regular or slow charging facilities and infrastructure is an essential requirement for adopting EVs. For this, the availability of parking locations where the vehicle can be charged while idle is important. Analysis of the responses on parking location in non-working hours shows that most cars (80%) are parked in the office premises and outside the office area during non-working hours, 16% park in public space or in street parking, and only 4% use garages for parking. Thus, the availability of parking space for slow charging is not a constraining factor. Figure 76 shows the parking location of electric cars during non-office hours.

Figure 76: Location of Parking Vehicle during Non-Office Hrs



A conventional taxi covers a distance of 210 km a day, whereas Ola/Uber fleet operators cover 400 km in the Delhi NCR region. As per our survey fleet, operators use their EVs to run all around the city throughout the day and cover only around 50 km to 180+ km on a working day. This shows the daily distance travelled by an EV taxi is low compared to conventional taxis. This could be because the range and time taken to charge these vehicles reduce the availability during working hours in a day. Figure 77 below shows the daily distance traveled by conventional and electric taxis owned by fleet operators and government departments in the Delhi NCR Region. Table 25 shows the standard deviation and mean of electric taxis owned by private operators and government departments.

The distance traveled by electric taxis in a working day has been divided into two parts; one owned by government departments and the other by private operators. Figure 78 shows that nearly 45% of government department-owned electric EVs run 71-80 km (40 km radius) whereas 19% of private operators run electric taxis run for around 91-100 km (50 km radius) and 47% of private operator taxis run for more than 100 km per day. Considering the range of electric taxis, the private operators utilise the vehicle to the maximum.

[7]High Resolution Emission Inventory of Major Air Pollutants of Mega City, New Delhi, SAFAR,2018-Page XX

Table 25: Electric Taxi-Statistical Info of daily Distance Travelled

	St.Dev (KM)	Mean (KM)
Electric Taxis \(Private Operators)	41.6	113.5
Electric Cars (Government Departments)	20.2	89.8

Figure 77:Daily Distance Travelled by Taxi (Conventional vs Electric)

Figure 78: Distance travelled by government department owned electric taxis

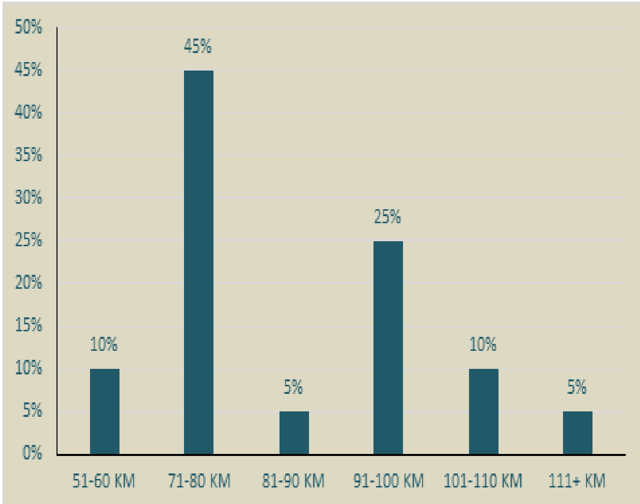
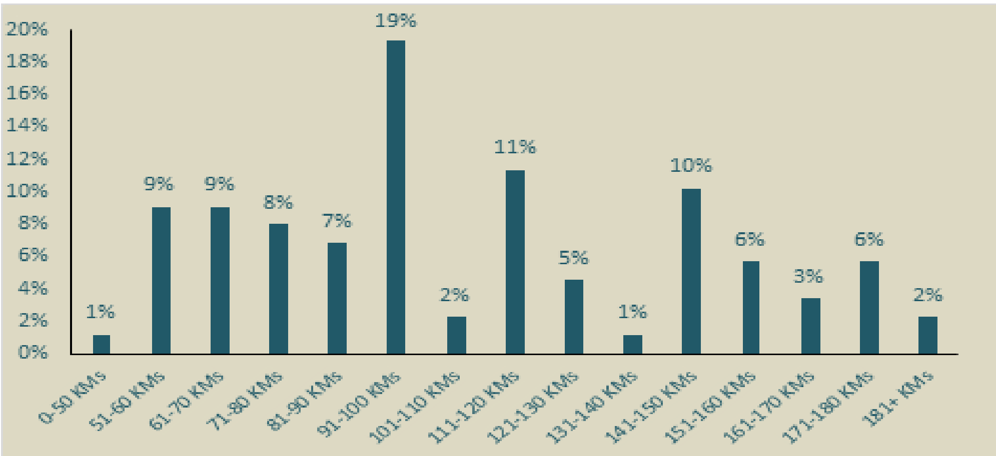


Figure 79: Average Distance Travelled – EV 4W – Working Day



3.4.2. Vehicle Servicing Pattern and requirements

The respondents were asked about the after-sales services they were currently availing themselves of and those they wished to avail themselves of. Almost 40% of respondents are availing regular maintenance and repair service of a vehicle once a year. This was followed by free service and battery check-ups. Table 26 below shows the services that drivers are currently availing and wish to avail themselves of on a regular basis. Free servicing, maintenance, repair, and battery replacement services are high on the respondents' wish list. Most of the services are equivalent to a conventional car, except for regular battery check-ups. The concern for battery replacement and checkup shows that there could be scope for a battery swapping market. The table also highlights that a part of respondents is unaware of after-sales services offered in the market. This suggests that more awareness and marketing of services is required for electric taxis. The respondents were also asked about the number of times they send their EV 4Ws for servicing and the average cost of service. It is observed that the EV 4W has a lower maintenance cost vis-à-vis conventional cars. Table 27 below shows the average number of services availed for an electric car and its cost.

Table 26: Services availed and willing to avail by EV Drivers

Sl No	After Sales Services	Currently Availing (Shares)	Willing to avail (Shares)
1	Maintenance and Repairs	40%	23%
2	Free Service	21%	26%
3	Battery Check-up	11%	6%
4	Don't Know about Servicing	11%	10%
5	Road Side Assistance	5%	5%
6	Washing	5%	1%
7	Battery Guarantee	4%	5%
8	Brake Check-up	3%	2%
9	Ac Filter Service	1%	1%
10	Battery Replacement	0%	18%
11	Vehicle Customisation	0%	3%

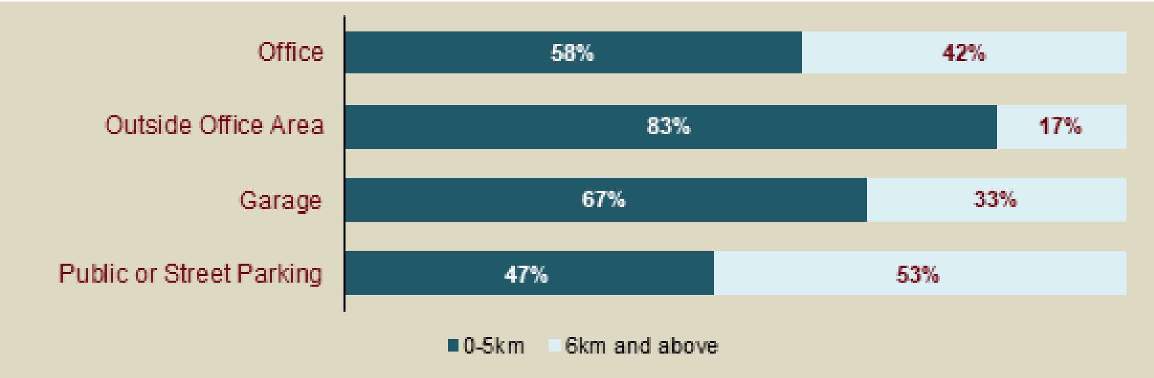
Table 27: Average Service Behaviour – EV 4W

Age of Vehicle	Average No. of Services Availed	Average Cost per Service (INR)
<1 Year	1	NA
1-3 Years	2	2,875

3.4.3. Charging Behaviour

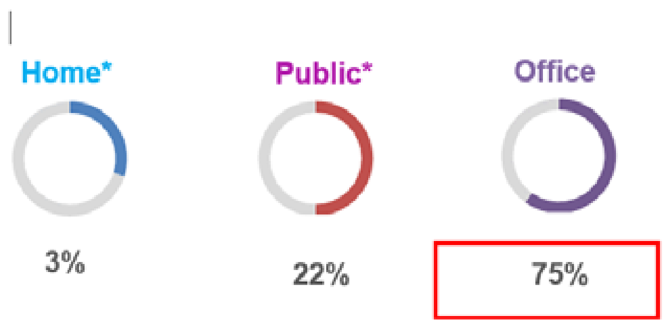
The city government is currently aiming to expand its charging infrastructure as per its announced EV policy to increase EV sales to 25% of all new vehicle registrations by 2024. Delhi currently has about 70 charging stations in that direction. The Delhi government plans to put charging stations at every 3 km radius to support the EV growth envisaged in its EV policy. To understand the outlook of the EV users and their needs from public charging, the survey asked the respondents about their experiences of public charging stations. The distance of the nearest public charging station from their regular parking spots and waiting time experienced during the most recent visit to a public charging station was noted. Based on the responses, the survey found that most of the surveyed drivers have public charging stations within a 5 km radius from their parking locations. Figure 80 summarises the drivers' responses for the distance of the nearest public charging station from their regular EV parking location.

Figure 80: Distance of Nearby Public Charging Station



Results from Figure 80 show that although public charging infrastructure lies within 5 km for a majority of the drivers. Yet, most drivers do not prefer to charge at public charging stations, as indicated in Figure 81, which shows the preferred location of charging on a working and a non-working day. Analysis of the responses shows that 75% of the respondents charge their vehicle at the office and 22% at the public charging station in a typical working day, and as the car does not run on a non-working day, no charging takes place that day. Figure 82 below shows that 46% charge their EV once a day, and 50% of the respondents charge their EV 4Ws twice a day on a working day. Very few drivers responded, saying they required charging more than twice a day. Given the limited number of times charging is required, the drivers do not seem to prefer to charge in public stations. This is shown in Figure 83, where only 58% of the respondents have visited public charging stations in the recent past, and of those who used public charging, 41% have waited less than 30 minutes, 26% have waited 30 minutes to 1 hour, and 33% experienced a waiting time of more than 1 hour.

Figure 81: Location of Charging in Working and Non-working Day	Figure 82: Frequency No. of Times/Day



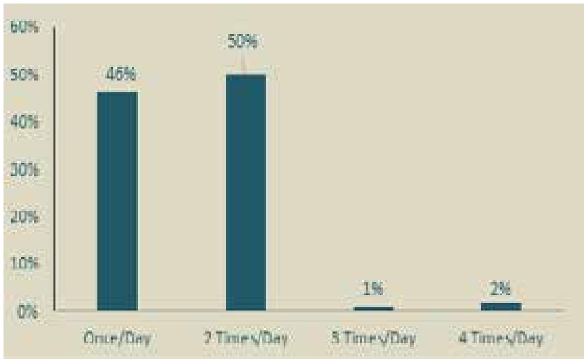


Figure 83: Experience & Waiting Time at Public Charging Station

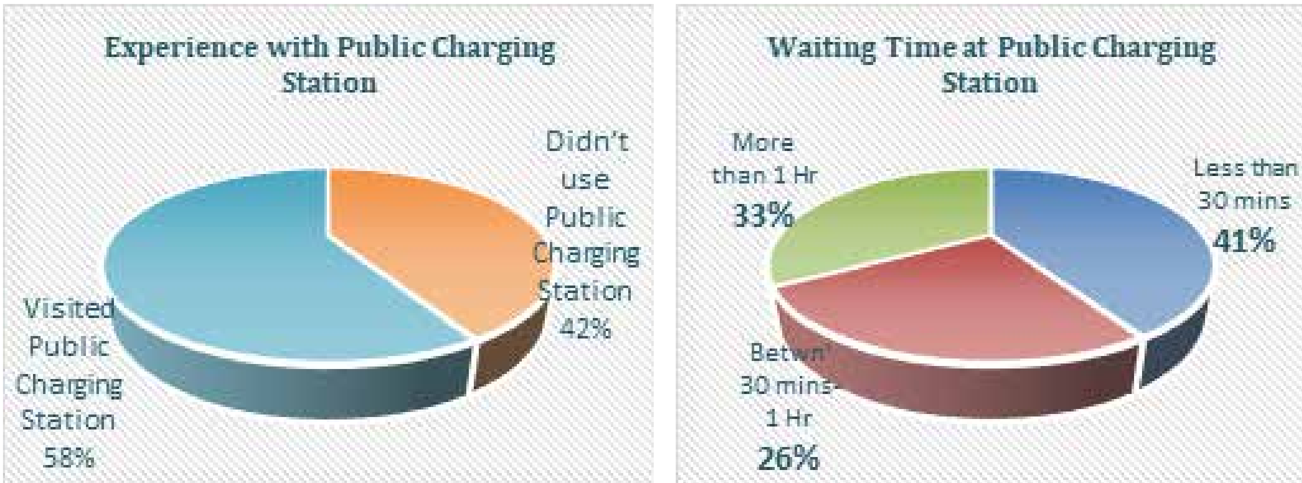


Figure 84 below shows the type of charging used by the drivers at different charging locations on a typical working day. Vehicle charging during working hours consumes time and affects the business. Hence drivers opt for the fast-charging option when charging during working hours. When the vehicle is not in use, they are charged either at home or in the office. Electric cars used in the fleet (Mahindra E-Verito and TATA Tigor EV) take up to 1.5 hours in fast charging and 6 to 8 hours for slow charging. As per the manufacturer's recommendation, EVs should be slow charged at least once a day. But almost all drivers opt for fast charging continuously. This type of charging behaviour impacts the vehicle's fitness, and drivers often experience vehicle seizures during the trip.[8] As shown in

[8]https://www.imeche.org/news/news-article/fast-charging-can-damage-electric-car-batteries-in-just-25-cycles

Figure 84, only around 3% of the respondents report charging at home, while 74% of the respondents, of which 86% used fast charging, report charging at office and 23% report that they charged their EV at public charging stations using the fast charging option. Clearly the respondents of the survey have been using fast charging for their vehicles in a majority of the cases.

Figure 84: Type of Charger Used

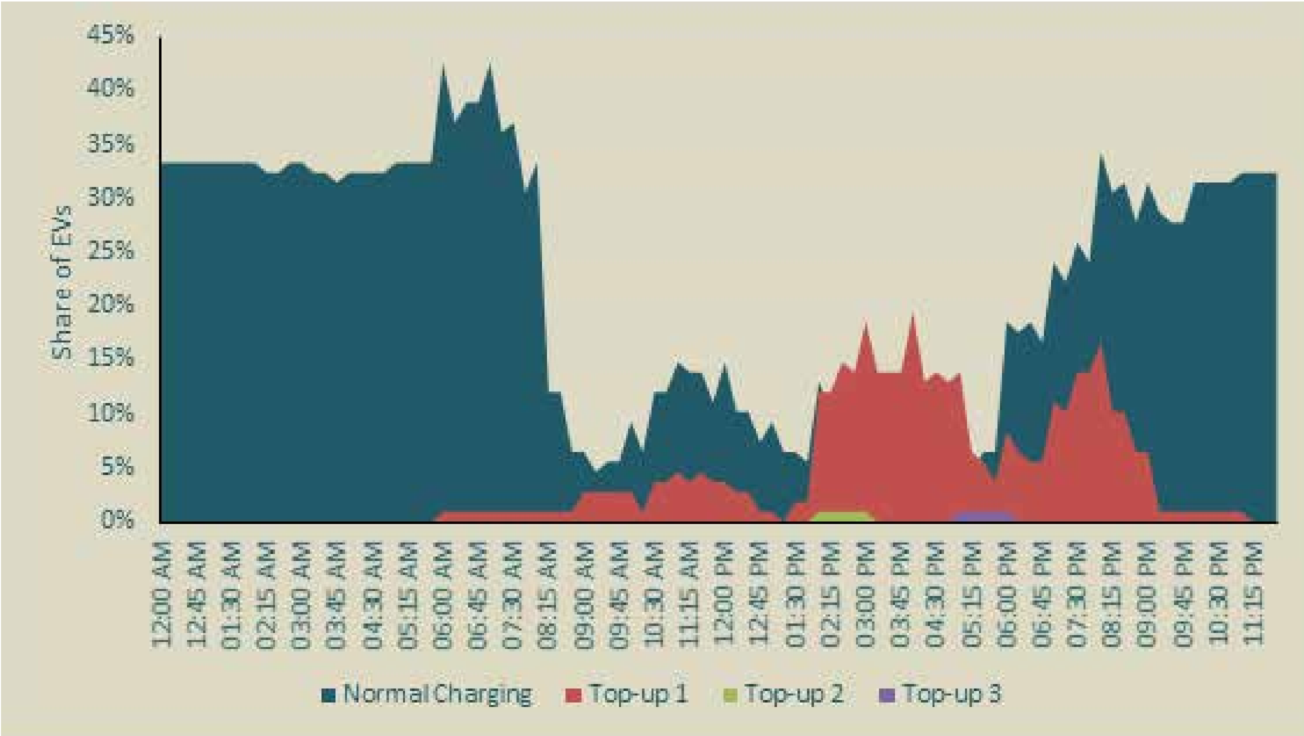
	Slow	Fast	Battery Swapping	
Home*	80%	20%	0%	*3%*
Public*	0%	100%	0%	*23%*
Office	14%	86%	0%	*74%*

Figure 85: Average Cost of Charging (₹)

	Home*	Public*	Office
Working Day	20	168	149

Further, the survey asked the respondents the average cost of charging at each of the three different types of charging locations. As per the analysis of the responses, only 28% of the respondents pay for charging their vehicles on office premises. Out of them, 20% of drivers belong to MERU, 4.63% of drivers belong to Lithium, and 1.85% of drivers belong to EESL. Figure 85 below shows the average amount spent by the drivers for charging their vehicles in a typical working day at home, public, and office premises.Charging behaviour is related to travel behaviour and the kind of vehicle the user drives. The survey has captured the charging behaviour on working and non-working days for all commercial Electric 4W vehicles. To estimate the electricity demand from the grid due to EV charging, each EV driver's plugin and plug-out time in a typical working day is computed from the survey response. The information is mapped to get the %age of total EV connected to the grid for charging at each hour. The results are divided into normal charging, which refers to the first charging of the day, top-up 1 refers to the second time charging, top-up 2 refers to the third, and top-up 3 refers to the third time charging of the day. The requirement of top-ups shows that the electric taxis are utilised to their maximum limits in a day, and their range/km needs to be improved. The following Figure 86 shows the %age share of total EV 4W institutional cars that are getting charged at each hour in a typical working day. It can be observed that almost 40% of fleet vehicles are charged in the early morning time slots of 6 to 7 am and around 30% in the evening slot of 8 pm. Morning 9 am to 5 pm is the least busy for charging; however, 5-10% of the vehicles are getting top-up charging during this period.

Figure 86: Charging pattern of EV 4Ws in a typical working day



The survey covered various electric models existing in the market today. To assess the on-road fuel efficiency of the EV 4Ws covered in the survey, the respondent drivers were asked the range that their electric 4W cars provided. Based on the responses, each model's actual range on the ground with and without AC is presented in Table 29, and their battery-charging volume and time are presented in Table 28. MG Hector ZS provides the highest range (km/charge) with and without AC, and in terms of battery charging capacity, Mahindra E20 and Tata Tigor are performing better compared to other EV variants. It is also seen that Mahindra E-Verito charges faster compared to other variants, and this is because of its low battery capacity (18.5 KWh) compared to Tata Nexon (30.2 KWh) and MG ZS EV (44.5 KWh). Tata Nexon EV and MG ZS EV also give a good charging experience compared to their battery capacity.

Table 28: Electric Car Range offer with and w/o AC

S. No	Category	Model	% of Respondents Using Model	Average Range (KM/Charge)	
				With AC	W/O AC
1	Hatchback	Mahindra e2o	6%	78	96
2	Sedan	Mahindra EVerito D2	56%	106	125
3		TATA Tigor	36%	115	139
4	SUV	TATA Nexon	1%	160	180
5		MG ZS EV	1%	300	380
6	Sedan			111	132
7	SUV			230	280
8	All EV			170	206

Table 29: Electric Car Battery Capacity

SOC - Plug-in	Average SOC (in %)	Average Battery Charged (in %)	Average Time Taken (in hrs.)	Proportion of Respondents
Working days				
5-10	9.0	85.4	5.5	3%
11-20	18.2	81.7	3.5	17%
21-30	28.5	70.6	4.7	33%
31-40	38.7	58.7	3.9	20%
41-50	49.4	46.1	2.9	18%
51-60	60.0	38.3	2.9	7%
61-70	68.3	31.3	1.7	2%
Average	38.9	58.9	3.6	100%

3.4.4. Consumer Opinion and Preferences

The survey sought to understand the consumer preferences of the respondent drivers of institutionally owned EV 4W. To assess the user experience of the respondent drivers from driving the EV 4W, the survey respondents were asked to rank the satisfaction from EV 4W on a scale of 1-5 (1-Not Satisfied; 2-Somewhat satisfied; 3-Neutral; 4-Satisfied; 5-Very Satisfied). The %age of rankings by the respondents for EV 4W is shown in Figure 87, which shows that driver satisfaction was notably high for EVs, with 91% of respondents (49% ranking as very satisfied and 42% ranking as satisfied) expressing satisfaction with their EV 4Ws compared to conventional cars. Earlier it was shown that the respondent drivers have more experience driving conventional vehicles yet, most of them prefer to drive an electric car. This shows the level of comfort and satisfaction of the drivers with their EV 4W cars.

Figure 88: EV Type Purchase Recommendations

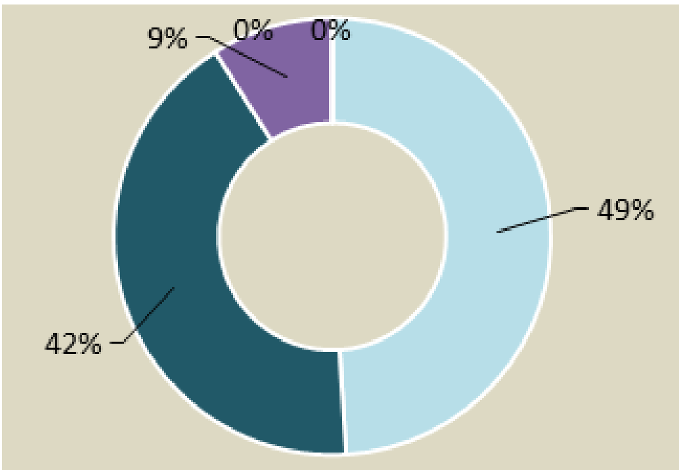
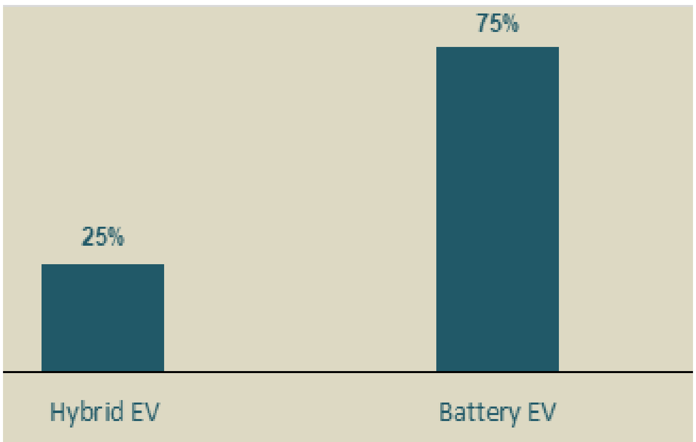


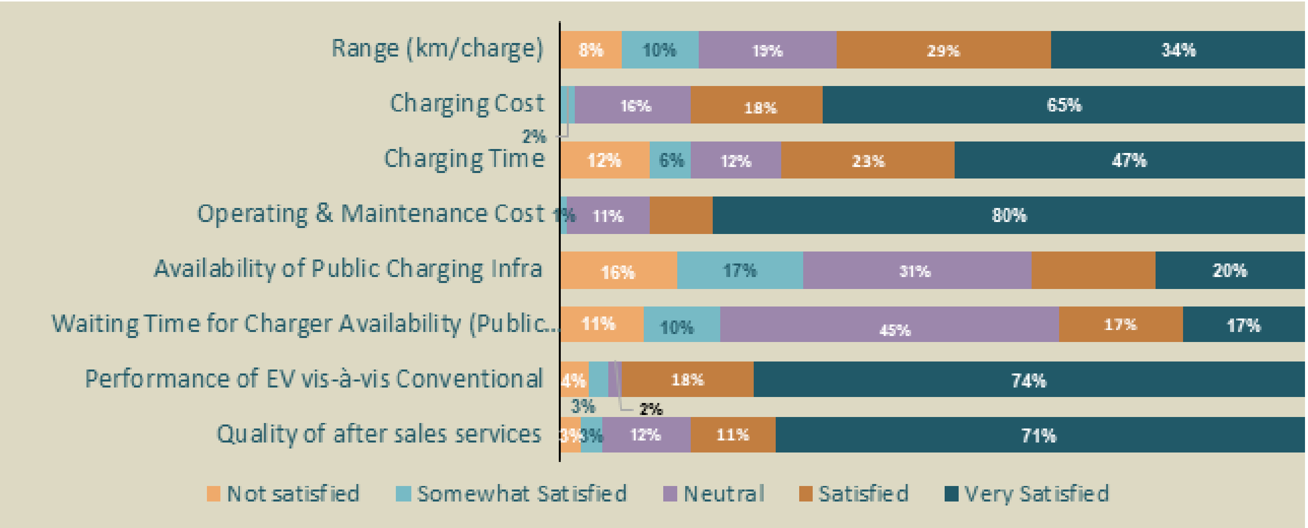
Figure 88: EV Type Purchase Recommendations



Based on the above analysis, it can be concluded that the level of satisfaction of driving an electric car is much higher compared to its conventional counterpart. Despite its few drawbacks, 100% of the respondents recommended an electric car for their future purchase. To ascertain if the user experience of drivers of EV 4Ws was similar to conventional cars, the respondents were asked if they would be purchasing a battery EV or Hybrid EV, which may help them overcome range and charging time issues. The driver responses presented in Figure 88 below showed that 75% would recommend a battery EV.

To understand more specifically various aspects of EV which are liked by the drivers and those that are constraints to the drivers in using EV 4Ws, we also assessed the satisfaction level among the sample respondent drivers about various factors of an electric car. Figure 89 below shows the %age share of respondent rankings for each aspect of EVs. The rankings are consistent with their overall satisfaction rankings for their EV 4W, shown in Figure 87 above. Availability of public charging infrastructure and higher waiting time for charging are the aspects for which the least number of respondents have ranked as satisfied or very satisfied and thus appear to be the major pain points for electric car users. A significant majority of respondents seem to be very satisfied with charging cost, operations and maintenance cost, the performance of EV vis-à-vis conventional, and the quality of after-sales service. In the case of range, 34% of respondents said they are very satisfied, while 29% said they are satisfied, and 19% said they are neutral. Similarly, 47% of respondents said they are very satisfied with charging time, while 23% said they are satisfied, and 12% said they are neutral. Thus, compared to the other aspects, there seems to be some scope for improving range and charging time for improving users' satisfaction levels.

Figure 89: Satisfaction of Respondents from various factors

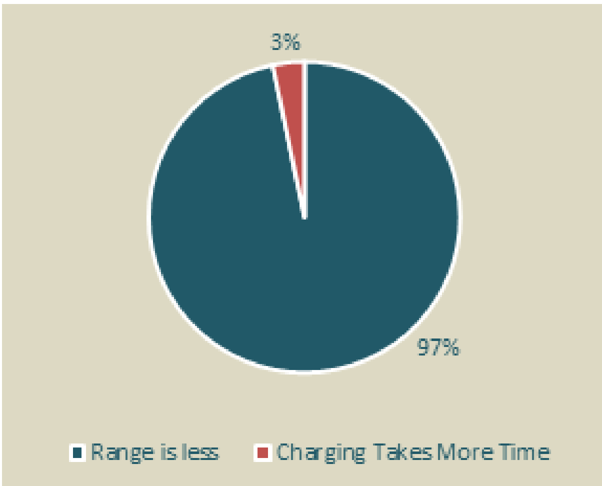


Issues and Suggestions for Various Aspects of EV Ranked

The respondents were also asked to mention the issues and suggestions for improvement on each aspect of the EV vehicle that they ranked. A summary of the responses on each aspect is provided below.

Range: Figure 90 shows that when asked to list issues with their EV, 93% of the respondents listed the range of their EV 4Ws as an issue, and when asked to suggest improvements, 89% suggested their manufacturers improve the range of the vehicles so that they could drive more on the same charge.

Figure 90: Issues and suggestions for the range of EV 4W



Charging cost: 12% of the respondents had an issue with the high charging cost as they are bearing the private electricity costs for charging their EVs, and 10% suggested that the charging cost should be less.

Charging Time: 34% of the respondents had issues with the charging time of their EV 4Ws, and 38% suggested that it should take less time to fully charge the vehicle.

Operational & Maintenance Cost: Almost all the respondents were satisfied with their EVs' operational & maintenance cost, and very few indicated that their manufacturer takes good care of the vehicle.

Availability of Public Charging Infra: 54% of the respondents complained about having a smaller number of charging stations within their vicinity. 43% wished to have a greater number of public stations, and 20% suggested having charging points everywhere.

Waiting Time for Charger Availability (Public Stations): 13% of the respondents experienced long queues at public charging stations and suggested having more machines or points in a single vicinity.

Almost all of the respondents were satisfied with the performance of their EV vis-a-vis conventional taxis and quite happy with the after-sales services offered by their manufacturers.

Suggestions for improvement: Respondents listed below have provided some suggestions for improvements from the drivers interviewed to make these electric more competitive than their conventional variants. Some of the suggestions are as follows:

1. The range (km/charge) of EV 4Ws should be more. 19% of the respondents suggested improving the range of EV 4W. Out of these, 47% suggested improving the range of their EVs to 200-250 KMs, and 40% suggested improving more than 250 km.
2. The availability of public charging stations should be improved.
3. The cost of charging should be affordable.
4. Charging efficiency should be more - faster charging. 13% of the respondents suggested improving the charging time of their EV 4Ws. Out of these, 36% suggested that their EVs should charge within 1 hour and 43% suggested charging time should be 1 hour, and 21% suggested charging time should be more than 1 hour.
5. The quality of after-sales services should be improved.
6. Operating and maintenance costs should be less.
7. The running cost of EVs should be less vis-à-vis conventional vehicles.

Of the total drivers surveyed, 28% visited public charging stations; the respondents were asked to list factors they liked and disliked about public charging. Table 30 reveals the reason for liking and not liking the public charging facilities.

Table 30: Factors of using public charging station

Factors of using Public Charging Facility	
Key Likeable factors	Key Non-Likeable factors
Faster Charging- 26%	Higher Waiting time-29%
Nearby Home or Office-12%	Less no. of charging stations-13%
No parking charges-1%	Poor infrastructural amenities-9%

3.4.5. Final recommendations

Driver and organisation profile

1. All the respondent drivers of the survey are male, and a majority of them, around 69%, belong to the age group of 24-39 years. Education-wise, the majority of them are either senior secondary school, secondary school or pre-secondary educated with low awareness of environmental issues.

2. The respondent drivers in the survey had a minimum of 1 -2 years of experience driving EV 4Ws and 1-5 years in driving conventional vehicles. Many of the drivers had ten or more ten years' experience in driving conventional cars also.

3. Among the vehicles from the seven organisations surveyed, 72% of the EVs surveyed belong to private firms.

4. Among the electric car variants surveyed, Mahindra E-Verito (56%) is the most preferred EV 4W model used by fleet operators, followed by Tata Tigor (36%). Most of the fleet operators have entered the market recently in the year 2020.

Travel pattern

5. Commercial EVs owned by government agencies are operational seven days a week. Those owned by private fleet agencies are operational six days a week. Sunday is a non-working day when the vehicle is idle and parked.

6. In non-working hours most of the cars (80%) are parked in the office premises and outside office area, 16% park in public space or in street parking, and only 4% use garages for parking.

7. Nearly 50% of government department-owned electric taxis run 71-80 km (40 km radius), whereas 20% of private operators run electric taxis run for around 91-100 km (50 km radius), and 53% of private operator taxis run for more than 100 km per day.

8. Daily average distance travelled by government EV cars is 90 km, and by private EV taxi operators are 114 km, which is low compared to a conventional taxi that covers 210 km a day or Ola/Uber fleet operators that cover 400 km a day.

Charging

9. Public charging infrastructure lies within 5 km for most of the drivers, yet most drivers do not prefer to charge at public charging stations. 75% of the respondents charge their vehicles at the office and 22% at the public charging station.

10. Nearly 97% of the respondents charge their EV 4Ws at most twice a day. Given the limited charging requirement, the drivers do not seem to prefer to charge in public stations due to the long waiting time

11. The lack of preference for public charging is seen from the fact that only 58% of the respondents have visited public charging stations in the recent past, and of those who used public charging, 41% have waited less than 30 minutes, 26% have waited 30 minutes to 1 hour, and 33% experienced a waiting time of more than 1 hour.

12. Only 3% of the respondents charge at home, while 74% of the respondents, of which 86% used fast charging, report charging at the office and 23% charge their EVs at public charging stations using the fast charging option. Vehicle charging during working hours consumes time and affects the business. Hence drivers mostly opt for the fast-charging option. Frequent and continuous fast charging affects vehicle and battery fitness.

13. 40% of the commercial EVs are charged in the early morning time slots of 6 to 7 am and around 30% in the evening slot of 8 pm. Morning 9 am to 5 pm is the least busy for charging. However, 5-10% of the vehicles are getting top-up charging during this period.

14. The average range of the institutionally owned EVs surveyed was 170 km and 206 km per charge in the case of with and without AC, respectively. The average SOC at the time of plug-in for charging was 39%, and the average time taken for charging was 3.6 hours.

Driver preferences

15. Most after-sales services are similar to a conventional car, except for regular battery check-ups. Free servicing, maintenance, repair, and battery replacement services are high on the wish list of the respondents. Additionally, drivers have expressed the need for battery replacement and checkup services, indicating a potential market for maintenance and battery services, including battery swapping. Lack of awareness about sales services offered, indicating advertising and awareness campaign for marketing of services is required for electric taxis.

16. The average number of services availed for an electric car less than a year old is one and by an electric car more than a year old is 2. An EV 4W has a lower maintenance cost vis-à-vis the conventional car.

17. Driver satisfaction was higher for EVs, with more than 91% of respondents (49% ranking as very satisfied and 42% ranking as satisfied) expressing satisfaction with their EV 4Ws, compared to conventional cars. Despite having issues with range and charging time, 75% of respondents recommended battery EVs and only 25% recommended hybrid vehicles.

18. Availability of public charging infrastructure and higher waiting time for charging are the aspects for which respondent drivers are least satisfied.

19. A significant majority of respondents seem to be very satisfied with charging cost, operations and maintenance cost, the performance of EV vis-à-vis conventional, and quality of after-sales service.

20. Compared to the other aspects, there seems to be some scope for improving range and charging time for improving the users' satisfaction levels. 90% of respondents listed range as an issue that needs improvement, and 54% listed availability of public charging infrastructure.

21. 19% of the total respondents suggested improvements in the range of EV 4Ws, of which 47% suggested a range of 200-250 km and 40% suggested more than 250 km.

22. 13% of the respondents suggested improving the charging time of their EV 4Ws, of which 36% preferred a charging time of less than 1 hour and 43% suggested a charging time of 1 hour, and 21% suggested a charging time of more than 1 hour.

23. Faster charging, near home or office, and no parking charges, are key likeable factors about public charging stations. Higher waiting time, a smaller number of charging stations, poor infrastructural amenities are key non-likeable factors about public charging stations by the respondent drivers.

3.5 E-rickshaws

3.5.1. Demographic Profile

A survey of e-rickshaw drivers (owners + renters) was conducted in Delhi in September 2020. The sample size of the survey was 122 and the reference period has been chosen to be February, 2020 (pre-lockdown normal month). Pilot surveys conducted before the survey had indicated that there was a significant difference in the travel and charging behaviour during weekdays and weekends. Therefore, the questionnaire was designed accordingly to assess the responses for weekdays (Monday to Friday) and weekends (Saturday and Sunday). The results are presented in the following sections.

Age Profile of Respondents (in years)

As the Table 31 shows, 52% of the drivers are between the age bracket of 25-39 followed by 30% who are between 40 and 55, and only 16% is between 18-24.

Table 31: Age Profile of Respondents

Age	18-24	25-39	40-55	56+
No. of e-rickshaw drivers	16%	52%	30%	2%

Educational Qualification

It has been observed that most of the e-rickshaw drivers have completed their pre-secondary and secondary education as, 55% of the e-rickshaw drivers are pre-secondary qualified (till, the eighth standard) and 33% have completed their secondary education. Only 7% of e-rickshaw drivers have completed senior-secondary, and 2% have completed graduation.

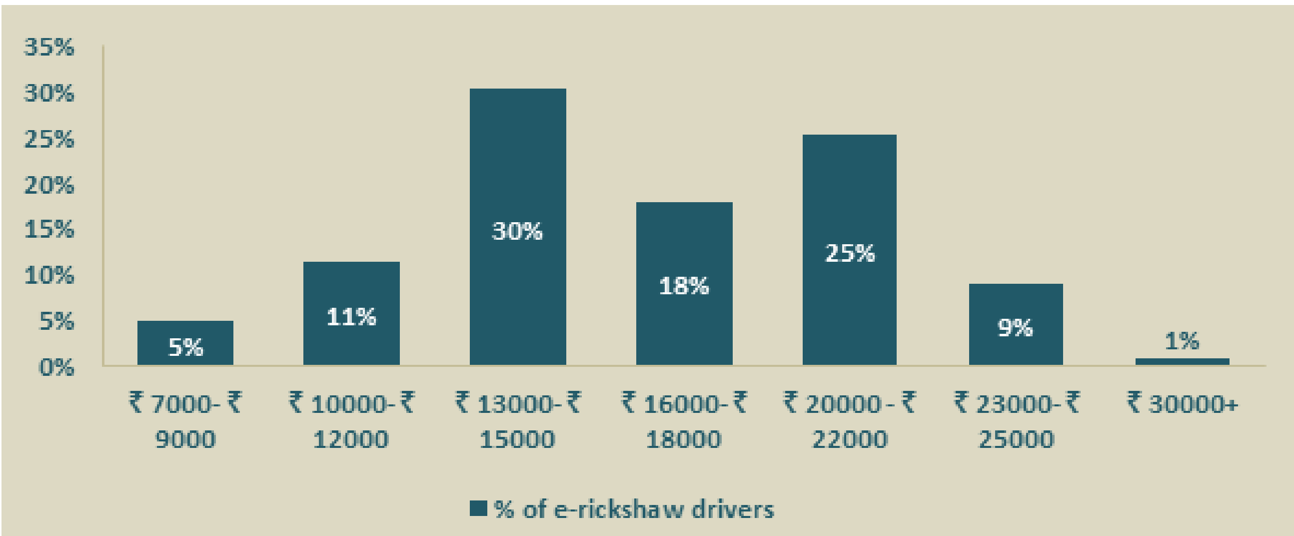
Table 32: Educational qualification of respondents

Education Qualification	Illiterate	Pre-Secondary	Secondary	Senior-Secondary	Graduate
% of e-rickshaw drivers	2%	55%	33%	7%	2%

Monthly Income

The average income of E-Rickshaw operators is INR16,786 per month, and the standard deviation is 323.137. For e-rickshaw owners, the average income is approximately INR17,237, whereas the renter e-rickshaw drivers' average income is approximately INR14,619. Overall, 30% of the e-rickshaw drivers had monthly income between INR13,000 -15,000, followed by 25% had income in the range of INR20,000- INR 22,000 per month. Only 1% e-rickshaw drivers had their monthly income above INR30,000.

Figure 91: Monthly income of e-rickshaw drivers



3.5.2. Vehicle Ownership & Usage Pattern

a. Year of Purchase

Table-33 depicts that 28% of the e-rickshaws have been purchased in 2019, 24% in 2018, 18% purchased in 2016 and only 8% were purchased between 2012-2015. 2/3rd of the e-rickshaws have been purchased between the years 2017-2019, and only 10% are less than a year old. The main reason for the increase in the demand of e-rickshaws between 2017- 2019 can be attributed to the increase in use of e-rickshaws as last mile connectivity for the working population commuting through metro and buses daily.

Table 33: Year of Purchase of E-Rickshaws

Purchase Year	2012-2015	2016	2017	2018	2019	2020
Number of e-rickshaws	8%	18%	13%	24%	28%	10%

b. Ownership Pattern

The government has paved the way for e-rickshaw buyers to buy their own vehicles by providing financial and non-financial incentives. Presently, 83% of e-rickshaw drivers have their own e-rickshaws, and 17% e-rickshaw drivers drive on rent.

Table 34: Ownership and Renters distribution

Own an Electric Rickshaw	Owner of e-rickshaw	Rents e-rickshaw
%age of e-rickshaw drivers	83%	17%

c. Purpose of using E-Rickshaws

E-rickshaws are being used for mainly two purposes: 1) ferrying passengers within the locality and 2) loading and unloading of goods, either from supermarkets or Kirana stores.

Table 35: Purpose of using e-rickshaws

Purpose of use of e-rickshaw	Ferrying Passengers	Commercial Goods Carriage	Both
	97%	2%	2%

The survey found that 97% of the e-rickshaws were used for plying passenger to metro stations and back to their destinations. Only 2% of e-rickshaws were being used for both loading and unloading of freight and passenger transport and no e-rickshaw is dedicated for commercial goods carriage only.

d. Rent paid per day

The average per day rent is approximately INR242, and the standard deviation is 7.27 for drivers who drive e-rickshaws on rent. The 33% renter drivers pay INR300/day as rent, and 28% pay INR250/day. Only 5% pay INR150 per day as rent.

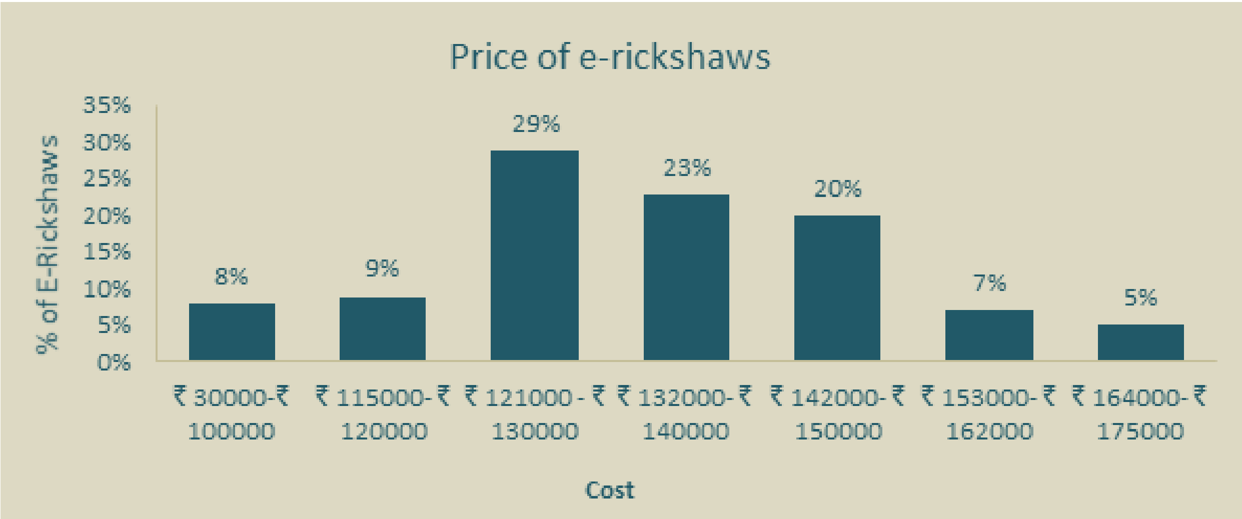
Table 36: Rent paid for driving e-rickshaws

Rent Per Day	INR 150	INR 200	INR 250	INR 300
%age of e-rickshaw drivers	5%	29%	43%	24%

e. Cost of E-Rickshaws

The average cost of e-rickshaw surveyed is INR13,2604, and the standard deviation is 1427.72. 50% of the e-rickshaws cost between INR1.18 lakhs to INR1.38 lakhs. Meanwhile, 36% of the e-rickshaws are reported to fall in the price range of INR1.40 lakhs to INR1.60 lakhs. Only 6% of the e-rickshaws fall in the higher price range of INR1.62 lakhs to INR1.75 lakhs. From this survey, the overall capital cost of an e-rickshaw (fitted with lead-acid batteries) is between INR1, 30,000 to INR1, 80,000.

Figure 92: Cost of E-rickshaws



f. Sources of finance for E-Rickshaws

Table 37 shows the mode of finance used by the e-rickshaw drivers for purchasing e-rickshaws. Approximately, 44% of e-rickshaw drivers purchased their e-rickshaw vehicles from their own money (previous savings). Bank finance was opted for by only 32%. This is primarily because mainstream financiers such as banks and non-banking financial companies do not provide financing to electric 3W drivers. They cannot meet lending requirements like self-funding for a minimum of 30% of the initial cost of auto-rickshaws and collateral of about 1.5 times the amount financed. If we also consider support from relatives and cash payment together, 52% of e-rickshaw drivers purchased their e-rickshaws through their family resources. 11% purchased through private finance and 6% from other finances. Clearly, self-financing is the dominant source of finance for e-rickshaw drivers.

Table 37: Source of finance for purchasing e-rickshaws

Mode of Finance	Own Money	Bank Finance	From Relatives	Cash Payment	Showroom Finance	Any Finance	Private Finance
%age of e-rickshaw drivers	44%	32%	2%	6%	2%	4%	11%

g. E-Rickshaw Battery Replacement practices

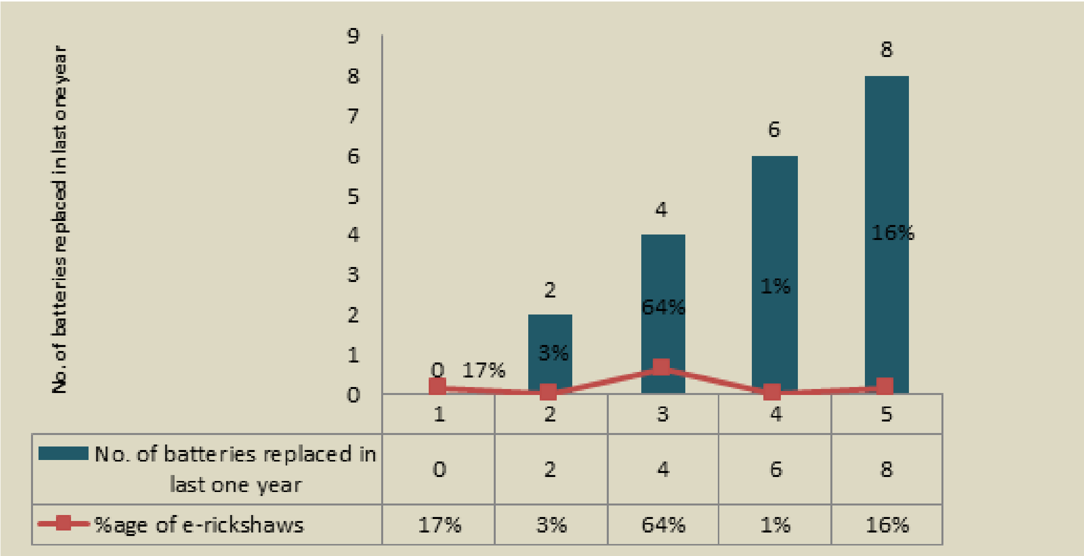
Batteries are the significant component of e-rickshaws and need replacement, depending upon the number of charges and discharges. An e-rickshaw comprises four sets of batteries (in case of lead-acid battery type) or two sets of batteries (in the case of Lithium-ion, or Li-ion battery type). In comparison to e-2Ws, the penetration of Li-ion batteries is relatively low in the electric 3Ws segment. In this survey, the sample showed that all of the e-rickshaws were found to be running on lead acid. However, people prefer fast charging, so preference for li-ion might rise in future.

Table 38: Battery Configuration

Battery Configuration	Lithium Ion	Pb Acid
%age of e-rickshaw drivers	0%	100%

The survey response on batteries replacement in e-rickshaws shows that 64% of the e-rickshaws got four batteries replaced with newer ones in one year, 16% had to replace eight batteries in a year, and 17% did not have to replace any.

Figure 93: Number of batteries replaced during FY2019-20 Feb & battery replacement practices



The average cost of a lead-acid battery came up to INR3,548 per unit, and the average batteries replaced in the last one year were four.

3.5.3. Vehicle Travel Pattern

This section analyses the travel pattern of e-rickshaws in Delhi. The peak time of the e-rickshaw is determined by the peak in the demand for e-rickshaws during a day. These peak hours are determined generally by the office-going people who use metro and buses daily for their regular commute.

a. Weekday - Morning & Evening Peak Hours

During weekdays, 64% of e-rickshaw drivers have reported their peak demand in the morning between 8 am and 11 am. On the other hand, 25% have reported their peak demand from 8 am to 10 am, followed by 22% who have indicated their peak demand time between 7 am to 11 am. Only 3% of the e-rickshaw drivers have reported their peak demand time between 8 am and 12 pm.

Table 39: Morning peak hours- weekday

Peak Hours Morning	7 am-11 am	8 am-10 am	8 am-11 am	8 am-12 pm	9 am-12 pm
% of e-rickshaws	22%	25%	39%	3%	11%

Table 40: Evening peak hours - weekday

Peak Hours Evening	4pm-10pm	5pm-9:30pm	6pm-9pm	7pm-9pm
%age of e-rickshaws	8%	32%	51%	8%

In the evening, 51% of the e-rickshaw drivers have reported that the demand for e-rickshaws peaked between 6 pm to 9 pm, followed by 32% having high demand between 5 pm to 9:30 pm. Only 8% of the e-rickshaw drivers reported their peak demand between 4 pm and 10 pm & 7 pm to 9 pm separately.

b. Weekend - Morning & Evening Peak Hours

On weekends 35% of e-rickshaw drivers have reported their peak demand between 10 am to 2 pm, followed by 36% of them having the peak in demand between 11 am to 1:30 pm. On the other hand, during the morning non-peak hours, only 91% of e-rickshaws are being used.

Table 41: Morning peak hours - weekend

Peak Hours Morning	8 am-12 pm	9 am-12 pm	10 am-2 pm	11 am-1:30 pm	11 am-4 pm	12 pm-3 pm
% of e-rickshaws	6%	10%	35%	36%	5%	9%

Table 42: Evening peak hours - weekend

Peak Hours Evening	4 pm-10 pm	5 pm-9 pm	6 pm-9:30 pm	7 pm-9:30 pm
% of e-rickshaws	3%	20%	58%	19%

About 78% of e-rickshaws reported their evening peak hours between 5:00 pm till 9:30 pm on a regular weekend. On the other hand, during non-peak hours, only 79% of the e-rickshaws are operating the evening hours during the weekend.

Table 43: Morning non-peak hours

Non-Peak Hours Morning	5 am-7 am	7 am-9 am	9 am-12 pm
%age of e-rickshaws	17%	70%	4%

Table 44: Evening non-peak hours

Non-Peak Hours evening	12 pm-3 pm	3 pm-6 pm	6 pm-9 pm
%age of e-rickshaws	35%	42%	2%

c. Range of E-Rickshaws

Range plays an important role in the decision making about any electric vehicle and the average range of e-rickshaws has been estimated as approximately 63.24 km/charge. However, the range varies for e-rickshaw drivers. 57% of the e-rickshaws drivers reported a range of 50 km-65 km/charge, 33% had the range between 70 km-85 km/charge and only 5% of the e-rickshaws had a range above 90 km/charge, and 6% had the range below 45 km/charge. Since the same e-rickshaw is used for ferrying passengers and for commercial loading, the range is the same for both the e-rickshaws.

Table 45: Range of E-Rickshaws

Range	30- 45 km/charge	50 - 65 km/charge	70 - 85 km/charge	90-105 km/charge
%age of E-Rickshaws	6%	57%	33%	5%

d. Distance Per Trip/Trip Length

Tables 46 and 47 provides the travel pattern of an e-rickshaw during weekdays & weekends for passenger e-rickshaws & e-rickshaws (goods carriage) respectively. The parameters included are average no. of trips, distance covered, peak & non-peak hours, number of persons ferried per trip in peak and non-peak hours, and the average revenue earned per trip.

Passenger E-Rickshaws

Table 46: Parameters for Passenger e-rickshaws

Type of day	Average no. of trips/hr	Average Distance/ per Trip in km	Average no. of Peak hours	Average no. of persons/per trip (Peak hrs)	Average no. of persons/per trip (non-Peak hrs)	Average Revenue Earned/Trip (Peak Hrs) (INR)
Weekday	2.50	3.64	6.44	4.89	2.67	INR 50
Weekend	1.95	3.64	5.17	4.69	2.32	INR 50

Commercial E-Rickshaws

Table 47: Parameters for commercial e-rickshaws

Type of day	Average no. of trips/hr.	Average Distance/ per Trip in km	Average Wt. in Kg. Carrying/trip	Average Revenue Earned/trip (INR)
Weekday	2.00	10.50	200.00	200
Weekend	1.00	8.00	150.00	165

Average revenue earned/per trip (during peak hours) by passenger vehicle E-Rickshaw is INR50 on Weekday & Weekend

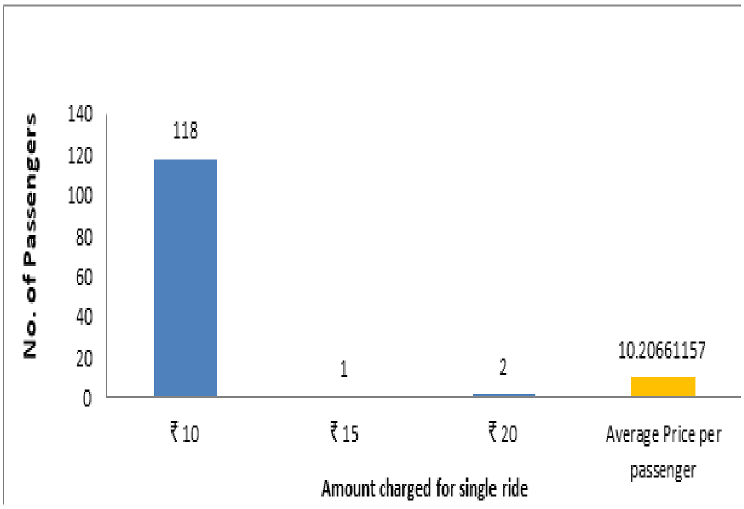
^Revenue Earned/Trip (INR) = Average No. of Persons/trip (Peak Hrs) *Average Price Charged per customer/per trip; Average charge per trip considered = INR10

e. Price/Per Passenger

The fare charged per passenger by the e-rickshaw operators varies between INR10 to INR20. Currently, there is no fixed structure for the fare to be charged from the passengers in Delhi. Passengers pay a minimum fare of INR10 for a single trip (one way).

As would be shown later, the average charging time for the e-rickshaw was found to be 10 hours (for both weekdays & weekends) implying a working time of 14 hours a day. On weekdays, e-rickshaws in Delhi had an average trip rate of 2.5 trips/hour with an average distance of 3.64 km/trip implying an

Figure 94: Fare charged per passenger/ ride & average price per ride



average daily VKT of 127 km/day while on weekends the average trip rate was 1.95 trips/hour with an average distance of 3.64 km/trip implying an average daily VKT of 99 km/day.

3.5.4. Vehicle Charging Behaviour

a. Modes of Battery Charging

There are three methods for charging an e-rickshaw battery. The respondents were asked about their mode of battery charging. Survey responses show that 57% of battery charging is being done at the private commercial charging facility, and 43% opt for home charging and none of the e-rickshaw drivers are using battery swapping mode for battery charging.

Table 48: Battery Charging Modes

Mode of Battery Charging	Home Charging	Commercial Charging	Battery Swapping
%age of e-rickshaw drivers	43%	57%	0%

b. Charger Types

As per the survey results, about 98% of respondents charge their e-rickshaw once in a day during weekdays & weekends. For regular and top-up charging, respondents prefer wall socket as a charging option. 72% of e-rickshaws use wall socket chargers and 28% use dedicated EV chargers for regular charging. At home, the wall socket is the most preferred charging option used; whereas in private commercial charging, people use both options, i.e., wall socket and dedicated EV charger. Top-Up charging refers to charging the vehicle for a shorter duration in addition to regular charging. Only 3 e-rickshaw drivers are doing top-up on weekdays and weekends. Hence, we can infer that since the e-rickshaws surveyed in this study are not very old, they give a good overall range.

Table 49: Charger Types

Total no. of public charging (i.e., pvt. commercial charging)	Total no. of e-rickshaws using wall socket in pvt. commercial charging area	Total no. of e-rickshaws using dedicated EV charger in pvt. charging area
69	35 (51 %)	34 (49%)
Total number of home charging	Total no. of e-rickshaws using wall socket in home charging	Total no. of e-rickshaws using dedicated EV charger in home charging
53	53 (100%)	0 (0%)
Regular	Total no. of e-rickshaws using wall socket for regular charging	Total no. of e-rickshaws using Dedicated EV charger for regular charging
122	88 (72%)	34 (28%)
Top-up charging	2%	

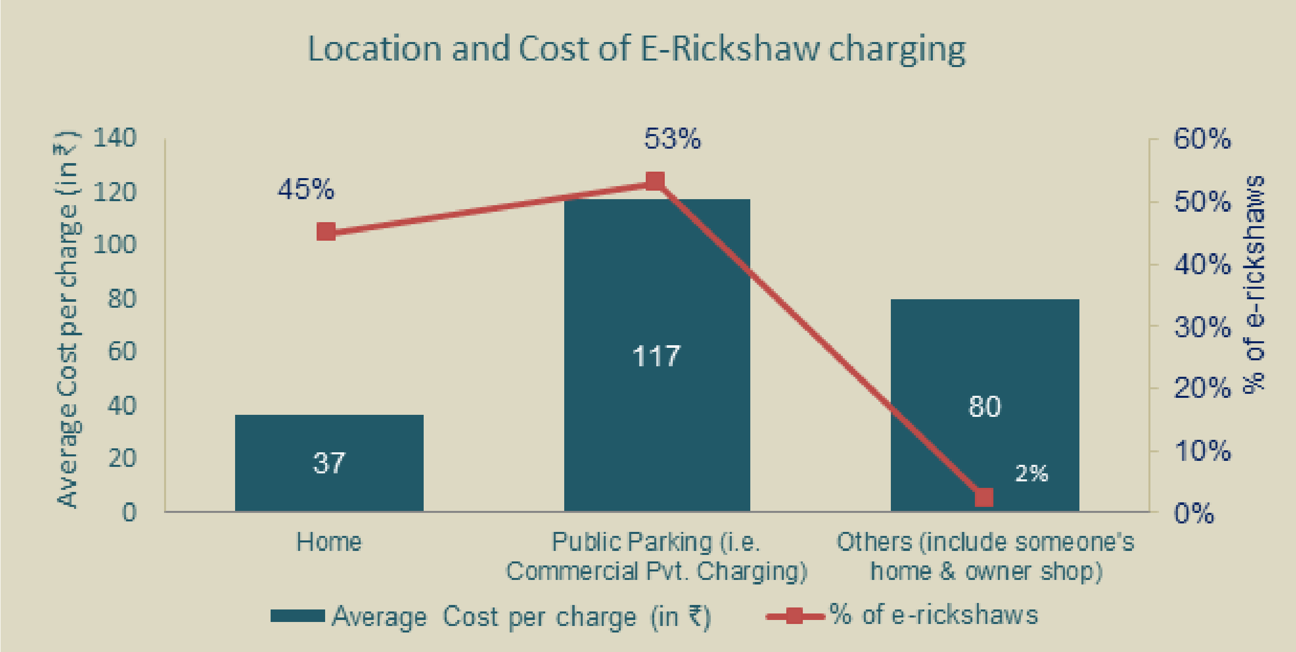
c. Location of e-rickshaw charging

53% of the charging is being done at private parking facilities, whereas 45% of the e-rickshaw drivers are charging their e-rickshaws at their homes. Only 2% of e-rickshaws are charged at other locations (i.e., homes of friends or relatives).

d. Cost per charge per day

Cost of charging refers to the money spent per day on the charging of e-rickshaw batteries. The average cost per charge of batteries has been estimated to be INR37, INR117 and INR80 for home, private parking and others respectively (for weekdays and weekends).

Figure 95: %age distribution for e-rickshaws using different charging locations & cost of charging per charge per day at various locations of charging



e. Frequency of Charging of e-rickshaw batteries

Frequency of battery charging is defined as the number of times the e-rickshaw battery is being charged in a day or a week. Survey results show that 87% of the operators fully charge their e-rickshaw batteries daily, 10% charges six times per week, 1% charges four times per week and only 2% operators charge their e-rickshaw batteries twice daily. Frequency of charging depends upon usage, health of the battery, and the battery type.

Table 50: E-Rickshaw charging frequency

Frequency of charging of e-rickshaw batteries per week	4 times/week	6 times/week	7 times/week	14 times/week
% of e-rickshaws charged per week	1%	10%	87%	2%

f. Battery Charging Capacity

The average charging time for the e-rickshaw batteries is 10hrs (for both weekdays & weekends). It is clear from Table-51 that the average SOC (State of Charge) of a battery on weekdays during plug-in & plug-out was 36.71% and 90.50% respectively. Whereas, the average SOC of battery on weekends during plug-in & plug-out was 37.08% and 90.628% respectively.

Table 51: Average Charging time & battery SoCs

	Average Charging Time (In hours)	Average SoC (%) Plug-in	Average SoC (%) Plug-out	Average battery capacity charged (%)
Weekday	10	23.42622951	99.3442623	75
Weekend	10	24.17213115	99.59016393	74

g. Charging Pattern of E- Rickshaws

The charging pattern for e-rickshaws depends primarily upon two modes, i.e., regular charging and top- up charging. Figures 96A and 96B show the daily average charging pattern of e-rickshaws in Delhi on weekdays

& weekends respectively. It has been found that all the e-rickshaws are charged fully during night-time. On an average, the plug-in time found in this survey during weekdays is between 9:00 pm to 8:00 am. Whereas, during weekends, the plug-in time shifts to between 10:00 pm and 9:00 am.

Weekday charging pattern of e-rickshaws

Figure 96: Weekend charging pattern of e-rickshaws

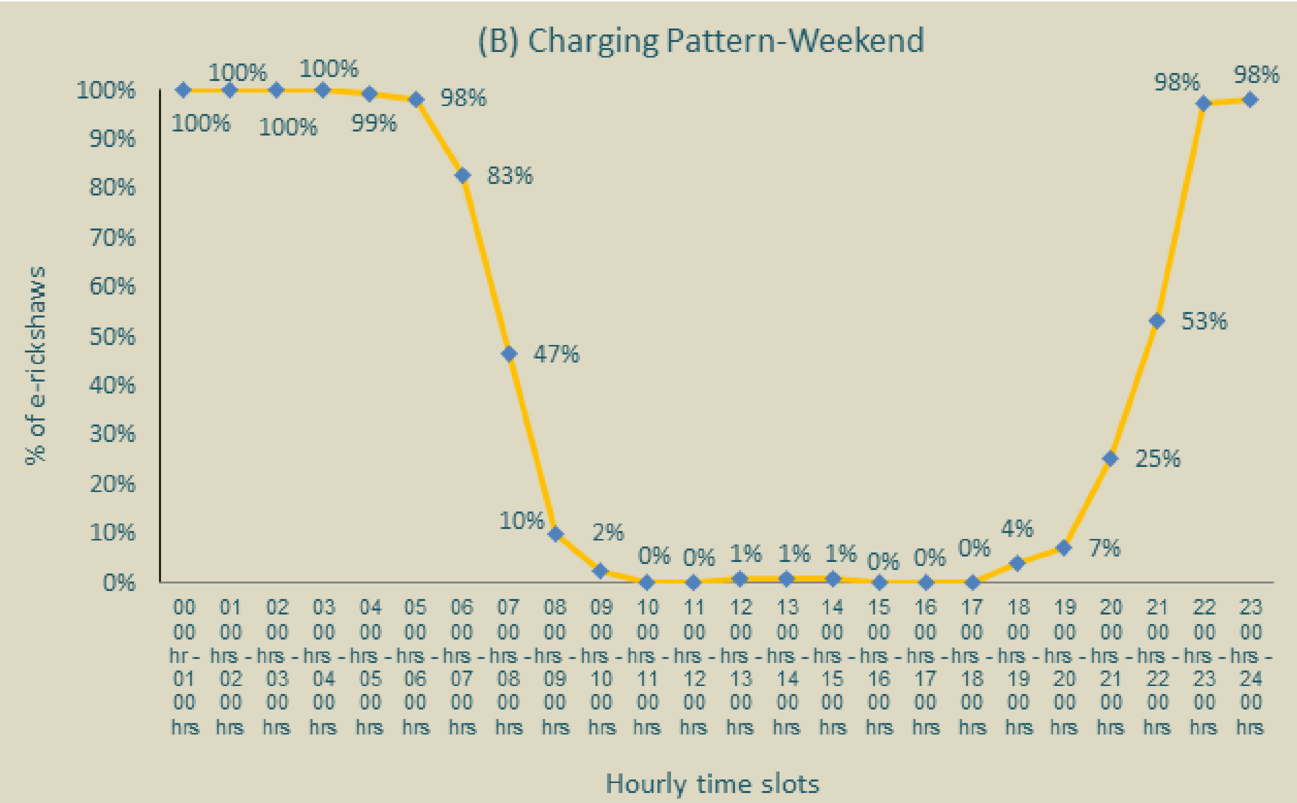


Table 52 shows the top-up charging pattern of e-rickshaws. The top-up happens when the e-rickshaw drivers are not using the e-rickshaws, and this is during the idle hours, which the survey respondents have mentioned on an average are 2 hours, but at different time points as shown in the table below. Among the 122 respondents surveyed, only three e-rickshaw drivers used the top-up facility to charge-up their e-rickshaws. The top-up pattern during weekdays and weekends was similar and was reported to be between 12 pm-2 pm & 2 pm-4 pm by two respondents and 1 pm-4 pm by the third respondent

Table 52: Top-up charging %age of e-rickshaws during weekday & weekend

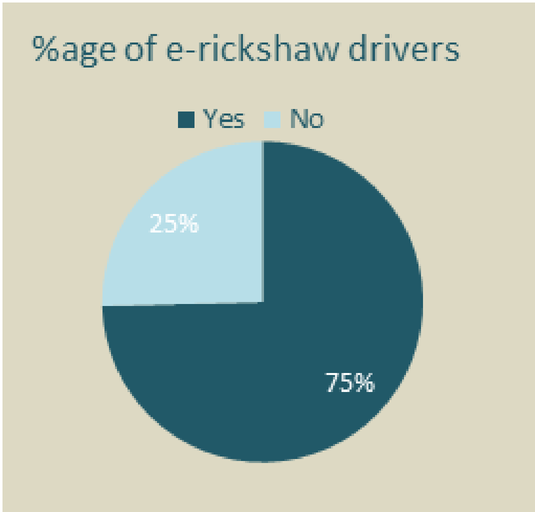
Top-Up Charge	%age of E-Rickshaws		
Charging time (in hrs.)	12 PM-2 PM 2 PM- 4 PM	1PM-4 PM	Average SoC%
Weekday	2%	1%	50
Weekend	2%	1%	50

Consumer Opinion and Preferences

a. Customers recommending e-rickshaws

Based on the present driving experience and the satisfaction level of the type of facilities, 75% of the e-rickshaw drivers said that they will recommend purchasing e-rickshaws to their friends and relatives. In comparison, 25% of the e-rickshaw drivers said they won't recommend buying e-rickshaws.

Figure 97: Recommendation %age distribution by current e-rickshaw drivers



b. Satisfaction level of the performance of e-rickshaws & convenience of private charging infrastructure

To understand the e-rickshaw drivers' expectation about the convenience of charging at private commercial charging stations, the survey asked the e-rickshaw drivers to rate their satisfaction level on Likert's 5-point scale. 64% of the respondents reported that they were very satisfied with their e-rickshaws, whereas only 2% of the total respondents were not satisfied with their e-rickshaw performance. Most e-rickshaw drivers were satisfied with the convenience of charging at private commercial charging stations. Almost 59% of the e-rickshaw drivers were satisfied or very satisfied with private charging stations' convenience, whereas 29% were either not satisfied or somewhat satisfied, and 11% were neutral.

Table 53: Satisfaction level of the e-rickshaw performance & the convenience of private charging

Parameters for the preference of e-rickshaws	Satisfaction level on Likert's' scale				
	Not Satisfied	Somewhat Satisfied	Neutral	Satisfied	Very Satisfied
Performance of e-rickshaws	2%	5%	9%	64%	20%
The convenience of private charging	9%	20%	11%	39%	20%

c. Return on investment in e-rickshaw

92.62% of the e-rickshaw drivers find e-rickshaws good return on the investment, while 6.56% did not experience good return on their investment on e-rickshaws, the rest were not aware about it.

Table 54: Opinion of e-rickshaw drivers on e-rickshaws being a good RoI

Do you think that e-rickshaws are a good return on investment	Yes	No	Don't Know
%age of e-rickshaw drivers	92.62%	6.56%	0.82%

d. Preference for fast charging options in future

The pilot surveys and field interviews by IRADe team of e-rickshaw owners & drivers, apart from those in this survey, concluded that in the current scenario, almost all the e-rickshaws in Delhi have lead acid batteries, and they take approximately 10 hours to get fully charged. There is no fast charging provision in view of the BMS (Battery Management System) of the lead acid batteries. However, preference for faster charging of the e-rickshaw batteries has been one of the most favourable options amongst the respondents. Approximately 64% of the e-rickshaw drivers believe that the fast charging facility must be provided to them for charging

About 49% of the e-rickshaw drivers said that the after-sales services provided for their e-rickshaws had played an essential role in making their next purchase of the e-rickshaw. Only 2% and 5% of the total respondents were of the opinion that the after sales services were somewhat important and not important, respectively, for them.

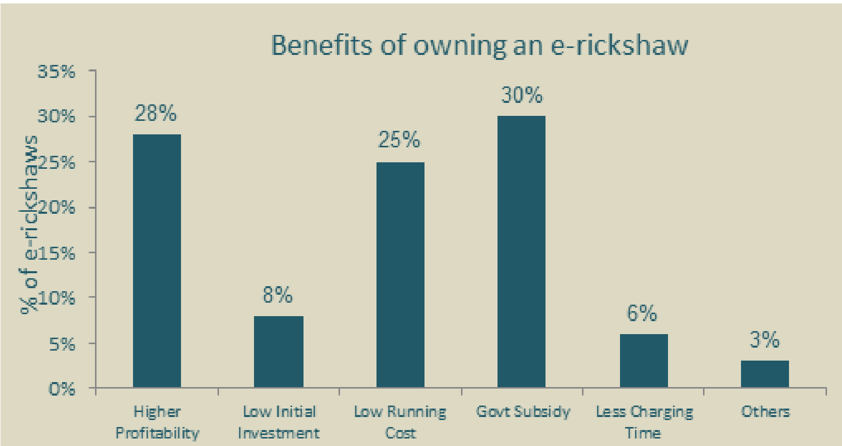
Table 55: Preference for fast charging in future & aftersales service affecting purchasing decisions

Parameters for preference of e-rickshaws	Preference of Fast charging in future				
	Not Interested	Somewhat Interested	Neutral	Interested	Very Interested
% of e-rickshaw drivers	5%	2%	2%	28%	64%
Parameters for preference of e-rickshaws	**Aftersales service availability affecting the purchasing decision**				
	Not Important	**Somewhat Important**	**Neutral**	**Important**	**Very important**
%age of e-rickshaw drivers	5%	2%	6%	49%	39%

e. Perceived benefits of owning an e-rickshaw

The e-rickshaws have been beneficial in many aspects and approximately 28% found e-rickshaws highly profitable. Further, low initial investment (8%), low running costs (25%), government subsidy (30%), less charging time (6%) and 3% others (good business in less cost, good option for livelihood, cheaper than CNG or petrol, less service charge, house expenses now manageable & very useful) are the major benefits that people receive by owning e-rickshaws.

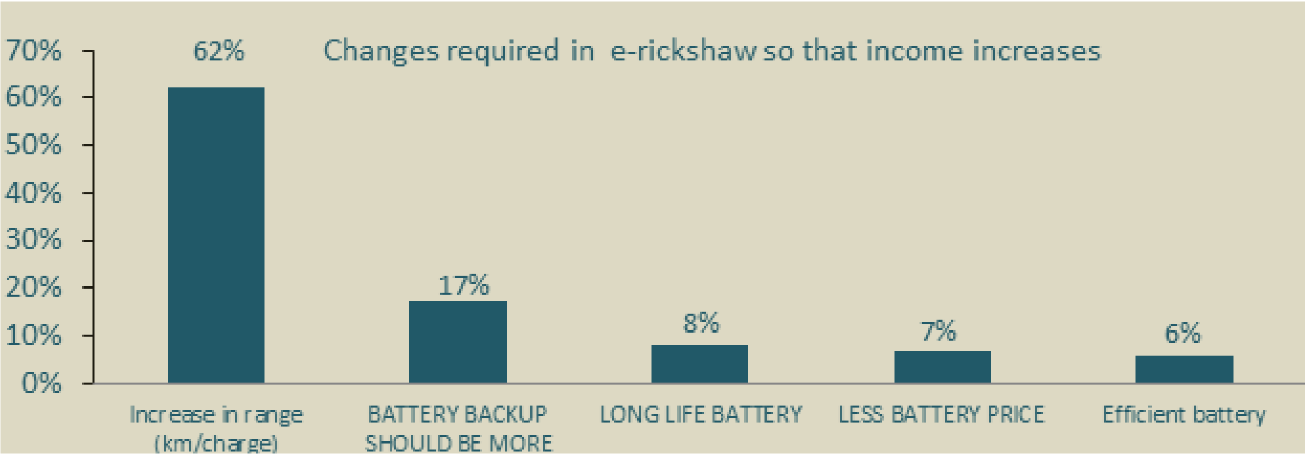
Figure 98: Factors determining the benefits of owning an e-rickshaw



f. Changes required in e-rickshaw to increase income

To increase income, about 62% of the respondents think that the range of their e-rickshaw should be increased. The battery is an important aspect of e-rickshaws as 17% of the respondents said that battery backup should be more, followed by 8% emphasising on long battery life while the remaining 6% and 7% of the respondents want an efficient battery and cheaper battery costs respectively. Hence, it's clear that a higher battery range will allow the e-rickshaw drivers to increase the trip length and this will lead to an increase in their overall revenue.

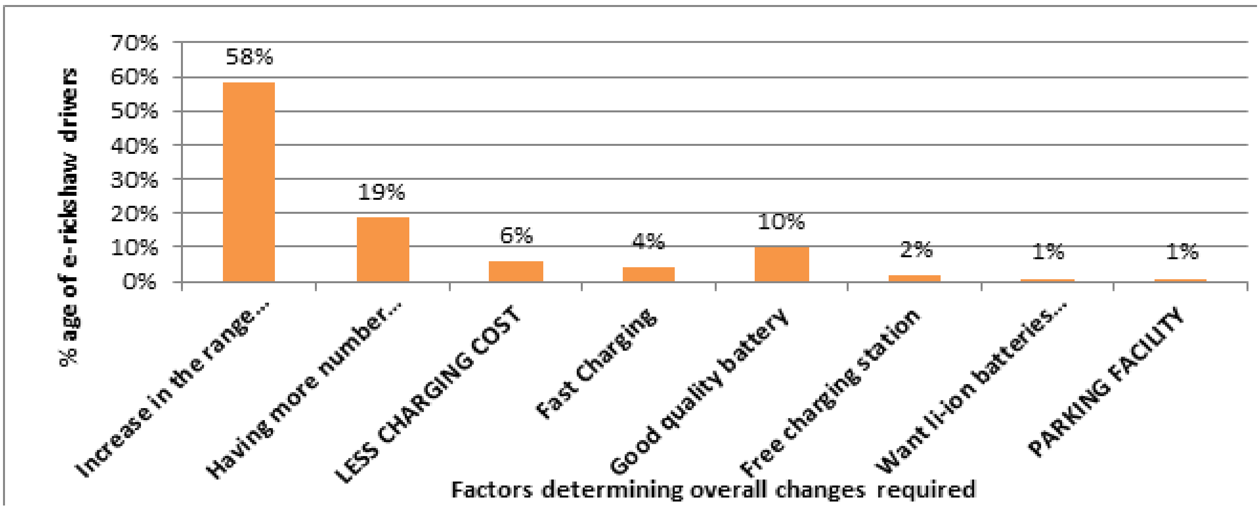
Figure 99: Various changes required in the e-rickshaw for increasing the drivers' revenue



g. Overall changes required

Approximately 58% of the respondents said they want an increase in range of the e-rickshaw battery as the overall change. 19% said that they want an increase in the number of charging points in their operation area. 10% of the e-rickshaw owners wanted fair quality batteries at a reasonable price so that the overall capital cost of the e-rickshaws can be cheaper. 6% of the respondents believed that the battery charging cost must be less than the current prevalent tariff rates. Moreover, 4% wanted a fast charging facility for their e-rickshaws.

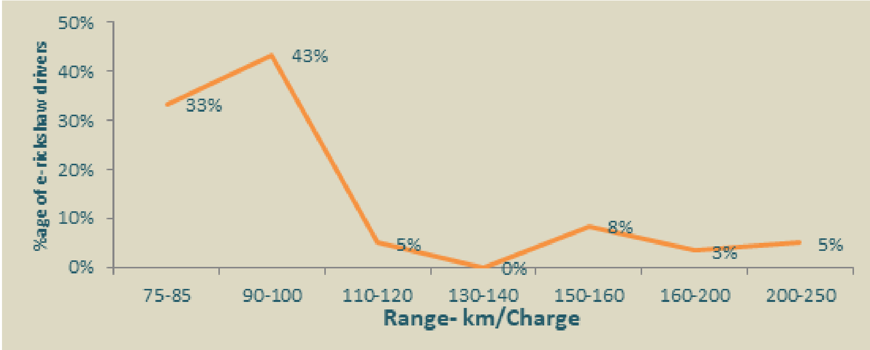
Figure 100: Factors denoting overall changes required in the e-rickshaws



h. Increase in driving range

About 43% of the e-rickshaw drivers want the e-rickshaw battery range to be increased between 75km/charge to 95km/charge. Whereas 38% wants the battery range to be increased between 100km/charge to 120km/charge. This implies that there is a strong demand for highly efficient batteries for e-rickshaws so that they can increase the trip length.

Figure 101: Average battery (Pb-Acid) range in the current e-rickshaws running in Delhi	Figure 102: E-Rickshaw battery range



After-sales service provided by manufacturer

The survey tried to identify the types of after-sales services offered by the e-rickshaw manufacturers/vendors. About 35% of the respondents said they were provided with the warranty of six months on their e-rickshaws battery and 16% said that they were provided with a six months' warranty on the e-rickshaw motor. On the other hand, 11% of the respondents said that they weren't provided with any services.

Figure 103: After-sales service currently provided by the e-rickshaw manufacturers in Delhi

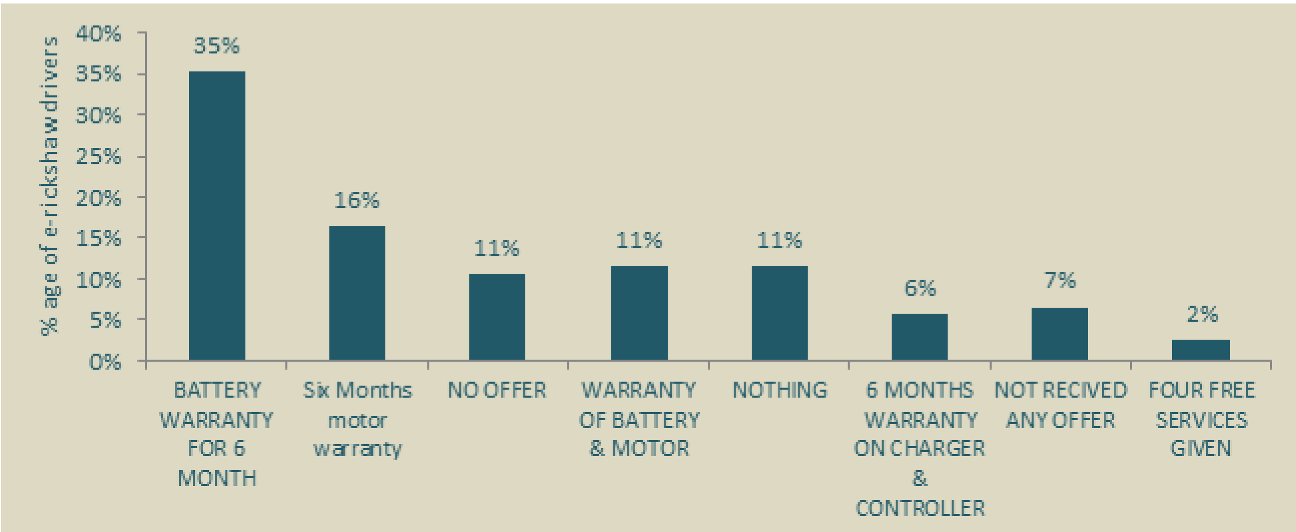
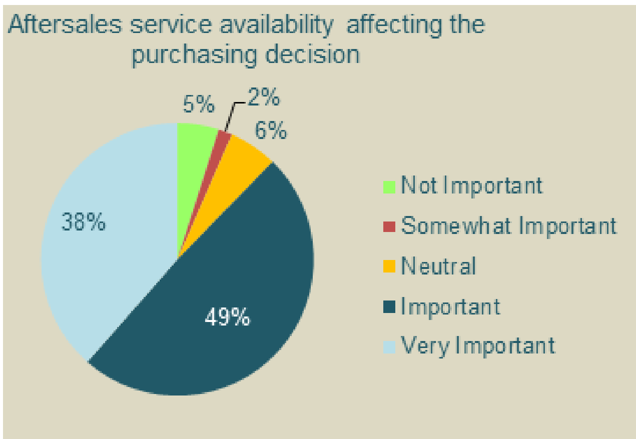


Figure-103 shows the effect of after-sales services on the decision to purchase e-rickshaws. 38% of e-rickshaw owners considers it a very important factor, followed by 49% of the respondents listing it as an important parameter. On the other hand, only 2% of the e-rickshaw owners feels that after-sales service is a somewhat important factor, and plays a very less important role in their purchasing decision.

Figure 104: After-sales service availability affecting the purchasing decision



Summary Conclusions

Driver profile

1. 52% of the survey respondents belong to the millennial age (i.e., 25-39 years). The majority of the drivers fell in the age bracket between 25 and 39 years. Moreover, 30% are between 40 and 55 years, and only 16% is between 18-24 years.

2. In terms of education level, 55% of the e-rickshaw drivers have completed their pre-secondary education (till the eighth standard). Only 33% have education up to the secondary standard (10th pass).

3. The average income of e-rickshaw operators is INR 16,786 per month. 30% of the e-rickshaw drivers had a monthly income between INR 13,000 and INR 15,000, followed by 25% of the e-rickshaws having an income between INR 20,000 and INR 22,000.

4. 28% of the e-rickshaws was purchased in FY 2019, followed by 24% in 2018. During the year 2012-15, only 8% of e-rickshaws was purchased. FY 2016 saw a rise of 125% in the number of e-rickshaws purchased than the total purchased between FY 2012 and 2015.

5. In terms of ownership distribution, 83% of the drivers were owners, while 17% were renters. 97% of the e-rickshaw drivers had their ferrying passengers' business, whereas 2% of those performed both ferrying and commercial freight loading-unloading operations.

6. Among the renters' drivers, 33% pays INR 300 as the daily rent, and 28% pays INR 250 daily. 22% of respondents pay INR 200, and 17% pay INR 150 per day as rent. On average, the daily rent is INR 242. Since the average cost of an e-rickshaw stood at INR 1,32,604, the e-rickshaw owners depended upon diverse EV financing sources to meet this considerable cost. 44% of the owners purchased their e-rickshaw vehicles through their monetary support, followed by 32% relying on the bank's financing. 11% purchased through private finance and 6% from other finances. Undoubtedly, self-financing proves to be the dominant source of finance for e-rickshaw drivers.

Travel pattern

7. More than 50% of e-rickshaws had their driving range between 50-65 km/charge and only 5% had their range above 90 km/charge. Since the same e-rickshaws were used for ferrying passengers and commercial loading, the range was the same for both the e-rickshaws.

8. On weekdays, e-rickshaws in Delhi had an average VKT of 127 km/day and on weekends the average daily VKT was 99 km/day due to lower trip rate.

9. In Delhi, currently, there is no fixed structure of the fare to be charged from the passengers. There is only a minimum fare of INR 10 that the passengers pay for a single trip (this trip usually starts from a metro station to the passengers' residence or locality. The price variation is seen when the passengers travel in an area where the metro stations are usually more than 3 km away from their residence.

Charging

10. For charging, there are predominantly two modes, i.e., home charging and commercial charging. From this survey, it has been found that as of now, none of the e-rickshaw drivers is using battery swapping mode for battery charging. Coming to the types of charger used for e-rickshaw charging, the respondents prefer the wall socket as a go-to option for both regular and top-up charging. A wall socket is the most preferred charging option at home, whereas, in private commercial charging, people use both options, i.e., wall socket and a dedicated EV charger.

11. E-rickshaw charging locations are concentrated mainly on charging done at private parking spaces, with 53% of e-rickshaws regularly getting charged at these locations. However, the home charging location caters to 45% of the total e-rickshaws; the remaining 2% of the e-rickshaws use the third-party home or owners' shop as a charging location.

12. As per the study of the charging pattern of the e-rickshaw batteries from the survey results, it has been found that the average charging time for the e-rickshaw batteries is 10 hrs (for both weekdays & weekends). Moreover, the average SOC of battery is 76% on weekdays & 75% on weekends.

13. Driver preferences

14. Based on the present driving experience and the satisfaction level of the type of facilities, three-fourths of the e-rickshaw drivers are of the opinion that they will recommend purchasing an e-rickshaw to their friends and relatives.

15. Most e-rickshaw drivers were satisfied with the convenience of charging at private commercial charging stations. Almost 59% of the e-rickshaw drivers were satisfied or very satisfied with private charging stations' convenience, whereas 29% were either not satisfied or somewhat satisfied, and 11% were neutral.

16. As of now, there is no provision of fast charging in the e-rickshaws running on lead acid batteries, keeping in view their battery management system configuration. But, on the contrary, the preference for faster charging of the e-rickshaw batteries has been one of the most favourable options amongst the respondents.

17. When it comes to the benefits of owning an e-rickshaw, higher profitability, low running cost and government subsidy were the major benefits perceived by the respondents.

18. In terms of the top overall changes that drivers wanted to see in e-rickshaw models, 58% of the respondents said they want an increase in range, 46% wanted batteries at cheaper price, 19% suggested having more public/private spots for charging, 10% preferred having good quality batteries, 6% wanted less charging costs and 4% suggested fast charging options. Other changes suggested were free charging stations, Li-ion batteries at the same price and parking facilities.

19. Close to 60% of e-rickshaw drivers suggested increasing range as an improvement for their vehicles and which would increase their incomes.

20. Among those drivers who suggested improvements to range, 33% wanted a range from 75-85 km/charge, 43% wanted a range of 90-100 km/charge, 5% wanted it in the range of 110-120 km/charge, 8% suggested a range of 150-160 km/charge, 3% wanted a range between 160-200 km/charge and 5% mentioned a range of 200-250 km/charge. A range improvement to 75-100 km/charge is preferred by 75% drivers.

21. After sales services were ranked as very important or important by 88% of the e-rickshaw drivers to their decision to purchase e-rickshaws. The survey found that 35% of the drivers were provided a warranty of six months on their e-rickshaws' batteries and 16% were provided with a six-month warranty on the e-rickshaw motor. On the other hand, 11% of the drivers said that they weren't provided with any services. This implies a scope for improvement of after sales services for the e-rickshaw.

Chapter 4: **Policy Brief for Accelerated Adoption of Electric Vehicles**

In order to assess the user experience of early adopters of EVs in Delhi and to gauge ways for future prospects of EV adoption, primary surveys covering 500 respondents in four distinct segments--current users of electric-2Ws, current users of electric-4Ws, electric-rickshaw drivers, institutionally owned EV 4Ws and prospective EV consumers (planning to buy a vehicle over the next six months)--was undertaken in Delhi from August to September 2020.

4.1 Private Transport

Consumer profile of early adopters of EVs and prospective consumers: Who are they?

Most early adopters of EV 2Ws in Delhi belong to lower household expenditure groups in the range of INR7,000 – 40,000 per month with an average expenditure of INR18,506 per month. Most are graduates or senior secondary educated and in the young and working age group of 25-40 years.

Majority of the early adopters of EV 4Ws in Delhi are male, 50% are business owners and 24% private salaried, belong to the age group of 25-55, and are graduates or postgraduates. They are in the higher monthly household expenditure range of INR 40,000 – INR 50,000 /month with an average expenditure of INR 44,286 / month. The early adopters of EV 2Ws and 4Ws in Delhi are all aware of air pollution compared to other issues like water pollution, noise pollution and climate change and global warming.'

Compared to early adopters among the prospective consumers, all women respondents preferred EVs over conventional for their mobility needs. Age and profession do not seem to be a factor for preference for EVs. Awareness of any of the environmental issues may not affect preference for EVs but education increases preference for EVs. Preference for EVs also increases with income or household expenditure. The average family expenditure of survey respondents who were 2W EV intenders was INR 23971 /month and for 2W conventional intenders was INR 12000 /month. Similarly, average monthly expenditure of respondents who were 4W EV intenders was INR 34,230 /month and for 4W conventional intenders was INR 28,382 /month.

Previous Vehicle Ownership of Early Adopters and Prospective Consumers

Nearly one-third of the early adopters of EV 2Ws already had a previously purchased conventional 2W or 4W. Similarly, early adopters of EV 4Ws were also people who chose an EV as their second or third vehicle. The early adopters of EV 4Ws already owned a conventional vehicle and among them, diesel 4W owners were more likely to purchase an EV 4W than a petrol 4W or 2W.

Even among the prospective consumers, EV is being seen as an additional vehicle rather than the primary vehicle for the household. People owning more than one vehicle were more likely to buy an EV, than people with only one vehicle or no vehicle at all, and people whose current vehicles were older were more likely to buy an EV.

What are their Travel Patterns?

Early adopters of EV 2Ws use them almost daily and most use them for regular commute on working days and for short distance travel on working and non-working days. The daily average VKT of the early adopters of EV 2W in Delhi, using their conventional 2Ws and 4Ws was estimated to be 29 km and 41 km on working days and 22 km and 51 km on non-working days. While their estimated average daily VKT using EV 2W is 22 km on working days and 11 km on non-working days. In general, 2W users are characterised by short distance travel of 1- 30 km per day and hence electric 2Ws perfectly suit their requirement.

Early adopters of EV 4Ws use it frequently and on most of working and non-working days. The two major purpose for which an EV 4W is used is for regular office commute and short trips. Majority of early adopters of EV 4Ws use it for short, medium, or moderate distance daily travel of less than 30 km on weekdays and weekends and only a few use it for more than 30 km travel, especially on weekends. The daily average VKT of the early adopters of EV 4Ws in Delhi, using their conventional 4W and 2W on a working day, is 51 km and 15 km respectively and on non-working day it is 59 km and 7 km respectively. While their estimated average daily VKT using EV 4W is 41 km on working days and 44 km on non-working days.

Even among prospective consumers, regular commute to workplace is the most prevalent and common purpose for which they use their conventional 2W and 4W. Some 4W users also use it for short and long trips especially on non-working days. The average VKT of prospective consumers for 2W and 4W was estimated to be 29 km/day and 34 km/day on working days while on non-working days this was 9 km/day and 50 km/day respectively. The important conclusion is that people who have short distance travel requirement of less than 30 km in addition to the regular commute are more likely to opt for purchasing EVs.

Determinants of Consumer Decisions

As factors that influence their decision to buy an EV 2W, prospective buyers of 2W listed range, capital cost and charging time while 90% of early adopters of EV 2Ws mentioned capital cost, range, operation and maintenance cost, government policies, high petrol prices and environmental impact. The early adopters of private EV 4Ws mentioned the factors of capital cost, operating & maintenance cost, range, performance vis-a-vis conventional car, high fuel prices and environment & emission impacts, while prospective buyers of EV 4Ws mentioned range, charging time, availability of public charging and government policies as factors that influenced their decision to buy an EV 4W.

Factors like resale value and availability of variants were not so crucial for prospective buyers of 2Ws while availability of variants, availability of public charging, performance vis-a-vis conventional 2Ws and high resale value were not so crucial for early adopters of EV 2Ws. In the case of 4Ws, factors like availability of variants and resale value were listed by prospective buyers of EV 4Ws and factors like availability of public charging, high resale value, government policies like subsidies and free parking, and availability of variants were listed by early adopters of EV 4Ws are factors not so critical to purchasing EV.

Based on their usage of EV 2Ws, early adopters were less satisfied with existing range, charging time, availability of charging infrastructure and waiting time at public charging stations. Early adopters of EV 2Ws based on their experience preferred free regular servicing in the first year and improved service quality with service centers all around. Around 62% of them suggested improvements in range, charging infrastructure, affordable cost of charging, availability of fast charging and better after sales service quality. Early adopters of EV 4Ws based on their user experience were most satisfied with charging cost, had a favourable opinion about charging time and the quality of after sale services, but disapproved of availability of charging infrastructure and waiting time for charger availability.

4.2 Electric Vehicle Policy

Technology Policy

From a technological point of view, improved performance, increased range, and reduction in vehicle cost need to be prioritised to increase sale of EVs to private consumers.

Current prices are higher than what most respondents prefer and there is a case for 54% to 36% reduction in prices of 2Ws and by 40% for SUVs and by 20-40% at least for sedans through subsidies and other measures.

Average range of electric scooters from the survey of early adopters of EV 2Ws was 54 km/charge and for motorcycles was 104 km/charge. Nearly 39% of the early adopters who suggested improvements in range preferred a range between 80-100 km/charge, 31% preferred a range from 100-200 km/charge and 10% preferred a range of 200-350 km/charge.

The survey of current users of EV 4Ws found that amongst the electric 4W models purchased by the early adopters in Delhi, the average range of hatchback models was 76-92 km/charge; sedan EV models have an average range between 120 -130 km/charge and electric SUVs had an average range of 280 -312 km/charge. The early adopters of EV 4Ws had a favorable opinion of the range but preferred a range of 350-400 km per charge which would meet their daily travel requirements. Prospective consumers preferred an improvement in the range of scooters from the average of 54 km/charge to 100 or 150 km/charge, 120 km/charge up to 300 km/charge for sedan buyers and from the current range of 300 km/charge up to 400 km/charge for SUVs. This is likely to strongly impact many who prefer conventional vehicles, who will then find EVs attractive and economical.

Battery EV is most preferred but a higher proportion among conventional intenders than EV intenders prefer hybrid vehicles over battery EVs indicating that range and performance issues matter to conventional intenders.

Parking Policy

Most early adopters of EV 2Ws have access to basic parking facilities at home and hence 90% of the respondents reported charging from home. A majority of 81% of the early adopters of EV 4Ws had parking facilities at home or garage and only 19% needed parking in streets or society spaces.

However, the survey of prospective consumers suggested that lack of parking facilities could be a hindrance to future adoption of EVs in Delhi, particularly for EV 4Ws, as people with no parking spaces were more likely to prefer conventional vehicles to 4Ws.

Public Charging Policy

The prospective consumers survey showed that people who prefer conventional vehicles listed public charging unavailability and high charging time as reasons for not buying EVs. There is a lack of public charging infrastructure and awareness about it. This is reflected in less than 10% of the prospective consumers knowing about the public charging stations near their regular parking spots of home or office. The lack of infrastructure and awareness about public charging is also confirmed by the survey of current users or early adopters of EV 2Ws and EV 4Ws. Amongst the early adopters of EV 2Ws, 90% reported charging from home and none of them visited a public charging station and were unaware of the waiting time there. Almost 94% of the early adopters of EV 2Ws were not aware of public charging facilities near their home or office. Among those who are aware of public charging stations, only 60% had a public charging station within 5 km of their home and 50% had a public charging station within 5 km of their office.

Early adopters of EV 4W also did not use public charging stations to charge their EVs even though 60% of them had public charging stations within 5 km of their home or office. 95% of the early adopters of EV 4Ws opted for home charging on a working day and on non-working days only one third of respondents' charged and they, too, opted for home charging.

Early adopters of EV 2Ws from their experience of using EV 2W suggested public charging stations every 2-3 km or at every petrol pump and all major commercial places. Similarly, around 60% of prospective consumers who were aware of public charging stations near their home and office, preferred to have a charging station within 1 km of their homes and offices. The early adopters of EV 2Ws also suggested lower waiting time, and amongst them, 36% preferred it to be 1 hour.

Similarly, the early adopters of EV 4W disapproved of the lack of charging infrastructure and higher waiting time for charger availability. It is interesting to note that, initially, for the early adopters of EV 4W, availability of public charging was not an important factor at the time of purchasing their EV 4Ws. However, while using it, the respondents found that availability of public charging station was a constraint. Based on their experience, they suggested having public charging infrastructure within 2 to 3 km range. Some suggested within 1 km of their regular parking spots. Additionally, some also suggested having a battery swapping facility available at every station. Thus, there is a clear preference for increasing public charging infrastructure and having public charging stations within 1-3 km of homes or offices.

The prospective consumer survey also suggested that public charging infrastructure may not be so crucial for EV 2Ws, but may complement its use, especially for those who have short distance travel requirements. However, for EV 4Ws, improving range and setting up public charging infrastructure is very essential.

In general, prospective consumers, irrespective of their preference for EVs, have a strong liking for booster charging over normal charging at public charging stations. Compared to 2W buyers, a higher proportion of 4W buyers preferred booster charging. This indicates the importance of increasing booster charging infrastructure in public charging facilities to promote the growth of EVs, especially EV 4Ws. The preference for booster charging is also reflected in the survey of the current users of private EV 4Ws, though none of the early adopters of EV 4Ws in Delhi uses top up charging (as regular, once a day, slow charging satisfies their daily travel requirement). However, they still mention their preferred fast charging time of less than 90 minutes, which would make EVs more useful for them. This shows that availability of booster charging facilities in public charging stations would help 4W users to travel longer distances and support its greater adoption.

The unavailability of office charging facilities is also a major hindrance as none in the survey of prospective consumers had charging facilities at home and 80% felt that having EV charging points in their office would increase their chances of buying an EV. Amongst the early adopters of EV 2Ws only 9% had charging options at office and only 5% of early adopters of EV 4Ws opt for office charging on a working day. This shows that offices and commercial enterprises need to be persuaded to have more EV charging points for people to adopt EVs on a larger scale.

4.3 Economic and Incentive Policy

Buy Back Policy

The prospective consumers survey showed that people owning more than one vehicle were more likely to buy an EV as an additional vehicle compared to people with only one vehicle or no vehicle at all. This was also the case in the survey of current users of EV 2Ws and EV 4Ws. At least one-third of the early adopters of EV 2Ws and 81 % of the early adopters of EV 4Ws already owned a previously purchased conventional 2W and/or 4W. However importantly, most purchasers of EV 2Ws in Delhi have replaced their conventional vehicles with EV 2Ws for their work related travel and most people who purchased EV 4Ws in Delhi have replaced their conventional 2W and minimised their use of conventional 4W for long distance travel needs. This implies that with a right amount of incentive and awareness, buyers may be willing to exchange their conventional vehicles for EVs. Thus a vehicle buy back policy with appropriate financial incentive for exchanging older, conventional vehicles with a corresponding EV along with awareness of the economic benefits of EVs can be designed to increase adoption of EVs in Delhi.

Parking Policy

The survey of prospective consumers showed that the lack of parking facilities could hinder future growth of EVs in Delhi, particularly for EV 4Ws as people with no parking spaces were more likely to prefer a conventional vehicle to a 4W. As a solution to ease parking constraint for EVs, roads and parking places in Delhi need to be de-congested. This can be achieved by introducing parking markets with a deferential price for less emitting vehicles and zero parking fee for EVs.

Subsidy and Other Incentives

EV 2W buyers, both current users and prospective users, belong to lower expenditure groups compared to EV 4W current buyers and prospective buyers. Higher subsidies may be considered for 2W buyers to increase EV adoption. Subsidies can be designed to bring down the cost by 54% to 36% reduction in prices of 2Ws and by 40% for SUVs and by 20-40% at least for sedans. Other enabling measures suggested by consumers that can help support their EV adoption are listed below.

Preferential access to express/speed lanes for EVs and limiting the registration of conventional vehicles per household were ranked highly as policies that would make it easier to buy an EV.

Waiving toll charges/parking charges of EVs, providing tax savings or rebate in purchase of EVs, providing free public charging points, and encouraging automakers to provide more models were policies that are likely to encourage buyers who prefer conventional vehicles to opt for EVs.

Providing special parking places in prime/congested areas in the city is a policy that would be particularly very helpful to EV buyers.

Levying CO2 or pollution tax on inefficient vehicles was a policy that 4W buyers found important to prompt them to buy EVs.

Providing tax savings or rebate in the purchase of EVs and providing free public charging points are policies that 2W buyers found to be important to prompt them to buy EVs.

4.4 Promotion & Awareness Campaign

Most early adopters of EVs were private salaried individuals and business owners. This was true among prospective consumers as well. Professional groups like women, students and salesmen have displayed a strong liking for EVs among prospective consumers. Promotion and awareness campaigns can be organised for reaching out to them through offices, business & market centers, and mobile and social media with advertisements. Education increases preference for EVs, hence promotional campaigns in universities, colleges, and high schools can help boost EV sales.

People who are frequent users of public transport modes like metro, auto rickshaws, shared cabs and e-rickshaws are more likely to consider buying EVs to substitute it. Hence, advertising about EVs in public transport like buses, bus stops, metro stations and metro trains can help increase EV penetration.

Given the limited range of current EVs and lack of public charging infrastructure, there is overwhelming evidence from the survey of early adopters, as well as prospective consumers, of the EV being the vehicle of choice for individuals with short distance travel requirement of within 30 km. An EV promotional campaign must highlight the utility of EVs to people with short distance travel requirement on a single charge without any need for visiting a public charging facility.

There is a lack of awareness about the economic benefits of EVs as evident in the prospective consumer survey where 52% of conventional 2Ws and 15% of conventional 4Ws opted for EVs when shown the comparative values of capital cost, operating cost, EMI for a loan period of 7 years, and the range/mileage for some existing EV and conventional vehicle models. Therefore, the EV promotional and awareness campaign must also focus on informing how EVs are economically more beneficial and how the higher capital cost is affordable through EMIs and compensated by low operating costs.

In addition, the advertising campaign for promoting EVs should highlight features such as "new battery-based technology", "less noise", "suitability for local travel" and the benefit of "less mechanical parts", in addition to new upcoming models, for improved impact.

The survey of the prospective consumers showed that less than 10% of the respondents knew about public charging stations near their regular parking spots of home or office. An awareness campaign aimed at informing people of public charging facilities near offices, commercial buildings and residential areas is required to promote the use of public charging stations.

4.5 Public Transport

Driver and Vehicle Profile

Institutional EV 4W

Drivers of the institutionally owned EV 4Ws were male, and a majority of them belong to the age group of 24-39 years. Education wise, a majority of them are either senior secondary school, secondary school or pre secondary educated with low awareness of environmental issues. The drivers had a minimum of 1-2 years of experience driving EV 4Ws and 1-5 years in driving conventional vehicles, with many having 10 or more than 10 years' experience in driving conventional cars also.

Among the vehicles surveyed, 72% of the EVs surveyed belong to private firms. Among the electric car variants surveyed, Mahindra E-Verito (56%) is the most preferred EV 4W model used by fleet operators, followed by Tata Tigor (36%). Most of the fleet operators have entered the market recently in the year 2020.

E-rickshaw

A majority of the drivers fell in the age bracket between 25 years-39 years. Most are pre-secondary qualified (till the eighth standard) or secondary (10th pass) qualified. The average income of e-rickshaw drivers is INR 16,786 / month with 30% of them having their monthly income between INR 13,000- 15,000 /month, followed by 25% of the e-rickshaws drivers having income in the range of INR 20,000- 22,000 /month.

Most e-rickshaws surveyed are of recent vintage, 28% of the e-rickshaws was purchased in FY 2019, 24% in 2018 and only 8% during the year 2012-15. Of the e-rickshaw drivers surveyed, 83% were owners and 17% had it on rent. In terms of purpose of use, 97% of the e-rickshaws were being used for passenger transport and 2% were into passenger and freight transportation. Among the renter drivers who pay daily rent, 33% pay INR 300, 28% pays INR 250, 22% pay INR 200 and 17% pay INR 150 per day as rent. There is no fixed structure of e-rickshaw fares in Delhi. A minimum fare of INR 10 exists for a single trip (usually from a metro station to the passengers' residence). The variation in fares is seen when trip distances are higher, such as in areas where the metro stations are more than 3 km away.

Travel Patterns

Institutional EV 4W

Commercial EVs owned by government agencies are operational 7 days a week while those owned by private fleet agencies are operational for 6 days a week, with Sunday being a non-working day. Daily average distance travelled by government EV cars are 90 Km/day and by private EV taxi operators is 114 km/day which is low compared to a conventional taxi which covers 210 km/day or Ola/Uber fleet operators which cover 400 km/day.

E-rickshaw

The average charging time for the e-rickshaw was found to be 10 hours (for both weekday & weekend) implying a working time of 14 hours a day. On weekdays, e-rickshaws in Delhi had an average trip rate of 2.5 trips/hour with an average distance of 3.64 km/trip, implying an average daily VKT of 127 km/day, while on weekends the average trip rate was 1.95 trips/hour with an average distance of 3.64 km/trip, implying an average daily VKT of 99 km/day.

Driver Preference

Institutional EV 4W

The EV 4W has a lower maintenance cost compared to a conventional car due to lower servicing needs per year. Most after sale services availed by the institutional EV 4W drivers are similar to a conventional car, except for regular battery check-up. Free servicing, maintenance, repair and battery replacement services are high on the wish list of the drivers surveyed. After sales services were ranked as very important or important by 88% of the e-rickshaw drivers to their decision to purchase e-rickshaws. Drivers have expressed the need for battery replacement and battery checkup services, indicating a potential market for maintenance & battery services, including battery swapping. Driver satisfaction with EV 4Ws is high with 91% ranking it satisfied or very satisfied despite issues with range and charging time.

A majority of drivers were very satisfied with the charging cost, operations & maintenance cost, and the performance of EVs vis-à-vis conventional vehicles and the quality of after sales service. Availability of public charging infrastructure and higher waiting time for charging are the aspects for which respondent drivers are least satisfied. Given their level of satisfaction and issues with range and public charging infrastructure and waiting and charging time, 25% recommended hybrid vehicles and 75% preferred battery EVs.

E-rickshaw

Three-fourths of the e-rickshaw drivers surveyed mentioned that they will recommend purchasing e-rickshaws to their friends and relatives based on their experience and satisfaction level and 93% of the drivers said that they felt that their e-rickshaw was good return on investment. As benefits of owning a e-rickshaw, the drivers mentioned higher profitability, low running cost and government subsidy.

In terms of the top overall changes that drivers wanted to see in e-rickshaw models, 58% of the respondents said they wanted an increase in range, 46% wanted batteries at a cheaper price, 19% suggested having more public/private spots for charging, 10% preferred having good quality batteries, 6% wanted less charging costs and 4% suggested the fast charging option. Other changes suggested were free charging stations, Li-ion batteries at the same price and parking facility. Clearly, an increase in range and lowering of costs of batteries, charging costs, and having more charging stations is the priority needs of the e-rickshaw drivers.

4.6 Promotion & awareness campaign

Institutional EV 4W

There is a lack of awareness among institutional EV 4W drivers about sales services offered, indicating that advertising and awareness campaigns for marketing of services are required for electric taxis.

E-rickshaw

After sales services were ranked as very important or important by 88% of the e-rickshaw drivers to their decision to purchase e-rickshaws and hence awareness and promotion campaigns for e-rickshaw purchase should highlight the after-sales services being offered.

4.7 Electric vehicle policy

Technology Policy

Institutional EV 4W

The estimated average range of institutionally owned EV 4Ws covered in the survey was 170 km and 206 km/charge with and without AC respectively. Improvement in range was mentioned as an issue by 90% of the drivers. Suggestion for improvement in range was provided by 19% of the drivers surveyed, of whom 47% suggested a range of 200-250 km and 40% suggested more than 250 km.

E-rickshaw

More than 50% of e-rickshaws had their driving range between 50-65 km/charge and only 5% had their range above 90 km/charge. Close to 60% of e-rickshaw drivers suggested increasing range as an improvement for their vehicle and which would increase their incomes. Among those drivers who suggested improvements to range, 33% wanted a range from 75-85 km/charge, 43% wanted a range of 90-100 km/charge, 5% wanted it in the range of 110-120 km/charge, 8% suggested a range of 150-160 km/charge, 3% wanted a range between 160-200 km/charge and 5% mentioned a range of 200-250 km/charge. Clearly a range improvement to 75-100 km/charge is preferred by 75% drivers.

Parking Policy

Institutional EV 4W

During non-working hours, most of the cars (80%) are parked in the office premises and outside the office area, 16% park in public spaces or in street parking and only 4% use the garage for parking. Since charging depends on parking location, providing parking facility or lower parking rates for cab aggregators who increase the proportion of electric cabs in their fleet may be a good way to promote electric cabs.

E-rickshaw

Parking facilities are being used by the e-rickshaw drivers during charging in non-working hours. Among the drivers interviewed, 53% were charging at private parking facilities and 45% were charging at their homes. Only 2% of e-rickshaws are charged at other locations. Therefore, almost half of the e-rickshaw drivers are dependent on parking facilities available in private charging stations, which can be a constraint to the growth of the e-rickshaws.

Public Charging Policy

Institutional EV 4W

Availability of public charging infrastructure as an issue was mentioned by 54% of the drivers surveyed. However, most drivers have pubic charging stations within 5 km, and yet 3% of them charge at home, 74% charge at office, of which 86% use fast charging, and only 23% charge their EV 4Ws at public charging stations using the fast charging option. Drivers clearly prefer charging at the office and using fast charging. \

There is a lack of use of public charging amongst institutional EV 4W drivers as can be seen from the fact that only 58% of the drivers have visited public charging station in the recent past, and of those who used public charging, 41% have waited less than 30 minutes, 26% have waited 30 minutes to 1 hour and 33% experienced a waiting time of more than 1 hour.

E-Verito and Tata Tigor are the models most commonly used as cabs in Delhi during the time of the survey and, on an average, these vehicles take 90 minutes for full charge using fast charging. Amongst the drivers surveyed, 13% suggested improving the charging time of their EV 4Ws and of them 36% preferred a charging time of less than 1 hour, 43% suggested 1 hour, and 21% mentioned a charging time of more than 1 hour.

Vehicle charging during working hours consumes time and affects business, hence drivers prefer fast-charging. Nearly 97% of the drivers charge their EV 4Ws at most twice a day. Given the limited charging requirement, the drivers do not seem to prefer to charge in public stations, probably due to long waiting time and charging time.

Faster charging, near home or office and no parking charges are key likeable factors listed by the drivers about public charging stations and higher waiting time, less number of charging stations, and poor infrastructural amenities are key non-likeable factors about public charging stations quoted by the respondent drivers. Clearly, public charging is essential to support the requirements of institutionally owned EV 4Ws especially electric cabs. Increasing public charging stations, reduced waiting and charging time are the main requirements for institutional EV 4Ws.

E-rickshaw

E-rickshaw drivers are charging through home charging or commercial charging. None of them reported using battery swapping. A wall socket is the most preferred charging option at home, whereas in private commercial charging, both wall socket and a dedicated EV charger is being used. Among the drivers interviewed, 53% were charging at private parking facilities, 45% were charging at their homes and only 2% of e-rickshaws were charged at other locations.

Most e-rickshaw drivers were satisfied with the convenience of charging at private commercial charging stations as 59% of the e-rickshaw drivers said they were satisfied or very satisfied with convenience at private charging stations. Whereas 29% were either not satisfied or somewhat satisfied, and 11% were neutral.

The fast charging option was suggested by 4% of the e-rickshaw drivers surveyed for overall improvement of e-rickshaws. As of now, there is no provision of fast charging in the e-rickshaws which are running on lead acid batteries, because of its battery management system configuration. Hence, the introduction of lithium-ion battery might be helpful.

Public transport like taxi cabs and e-rickshaw are a lot more dependent on public charging than privately owned EVs, so public charging policy must prioritise the needs of institutionally owned EV 4Ws, electric cabs and e-rickshaws, increase public charging stations, and reduce waiting time and charging time at public charging stations. A policy for promoting private business for providing parking and charging facility to electric cabs and e-rickshaws may be necessary.

Economic and Incentive Policy

Institutional EV 4W

Tax breaks to electric cab aggregators and other cab aggregators based on their share of EVs may be considered. To increase use of EVs by private and public companies, tax breaks may be considered for those who use electric cars to meet their transport requirements. Electric car use by government can be increase through mandates and policy stipulation.

E-rickshaw

Given that the e-rickshaw drivers are from a low income economic background, financing their e-rickshaw purchase becomes a constraint. Among the e-rickshaw drivers surveyed, 44% of the owners purchased through their monetary resources, 32% through bank financing, 11% through private finance and 6% from other finances. Self-financing is the most common source of finance for e-rickshaw drivers, so supporting them through easy finance schemes may help increase e-rickshaw growth.

Charging Behaviour

EV 2W

Amongst the respondents in the survey, 39% charge their EV 2Ws once a day and 55% charge less than once a day. During regular charging at the time of plug in, 63% of respondents have 10% - 30% SOC on working days and 52% respondents have 40% - 60% SOC on non-working days. Regular charging requires around 7 to 8 hours and takes place in the time slot of 7 pm to 8 am. Only 9% of the respondents were found to have done top up charging on weekdays and only 16% did top up charging during weekends.

EV 4W Private

Almost one third of the respondents charge their EV 7 times a week (equivalent to once a day) and another one-third charge it 3 times a week. This shows that the respondents' travel demand is such that they don't need to charge regularly or they have adjusted their travel behavior, given the range offered by their EVs and use it for short and planned trips. Thus they do not require to charge their EV more than once in a day.

The regular charging time in weekdays and weekends is from 5 pm to 7 am, which is considered as non-working hours. On an average, it takes 9-10 hours in normal charging mode and up to 2 hours in fast charging mode to completely charge an electric 4W vehicle. The average plug-in SOC during full charge for EV 4Ws on a working day is 34%. Similarly, for non-working days, it is 36%.

EV 4W Institutional

The average SOC at the time of plug in for charging is 39% and the average time taken for charging was 3.6 hours. Of the commercial electric 4Ws, 40% are charged in the early morning time slots of 6 to 7 am and around 30% in the evening slot of 8 pm. Morning 9 am to 5 pm is the least busy for charging; however, 5-10% of the vehicles are getting top-up charging during this period.

E-rickshaw

As per the study, the average charging time for the e-rickshaw batteries is 10 hrs (for both weekday and weekend). The average SOC of battery is 76% on weekdays and 75% on weekends. On an average, the plug-in time during weekdays is between 9:00 pm and 8:00 am. Whereas during weekends, the plug-in time shifts to between 10:00 pm and 9:00 am. The top-up pattern during weekdays and weekends was similar and was reported to be between 12 pm-2 pm and 2 pm-4 pm by two respondents and 1 pm-4 pm by the third respondent.

Chapter 5:

Impact of EV on System Load of Delhi – A survey-based analysis

EVs are expected to substantially increase their share in the transportation sector owing to multi-pronged benefits emanating out of their adoption. Their benefits include, but are not limited to, usage of comparatively cleaner technology that reduces local air pollution, is sustainable in the long term and helps in mitigating the over-dependence of the Indian transport sector on crude oil (India imported over 80% of its consumption, i.e., crude oil worth $129.43 billion, in FY 2019-20). LBNL, in a study published in 2017, estimates that EVs can help the country avoid the import of 360 million barrels (16% of total crude oil consumption in 2030), saving nearly USD 14 billion in 2030.[9]

While it is inevitable that the EV count on the roads will only increase from its current status, it brings with it a separate set of challenges. These challenges include the need for vehicle batteries of higher capacities to reduce range anxieties, provision of easily accessible charging stations, developing quick/fast charging facilities to reduce vehicle engagement time at charging terminals, impact on local electricity distribution system owing to sudden load surges, especially during peak hours, and harmonic imbalances. Of all these challenges, the impact on the local distribution system needs to be paid especial attention for the safe and economic operation of the grid. Hence, a proper study of the EV location and movement to gauge the charging station load pattern at different times of the day is necessary to design an economic and implementable plan for the electricity distribution system.

This chapter aims to bring in learnings from the survey carried out to understand the typical charging pattern for 2Ws, 3Ws and 4Ws--private and institutional vehicles--and analyse the same to suggest measures for safe adoption of EV charging in the existing system. An Excel-based model has been developed, based on carefully designed survey questionnaires, to capture the charging behaviour of EV users. Since the charging behaviour differs during a typical weekday and weekend, separate analysis of data for weekdays and weekends has been done through the model to arrive at the load impact on the local grid due to EV charging. Further, EVs can be charged through slow AC charging or DC moderate charging, and hence the impact of slow and moderate charging is kept separate to understand the hourly impact of such charging.

5.1 Technical Background

Studying the impact of EVs on the distribution system necessitates the understanding of few critical components of an EV vehicle.

A. EV Batteries

Batteries in EVs are one of the most significant components both in terms of weight and cost. In India, the battery in an EV is its most expensive component, accounting for 50 per cent of its total cost; thus, the affordability of

[9]Source: http://thefrenchnuclearway.anegeo.org/GIECqueries/docsGiec/docs/voit_elec_Lawrence_Berkeley_2017.pdf (accessed on 10th Jan 2021)

EVs is directly proportional to the affordability of a battery[10]. Hence, the affordability of the battery will play an instrumental role in overcoming the cost barrier to better adoption of EVs in India's transport system. A battery is typically chosen on the basis of its weight, power, energy density, cost, etc. During the EV evolution, conventionally, Lead-Acid batteries were deployed due to their moderate cost and mature technology. With the advancement of technologies, which is continuously evolving, various new kinds of batteries, namely Nickel-Metal hydride and modified Li-ion batteries, have taken over. The maturity of technology for Li-ion is moderate and significant development of the technology is anticipated over the next decade. Technology advancement is expected to not only increase the energy density, and hence reduce the weight of the batteries, but is also likely to become more economical so as to incentivize faster adoption in comparison to existing Internal Combustion (IC) engines.

Almost all modern cars are deploying Li-ion battery technology to power the vehicle. Current Li-ion batteries, compared to their predecessor, are lighter, pack higher power density, require less charging time and have increased life. Above all, the innovation in Li-ion technology has resulted in the cost being significantly reduced. A Li-ion battery pack, which used to cost $1100/KWh in 2010, has reduced to $137/KWh in 2020, an 89% price drop. (Source: Bloomberg NEF)[11]. The average price is estimated to break the $100/KWh barrier by 2023.

The survey carried out under this study found that lead-acid batteries in Delhi are primarily used in e-rickshaws which have lately seen a switch to Li-ion batteries to some extent. The 2W segment of EVs is dominated by vehicles that use Li-ion batteries, although a few vehicles still use lead-acid batteries. Li-ion batteries dominate the 4W segment in the capital, and the same trend is expected with vehicles in the near future, owing to its capabilities mentioned above.

B. Vehicular Considerations

The survey conducted to understand the load pattern and charging behaviour of EV users considered all vehicles currently plying on the roads in Delhi and the people operating them. The vehicle modes considered for the survey were 2Ws, 3Ws or battery-operated e-rickshaws and 4Ws-- privately owned or institutionally operated. The survey did not cover any EVs meant for heavy-duty use, viz., goods carrier, buses, etc.

While e-rickshaw categorisation was not available and similar battery-operated e-rickshaws (3Ws) were surveyed, the categorisation was obvious in 2Ws and 4W EVs. Electric 2W vehicle models included in the survey are mentioned in the Table below along with a few important parameters of the vehicles used for analysis.

Table 56: Two wheelers with important parameters considered for the survey

Parameter	Hero Electric Cruz	Hero Electric Optima	Hero Flash	Hero Nyx	Hero Electric Maxi	Okinawa Ridge	Hero Wave	Revolt 400	Lohia Royal	Gowel ZX	Avon 207	YoXplor
Battery Capacity* (KWh)	1.15	2.69	1.34	1.34	1.15	1.25	1.58	3.24	0.96	0.29	0.96	1.15
Time taken to charge from 0-100% * (Hrs.)	5	5	5	5	8	5	6	4.5	7	7	7	7
Charging Rate (kW)	0.23	0.54	0.27	0.27	0.14	0.25	0.26	0.72	0.14	0.04	0.14	0.16

**Battery Capacity and Time taken to charge from 0-100% is as per manufacturer's product brochure claimed in /zigwheels.com/bikewale.com/carandbike.com*

[10]https://shaktifoundation.in/wp-content/uploads/2020/02/Exploring-Cost-Reduction-Strategies-For-Electric-Vehicle-EV-Batteries.pdf

[11]Source: https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/ (Accessed on 26 Jan 21)

As seen in Table 56, the vehicles are categorised on the basis of battery capacity along with the total time of charge from 0 to 100%, as provided in the specifications of the 2Ws. The same is done for all 4Wsand e-rickshaws as well. Battery capacities and time taken to charge from 0-100 % are considered as per the manufacturer's manual for each vehicle which is used to calculate the hourly charging rate. The charging rate is vital as the load drawn from the grid will depend on it along with the vehicle's SoC at the start of charging. For the purpose of this study, the battery is assumed to be charged linearly till it reaches its maximum charging capacity.

For the 4W survey, institutional as well as privately owned vehicles were surveyed to understand the charging pattern and consequent impact on the grid due to their charging timings. In the case of 4Ws, slow as well as moderate charging behaviour of the vehicle operators were considered. Consequent to moderate (Bharat DC 001) charging norms as well as slow (Bharat AC 001) charging norms (discussed later in the chapter) in use around Delhi, vehicles with the capability of getting charged quicker subject to their manufacturer's guidelines were also considered. 4Ws considered in the study with specific parameters are mentioned in Table 57.

Table 57: Four Wheelers with important parameters considered for the survey

Parameter	Mahindra E20 Plus	Mahindra e-Verito D2	MG ZS EV	Tata Tigor EV	Tata Nexon EV
Battery Capacity (KWh)*	16	18.55	44.5	16.2	30.2
Time taken to charge from 0-100% (Hrs.) *-Slow	9	11.5	8	11.5	9
Slow Charging Rate (kW)	1.78	1.61	5.56	1.41	3.36
Total Count of Vehicles-Slow Charging	2	10	1	5	
DC Moderate Charging Rate* (kW) {Subject to Maxm charger capacity of 15 kW in Delhi}	10.7	9.3	NA	8.1	15.0
AC Moderate Charging Rate- (kW)	3.3	3.3	NA	3.3	3.3
Total Count of Vehicles	5	89	NA	53	2

*Battery Capacity and Time taken to charge from 0-100% is as per manufacturer's product brochure as claimed in cardekho.com/ zigwheels.com
NA- Not Applicable

Table 57 depicts the vital parameters of the vehicles required to estimate the load on the system/grid due to the charging of the respective vehicle. For the purpose of this study, the rate of charging (as mentioned above) is essential. In the case of 4Ws the charging rate varies depending on the Electric Vehicle Supply Equipment (EVSE) used for either slow or moderate charging.

C. Charger Considerations

The rate of charging is vital to calculate the instantaneous EV load in a system. This parameter is dependent primarily on two aspects: the maximum rate at which batteries of an EV can be charged and the maximum rating of an EVSE, i.e., the maximum rate at which a charging terminal can transmit the energy to a vehicle. A charger can be a normal AC charger or a technically superlative DC charger that has the capacity to fast charge compared to its AC counterparts. In India, DC chargers are limited as of now and is mostly operated by distribution companies (Discoms) guided by state regulations due to the challenges it poses to the system harmonics because of its power electronics components and its capability to unbalance the local load profile. Although installation of public charging stations has lately been de-licensed[12] subject to compliance of technical norms, the cost of installation of DC fast chargers is still out of the purview of many.

[12]MoP notification dated 01/10/2019 titled "Charging_Infrastructure_for_Electric_VehiclesRevised_Guidelines_Standards"

While standards of charging for different vehicles may vary depending on the type of metal hydrides the batteries employed or the technology it supports, efforts have been made lately to standardise the charging by the Ministry of Power (MoP). Table 58 shows the charger type, connectors, and voltage of operation of the charger.

Table 58: EVSE charging type approved by MoP for public charging infrastructure in India (Notification dated 14 Dec 18)

Charger Type	Charger Connectors	Rated Voltage (V)
Fast	CCS (min 50 kW)	200-1000
	CHAdeMO (min 50 kW)	200-1000
	Type-2 AC (min 22 kW)	380-480
Slow/ Moderate	Bharat DC-001 (15 KW)	72-200
	Bharat AC-001 (10 kW)	230

*Note- For the purpose of this study, 15 kW DC Charger is considered as moderate charger

As seen in Table 58, the fast chargers are not in commercial operation as of now in Delhi and existing public chargers are either Bharat AC-001 or Bharat DC-001.

D. State of Charge

A vehicle battery's existing state of charge is defined as the residual charge in the battery at any given time. A 100% (SoC is a state wherein the battery can't be charged anymore and its drawing current becomes zero and it goes into a no-load condition even if connected to the grid/charging socket. Subject to the maximum charging rate of the charger and the battery, the battery is assumed to be charged linearly till it reaches its maximum charged capacity for our calculations. The survey, for each mode of vehicle, collected the SoC, plug-in time and plug-out time from the respondents for each time they charged their vehicle on the last working and non-working day. The SoC at the time of plug-in for each vehicle and battery charging parameters for each vehicle and their charges are used to calculate the SoC of each vehicle at each hour so as to ascertain the exact load it is going to put on the grid for the upcoming hour, subject to the slow/moderate charging modalities using the methodology described below.

5.2 Assumptions & Methodology for Studying the Impact of EV on the Distribution System

5.2.1 Excel-model Assumptions

To estimate the impact of charging of EVs on the grid, the study makes the following assumptions as mentioned below:

i. Charging is assumed to occur linearly over the charging cycle.

ii. SoC data categorisation done in 6 datasets.

   a. 10% and below considered having a charge of 10%.

   b. 11%-20% considered having a charge of 20%.

   c. 21%-30% considered having a charge of 30%.

   d. 31%-40% considered having a charge of 40%.

e. 41%-50% considered having a charge of 50%.

f. 51%-60% considered having a charge of 60%.

g. 61%-70% considered having a charge of 70%.[13]

viii. Common plugging out time assumed for multiple datasets of identical vehicles with similar SoC and plug-in time and connected to the same rate of charging.

ix. Based on inputs by survey respondents, weekday: Monday-Friday except for 4W-Institutional where weekdays are assumed to run from Monday-Saturday; Weekend: Saturday-Sunday.

x. Some respondent drivers of institutionally owned EV 4Ws and some private owners of EVs reported multiple charging in a day. In the analysis, multiple charging of the same vehicle in a day is considered as separate independent data for hourly load calculation.

xi. For simplifying calculation, any vehicle that starts charging from the middle of the hour (as per survey data) is deemed to begin charging from the start of the hour.

5.2.2 Methodology Employed in Load Calculation

In order to calculate the load across any hour of the day, and hence over the whole day, the following methodology was used.

1. Following data from the survey was sourced (for weekday as well as weekend):

   a. Battery capacity in KWh (if KWh not available, then capacity in an hour and charge voltage was used to find out battery capacity in KWh).

   b. Time taken to charge from 0-100% (in hours); partially manufacturer's manual also used for sourcing this data.

   c. Total count of vehicles surveyed - segregated based on the manufacturer.

   d. Time of plug-in and plug-out.

   e. SoC at the time of plugin.

6. Based on the above data, following results were calculated:

   a. If charging rate explicitly not available : Charging rate (Assumption made that vehicle is charged linearly at the same speed throughout its charge) = {(Battery capacity)/ (Time taken to fully charge from 0-100%)}.

   b. %age of individual vehicle types in total vehicle count.

3. Thereafter, each category of vehicle was segregated into groups depending on its charging plug-in time, viz., if, say, a group of "Hero Electric Cruz" is plugged in for charge at 9 pm, it will form Group 1 ; if, say, another group of "Hero Electric Cruz" is plugged in for charge at 10 pm, it will form Group 2 ; and so on until the whole count of "Hero Electric Cruz" is segregated to 'n' number of groups.

4. Each group is then assigned the share of that specific category of vehicles charged at its plug-in time, viz., if 2 out of a total of 10 "Hero Electric Cruz" are charged at 9 pm, the share of "Hero Electric Cruz" charged at 9 pm is 20% (i.e., 2/10).

[13]The sample size of surveyed vehicles did not show any vehicle of more than 70% SoC getting plugged in for charging.

5. Steps 3 and 4 are repeated for separate (SoC) values, viz., if a group of "Hero Electric Cruz" with 10% SoC is plugged in to charge at 9 pm and another group of "Hero Electric Cruz" with 30% SoC is plugged in to charge at 9 pm, a separate group is to be made and entered in the model.

Equation for Grid Load Calculation

$$\sum_{n=1}^{24} (Grid)_{\text{EV Load}} = \sum_{n=1}^{24} [\ \text{SoC} \times \text{N}_{\text{charged}} \times \beta\ ]$$

Where,

n = hour of the day

$(SoC)_n$ = State of Charge of the vehicle in n^{th} hour

$= [\ (SoC)_{n-1} + \frac{\beta}{\omega}],$

where, β = charging rate, and

ω = Battery Capacity

5.3 Result

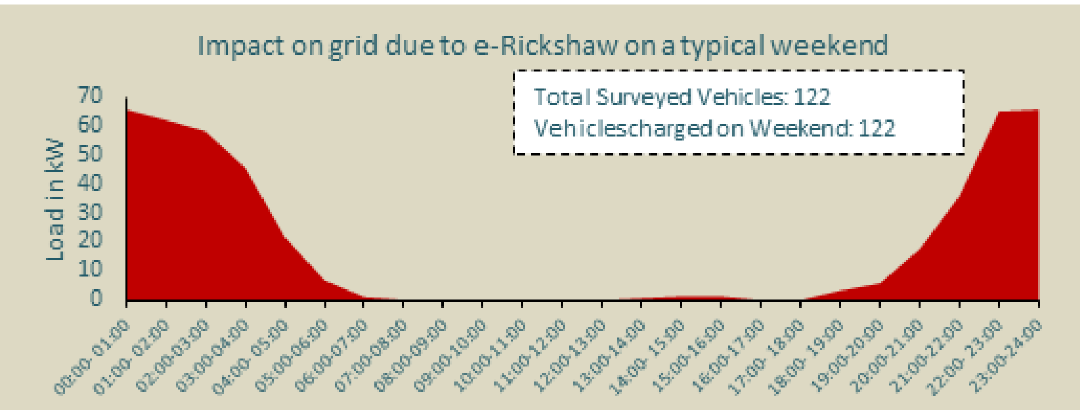
Delhi has seen unprecedented growth in vehicular population in the last decade. The number of vehicles per thousand population increased 66% from 374 in 2008-09 to 616 in 2018-19 while at the same time its population grew from 17 million to 22.5 million. The economic as well as environmental impact due to the growth in usage of personal vehicles as well as the commercial vehicles is immense. Notwithstanding the growth of vehicles in the capital, even a small shift towards using EVs would impact emissions, local air pollution and the load profile on the electricity grid substantially. The next section illustrates the impact of electric 2Ws, 3Ws and 4Ws on the grid in terms of load.

A. Impact of 3-Wheeler (e-rickshaws) on EV Load based on survey count

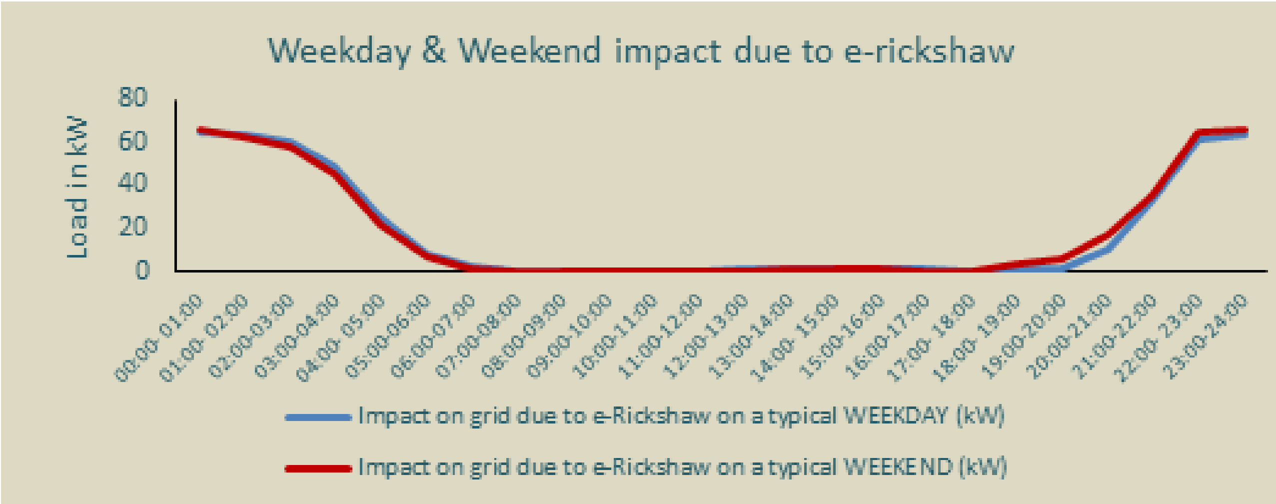
Delhi has a significant population of e-rickshaws with licensing mandated. The proliferation of e-rickshaws is a welcome move to limit IC engines plying in the city, which is already suffering from vehicular pollution, but this poses a separate set of challenges in managing the local electric grid load.

In the survey, the time of charge of each e-rickshaws was recorded and used so that a pattern emerged. The survey sample included a total of 122 e-rickshaws plying in various parts of Delhi. Figure 105 shows the hourly load due to e-rickshaws over a typical weekday and a typical weekend based on the survey count.

Figure 105: Hourly impact of e-rickshaw on the grid (weekday & weekend) based on surveyed vehicles



[14]Source: Projected Population- censusindia.gov.in



As seen in Figure 105, major charging happens at the end of the day. Most of the e-rickshaws are plugged in around 8-9 pm every day till they are fully charged at around 4-5 am in the morning. Further, around 2-4 pm in the afternoon, a limited number of vehicles are plugged in, which puts an additional minor load onto the system.

B. Impact of 2-Wheelers on EV Load based on survey count

Delhi is a hub for personalised motorised vehicles in India. Total motorised vehicles in Delhi, as of 31st March 2019, stood at approximately 1.14 Crore[15] out of which 2/3rd is the 2W count. With the ever-increasing population and more disposable income, vehicle registration is only expected to increase. It's important that this increase is controlled and adoption of vehicles using electricity is preferred in the near and distant future.

As part of this study, a survey was conducted to understand the pattern of charging of electric 2W owners. The survey covered a total of 12 models of motorcycles and scooters as shown in Table 59. These twelve models of electric 2Ws comprised a total count of 123, and out of them, while all charged during a typical weekday, only 56 vehicles (45%) charged during the weekend. As shown in Table 59, most of the 2Ws had a battery capacity between 1kWhr -2 KWh with the only exceptions being the Hero Electric Optima and Revolt 400, which had a battery capacity of 2 to 4 kWh. The various 2Ws with different battery capacities are depicted in Table 59.

Table 59: EV 2Ws surveyed, their battery capacities and share in vehicles charged on weekday (123 nos.) / weekend (56 nos.)

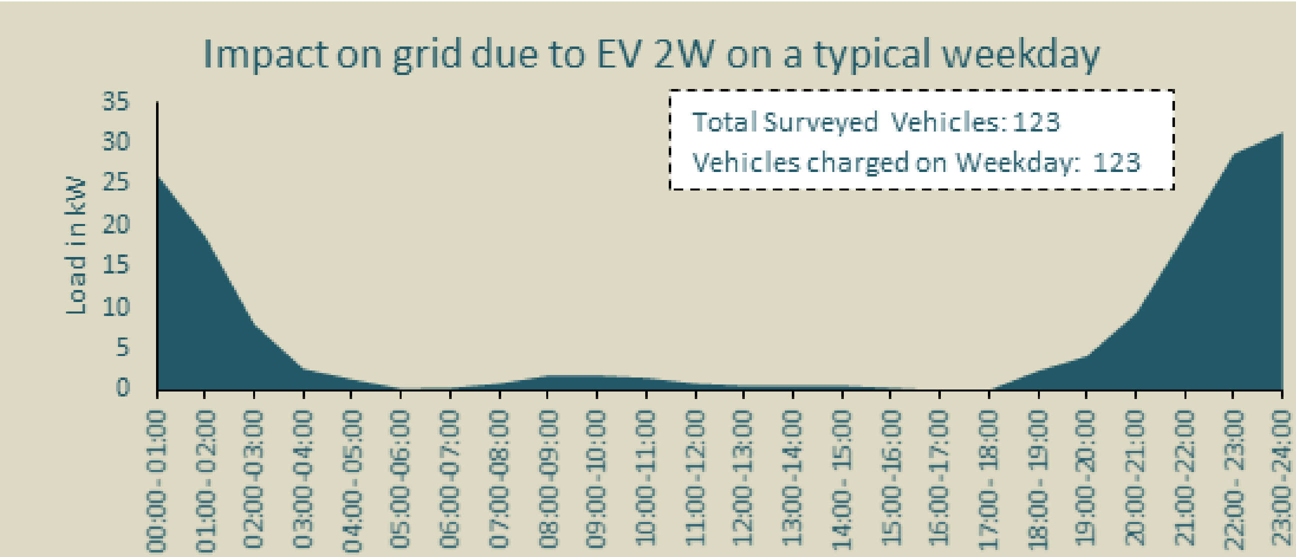
S. No.	EV 2Ws	Battery size (KWh)	Share in the vehicle charging on weekday (%)	Share of the vehicles charging on weekend (%)
1	Hero Electric Cruz	1.15	8%	13%
2	Hero Electric Optima	2.69	20%	20%
3	Hero Flash	1.34	43%	36%
4	Hero Nyx	1.34	3%	4%
5	Hero Electric Maxi	1.15	10%	11%
6	Okinawa Ridge	1.25	2%	4%

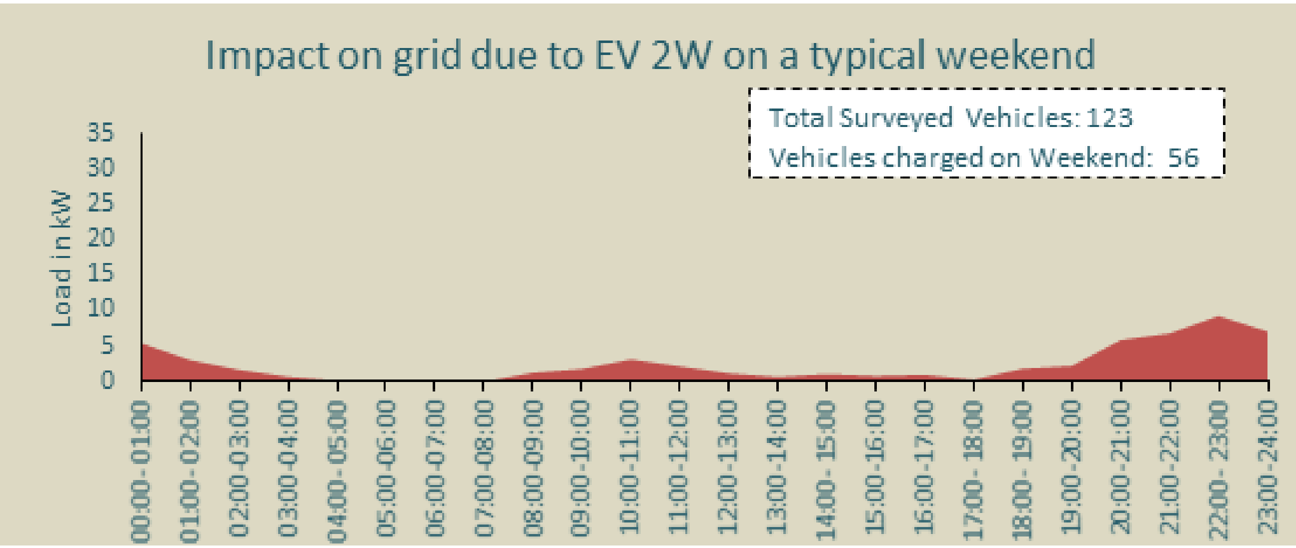
[15] Source: Delhi Economic Survey, 2019-20

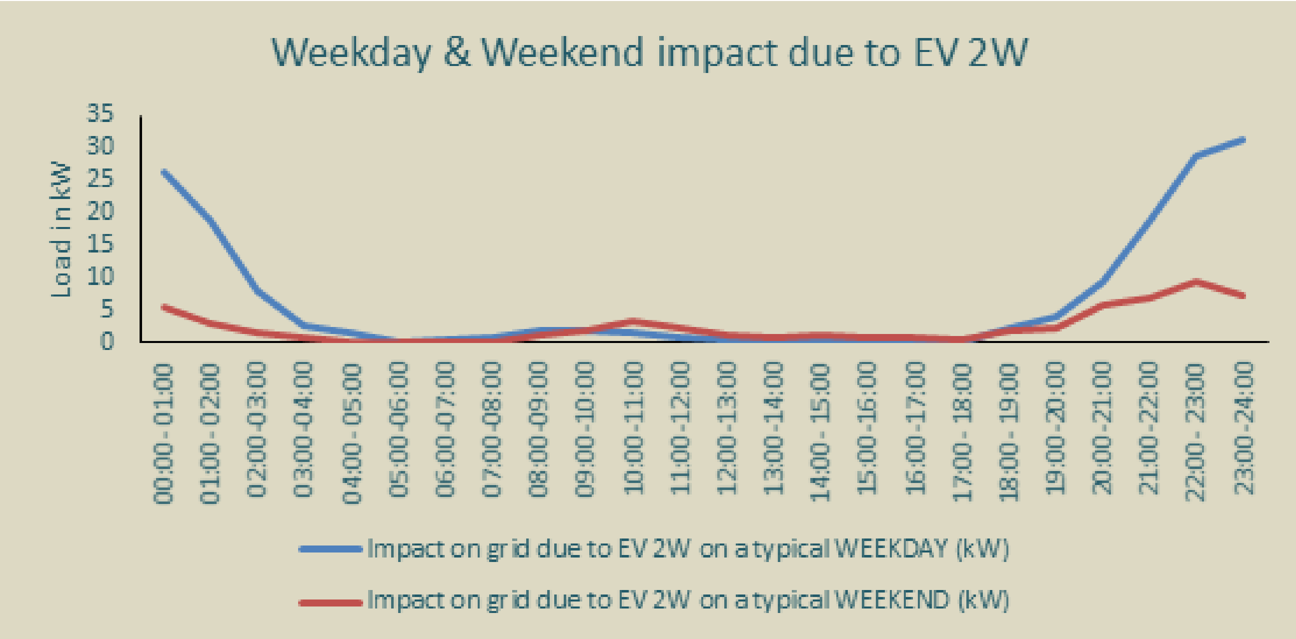
S. No.	EV 2Ws	Battery size (KWh)	Share in the vehicle charging on weekday (%)	Share of the vehicles charging on weekend (%)
7	Hero Wave	1.58	1%	2%
8	Revolt 400	3.24	8%	4%
9	Lohia Royal	0.96	1%	2%
10	Gowel ZX	0.29	1%	-
11	Avon 207	0.96	2%	4%
12	YoXplor	1.15	2%	4%

The charging pattern and hence the load impact on the grid has been estimated. A typical weekday and weekend load pattern on the grid due to electric 2Ws based on the surveyed vehicles is shown in Figure 106.

Figure 106: Hourly impact of EV 2W on the grid (weekday & weekend) based on surveyed vehicles







As can be seen in Figure 106, electric 2Ws are primarily plugged in for charging after office hours, typically at around 7 pm. The peak load due to the EV 2Ws is at around midnight. A minor additional load on account of charging of 2Ws on the grid is also observed in the afternoon. It is to be noted that of all the 123 respondents asked about their charging time and preferences on weekends, only 56 respondents confirmed that they do the charging on the weekend. Thus, 55% of the e-2W owners from the sample do not charge their vehicles on Saturdays and Sundays.

C. Impact of 4-Wheelers on EV Load based on survey count

The growth of 4W in Delhi has been unprecedented over the last decade. The 4W population (cars, jeeps, taxies, and ambulances) during the previous five years alone has increased from around 28.7 lakh to 33.6 lakh[16]. The government is pushing hard for the adoption of EVs in the state with financial as well as other benefits extended to EV buyers through notification of the Delhi EV policy 2020.

For our analysis, it's important to segregate the institutional and private EVs for 4Ws. This is vital because the quantum of load and charging pattern for a vehicle for commercial and personal purposes would be different, and hence their impact on the grid. Furthermore, exposure of institutional vehicles to moderate/fast charging is more as compared to private vehicles.

The number of private vehicles surveyed was less compared to institutional vehicles due to less EVs owned for private use at the time of the survey, although the same is expected to increase at a rapid pace owing to favourable policies, and increasingly volatile fuel prices.

D. Impact on load due to EV 4W (Private)

The EV 4W private owners who were the respondents in this survey used vehicles mentioned in Table 60. It was observed that these vehicles are subjected to only AC slow charging.

[16]Source: Delhi Economic Survey 2019-20

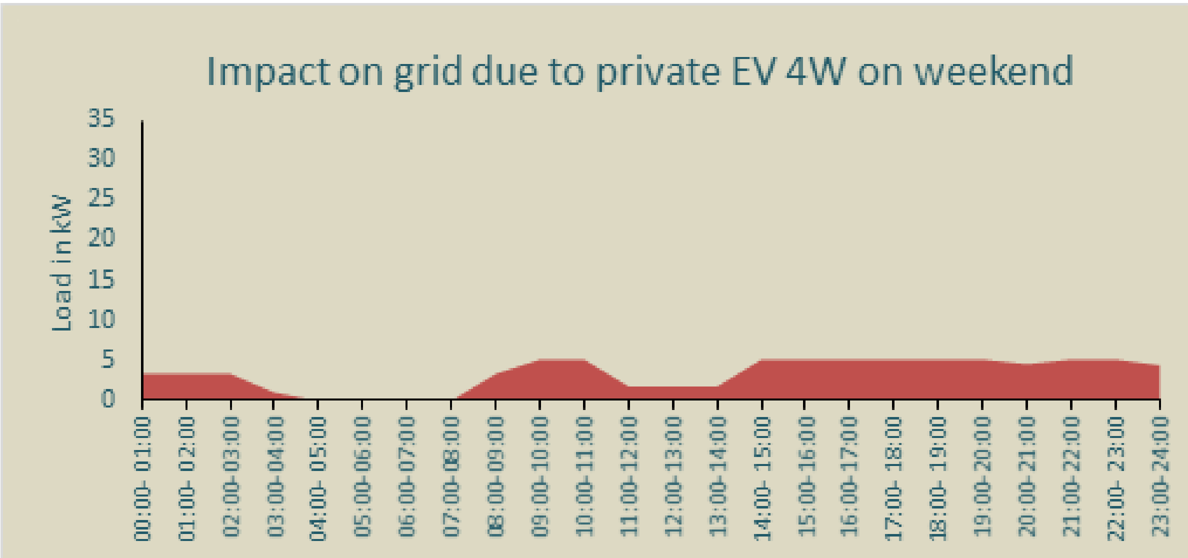
Table 60: EV 4-Wheeler (Private) surveyed, their battery capacities and share in vehicles observing charging on weekday (20 nos.) /weekend (7 nos.)

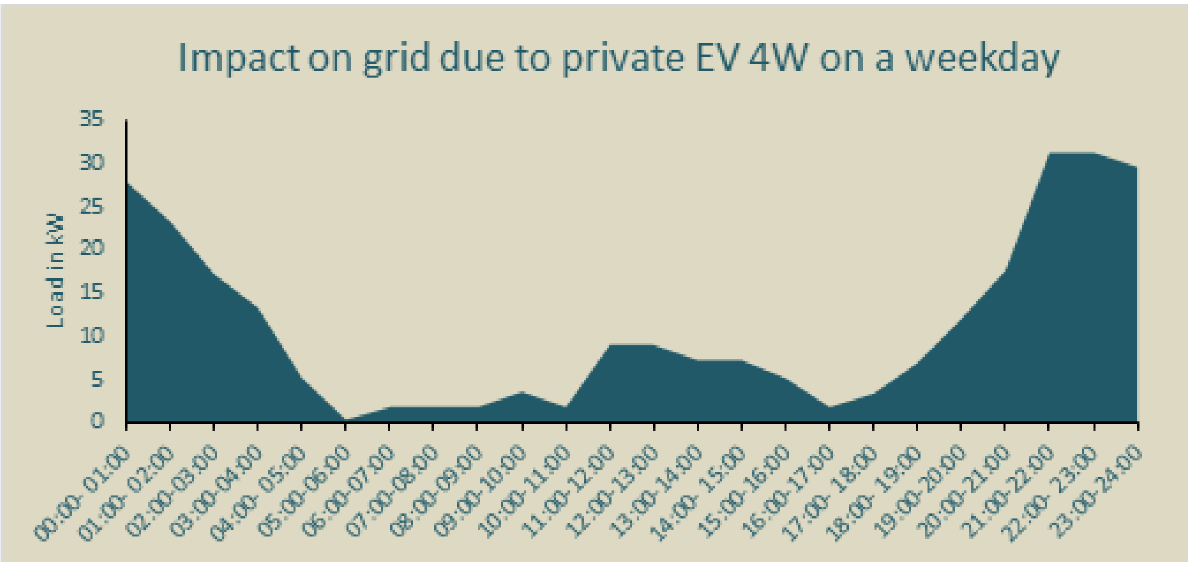
S. No.	EV 4-Wheeler	Battery size (KWh)	Share in the vehicle being charged on weekday (%)	Share in the vehicle being charged on weekend (%)
1	Tata Nexon EV	30.2	40%	43%
2	Mahindra e20 Plus	16	50%	57%
3	MG ZS EV	44.5	5%	NA
4	Mahindra e-Verito D2	18.55	5%	NA

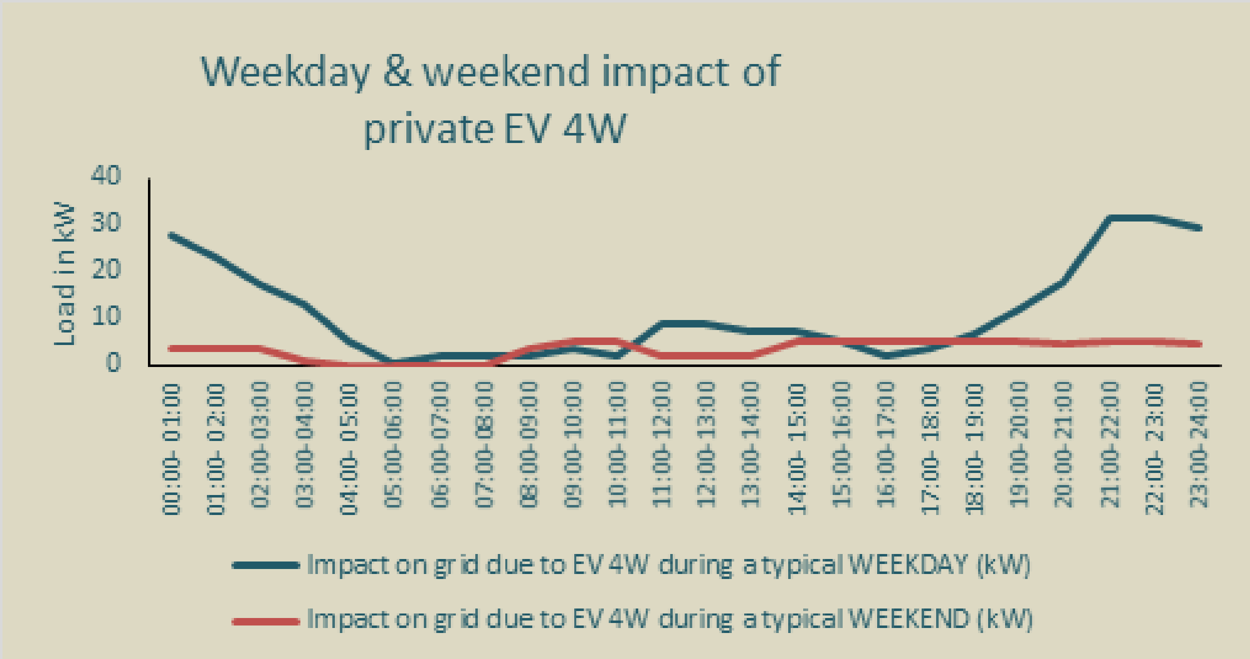
NA – Not Applicable

As is clear from Table 60, among the surveyed vehicles, Mahindra E20 Plus is the most popular privately owned EV-4W among the people surveyed, followed by Tata Nexon EV. The total survey count for weekdays under this sub-category of the survey was 20. Out of the surveyed count, only 7 charged their vehicles on weekends. Typical load on the grid due to weekday/weekend charging of these surveyed vehicles is shown in Figure 107.

Figure 107: Hourly impact of EV 4W (private) on the grid (weekday & weekend) based on surveyed vehicles







As shown in Figure 107, the hourly load distribution over 24 hours on a typical weekday has its peak around 10 pm after gradually increasing from 6 pm onwards. As can be seen in the graph, the plugged-in vehicles are getting charged, and the load on the grid gradually reduces by 5 am. There is a charging load around mid-day due to the top-up on DC moderate charging that the vehicles underwent. Thus, the EV 4W (private) charging behaviour shows a similar trend compared to EV 2W charging on a typical weekday.

E. Impact on load due to EV 4W (Institutional)

It is observed from the survey that the institutional vehicles account for a substantial count of electric vehicles plying on the roads currently, and the surveyed vehicle count is also the maximum in this sub-category. **Out of the total surveyed sample size of 167, eighteen used slow charging while the rest used AC moderate charging (3.3 kW) and DC moderate charging (15 kW)[17].** In this survey sub-category, five different brands of EV 4Ws were covered and are mentioned in Table 61 along with their share in total vehicle count. Each vehicle from the survey was grouped separately to slow and moderately charged categories

Table 61: EV 4-Wheeler (institutional) surveyed, their battery capacities and share in vehicles observing slow charging (18 nos.) and moderate charging (149 nos.)

S. No.	EV 4-Wheeler	Battery Size (KWh)	Share in the vehicles observing slow charging (%)	Share in the vehicles observing moderate charging (%)
1	MAHINDRA E20 PLUS	16	11%	3%
2	MAHINDRA e-VERITO D2	18.55	56%	60%
3	MG ZS EV	44.5	6%	NA
4	TATA TIGOR EV	16.2	28%	36%
5	TATA NEXON EV	30.2	NA	1%

[17]Wherein explicit DC or AC was not available during survey, careful assumptions were made based on time required for full charging when plugged in

As observed during the survey and as is clear from Table 61, Mahindra e-Verito D2 is the preferred vehicle for institutions followed by Tata Tigor EV. In the analysis, segregation of slowly charged and moderately charged surveyed vehicles are done as seen in Figure108.

Figure 108: Institutional EV 4W load on a typical weekday--slow charging (based on surveyed vehicles)

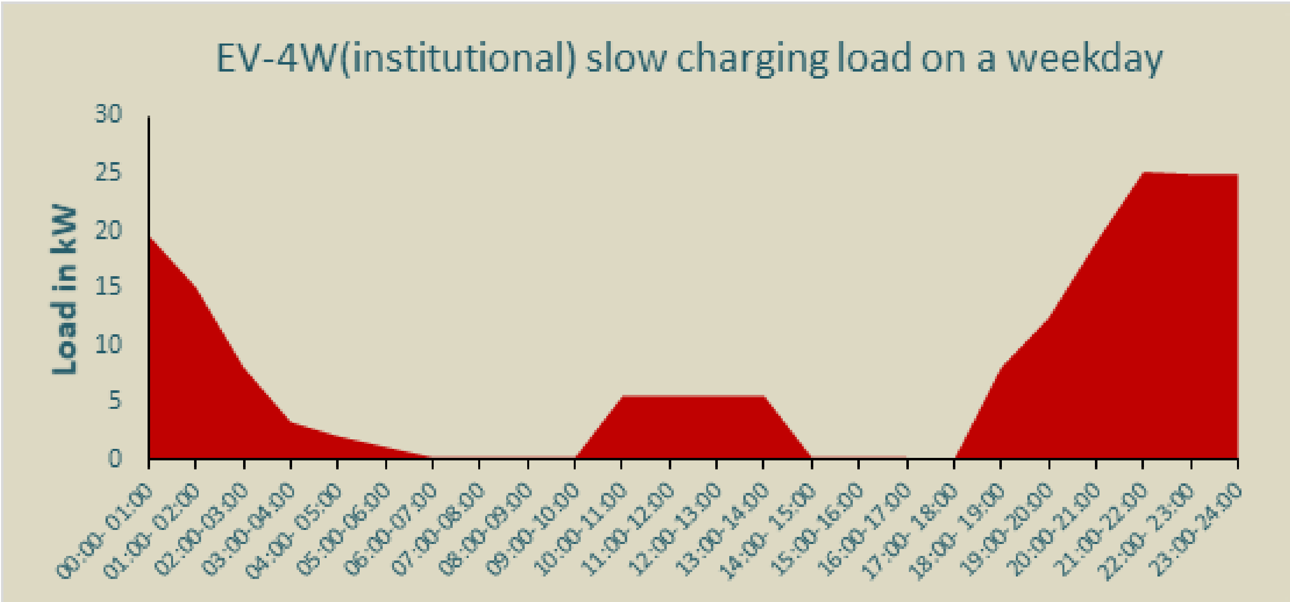


Figure 108 depicts that apart from a mid-day top up, primarily the load due to EVs is in the late evenings with its peak around 10 pm-12 midnight.

Figure 109: Institutional EV-4W load on a typical weekday--moderate charging (based on surveyed vehicles)

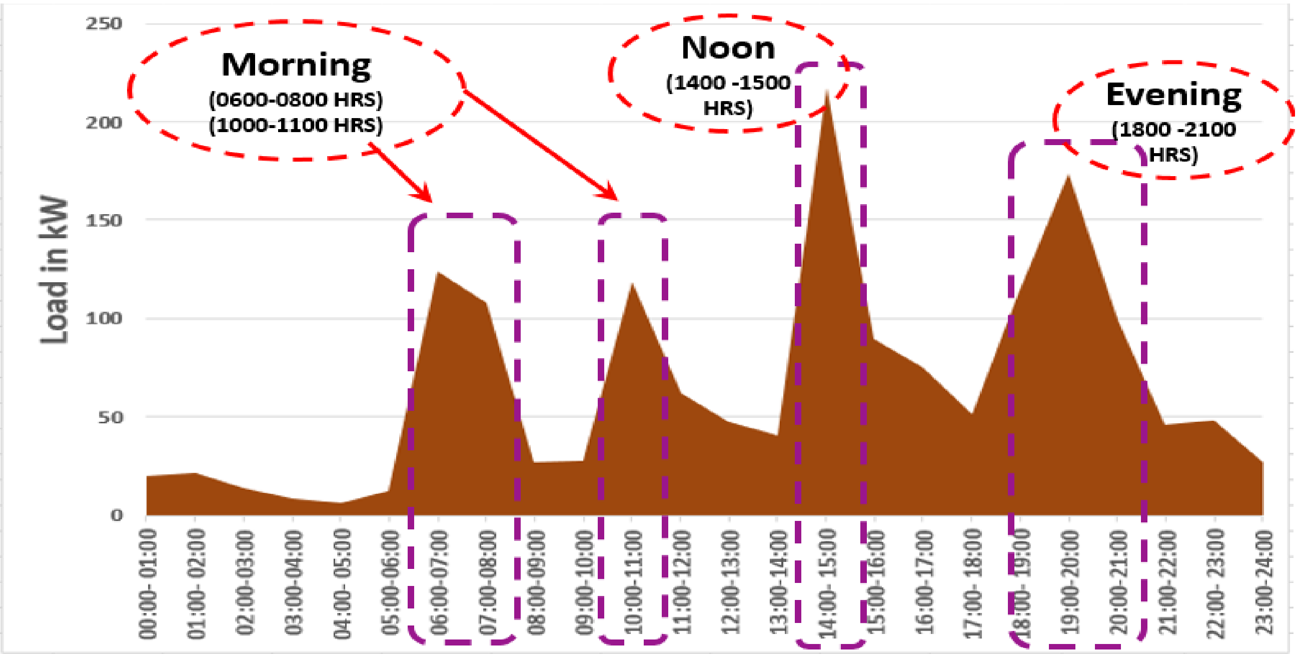
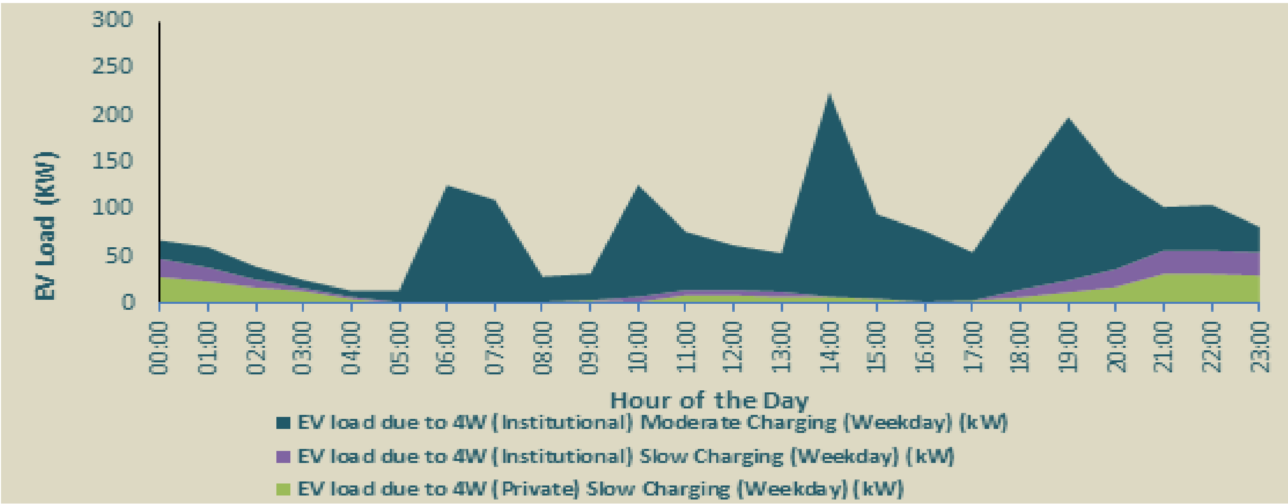


Figure 109 shows the load due to DC moderate charging speed of surveyed EV 4W(institutional) on a typical weekday. The graph's surges show that a substantial number of vehicles are subjected to DC-moderate charging whenever not plying on the roads. The peak is at around 2 pm.

F. Cumulative impact on weekdays due to EV 4W (private & institutional)

EV 4Ws have a comparatively larger battery size among the EVs plying on the road in Delhi at the time of the survey and are also technologically adaptable to quick charging. Due to this, EV 4Ws are expected to be significant load contributors, especially during peak loads. Since load management is not only an economic problem as the cost of electricity price varies according to demand, but also a system issue, it's essential to understand the load curve of EV 4Ws compared with Delhi's hourly load. Figure 110 shows the cumulative impact of EV 4W load {EV 4W (private)-20 nos.; EV 4W (institutional)-167 nos.} at different times on a weekday.

Figure 110: Cumulative hourly impact of EV 4Ws on a typical weekday {EV 4W (private)-20 nos.; EV 4W (institutional)-167 nos.}



As seen in Figure 110, the peaks on the graph are primarily due to the impact of EV 4W (institutional) charging in Delhi. While the individual loads due to private and institutional slow charging EV 4Ws are high at night, the low existing count of those vehicles surveyed is not impacting the load.

The load issue from moderate DC charging due to EV 4W institutional vehicles is substantial, and it is essential to plan the management of such spikes better. Possible interventions are discussed at the end of this chapter to alleviate this situation.

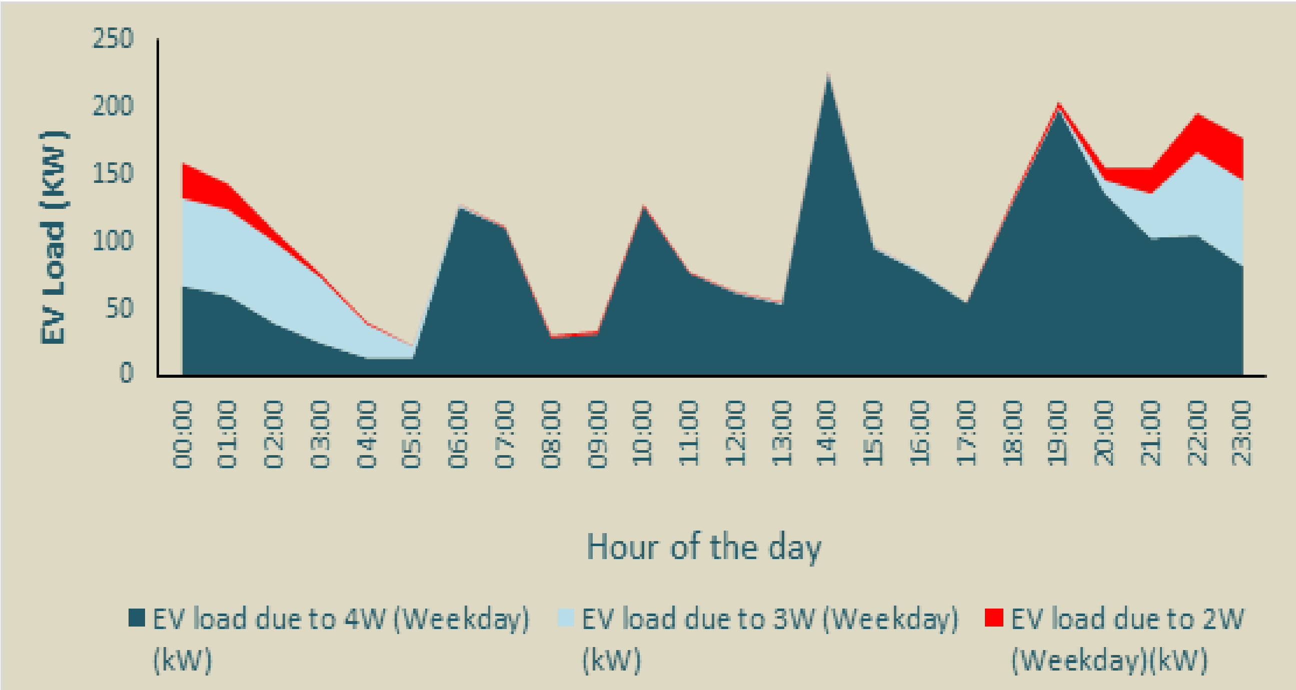
G. Cumulative impact on grid due to surveyed EVs (2W+3W+4W)

The individual impacts of different types of EVs are shown in the previous section in isolation. It is also important to understand the cumulative hourly implications of electric vehicles on the grid. Table 62 shows the summarisation of vehicle category, survey count and their charging categorisation. Figure 111 shows the cumulative hourly impact of a different kind of EVs on the grid. The low load of EVs is due to the limitation of the count of EVs surveyed, but the curve depicts the actual variation due to the charging of EVs.

Table 62: EV category, count and their charging categorisation

S. No.	Vehicle Category	Total Sample Count	Charged on Weekday	Charged on Weekend
1	EV 3W/ e-rickshaw	122	122	122
2	EV 2W	123	123	56
3	EV 4W (private)	20	20	7
4	EV 4W (institutional)	167	167 (Slow- 18; Moderate- 149)	-

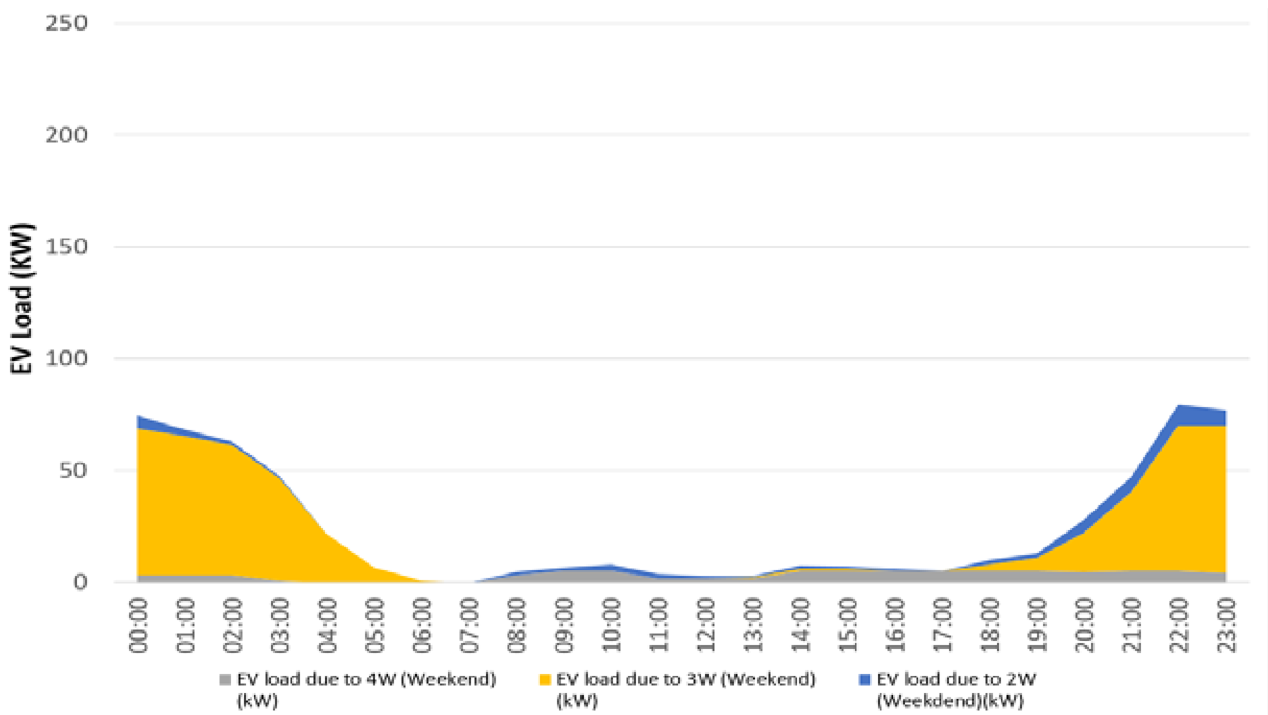
Figure 111: Surveyed cumulative EV load (stacked up area graph) variation



As seen in Figure 111, the major impacts and surges in the graphs are primarily due to the 4W vehicle charging, especially moderate DC charging, in the afternoons and early evenings. These times are generally peak load times, hence they add to the load pressure on the grid.

Figure 112 shows the cumulative EV load variation on weekends. The 4W institutional load is non-existent in the graph below due to the non-plying of institutional vehicles on weekends (in the survey, institutional vehicle drivers mentioned that Saturday is a working day and, therefore, considered a weekday while their off day is only on Sunday) and thus the day top-ups of vehicles are relatively flat.

Figure 112: Surveyed cumulative EV load (stacked up area graph) on a typical weekend



H. Impact on grid due to EVs (2Ws+3Ws+4Ws) in 2019-20

The last section's analysis of charging load due to EVs was based only on the survey results. While it does well in asserting the load curves from the sample vehicles, the actual impact due to the existing vehicle count in FY 2019-20 needs to be ascertained. IRADe estimated the vehicle count for each mode of vehicles in FY 2019-20 based on its statistical road transport model for Delhi. The projected vehicle for each mode in 2019-20 is shown in Table 63.

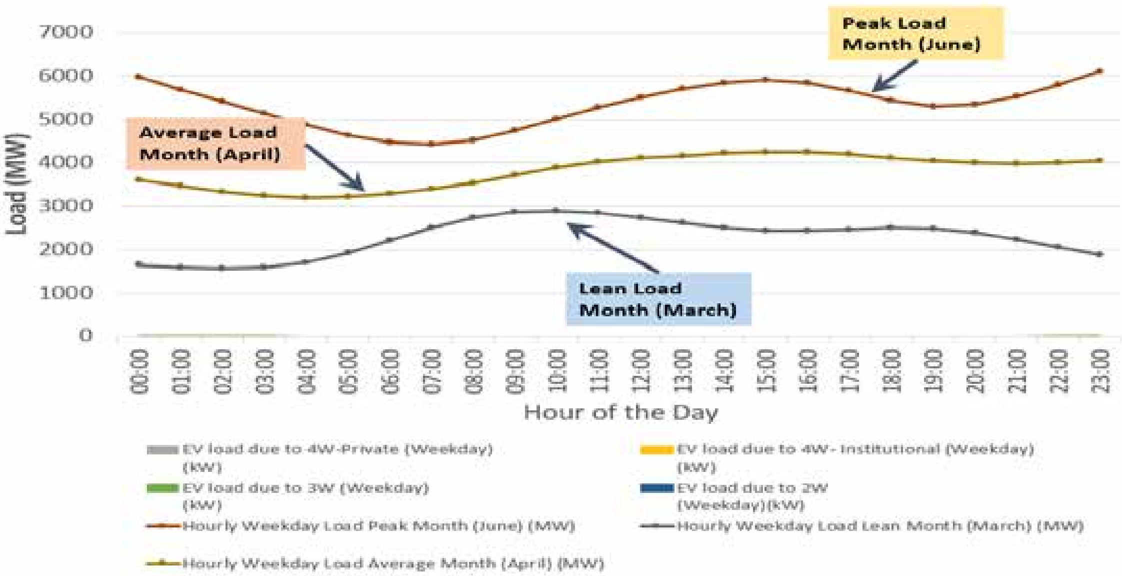
Table 63: EV count of select vehicle category in FY 2019-20

S. No.	Vehicle category	Total estimated EV count in 2019-20*	EV %age in total vehicle count	EVs getting charged on a weekday **	EVs getting charged on a weekend**
1	EV3W(e-rickshaw)	88,945	100%#	88,945	88,945
2	EV 2W	3,346	0.10%	3,346	1,523
3	EV-4W (Private)	1,664	0.08%	1,664	583
4	EV-4W (Institutional)	2,337	2.25%	2,337	-

*IRADe model estimates; ** Estimated count based on survey results; # includes only e-rickshaws

Integrating the above numbers in the model and analysing the impact of the consequent EV load on Delhi's average load for a weekday, the hourly load impact shown in Figure 113 is obtained. In the figure below, please note the peak month, average month and lean month load curve which is obtained by plotting the average hourly load curve in Delhi in FY 2019-20 (IITK CER database). Please see Annexure III for details in this regard.

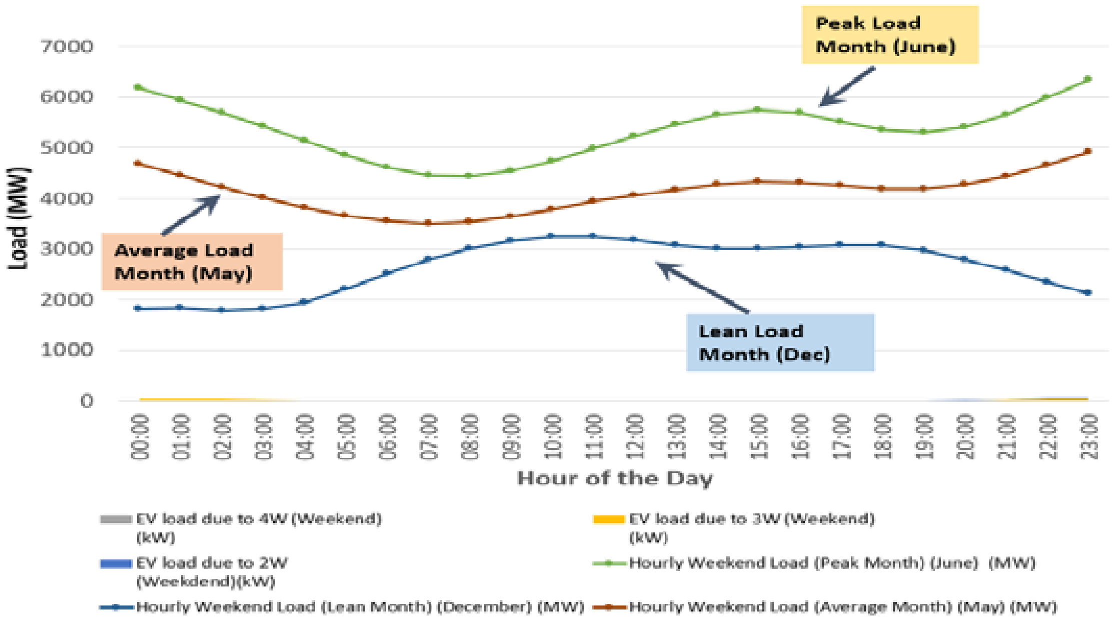
Figure 113: Hourly load impact of EVs on a typical weekday load in Delhi in FY 2019-20



Source: IIT-K CER and IRADe Analysis

It can be seen from Figure 113 that the impact of EVs in FY 2019-20 is minor compared to the average hourly load in Delhi. Please note that the peak load, lean month, and average load month are separately shown in the figure above. This is primarily due to significantly less count of EV 4Ws, which have comparatively larger batteries among EVs. The higher count of e-rickshaws is not putting much load on the grid because of the minimal size of batteries used in them. A far lesser impact of EVs was registered when the charging behaviour of EVs during the weekend is analysed. Figure 114 shows the impact of EVs on the weekend in FY 2019-20.

Figure 114: Hourly load impact of EVs on a typical weekend load in Delhi in FY 2019-20



Source: IIT-K CER and IRADe Analysis

I. Estimated impact on grid due to EVs (2Ws+3Ws+4Ws) in 2030

EVs are expected to increase substantially in numbers this decade. So it is essential to understand the impact that it would have on the grid. The 2W, 3W/e-rickshaw and 4W (private and institutional) on road vehicle stock was estimated using the IRADe road transport model up to the year 2030. In the electrification scenario, it is assumed that for 2Ws and private cars in 2020, 25% of sales is EVs and this increases to 50% by 2030. For public transport- 3Ws, taxis and buses in 2020, 50% of sales is electric and this increases to 100% by 2030. In the case of freight vehicles, the share of EVs in the total sales was assumed to be the same as private cars and 2Ws. This is an ambitious but not impossible scenario, given that almost 50% respondents in the prospective consumer survey already wanted to buy an EV. The estimated vehicle count is shown in Table 64.

Table 64: EV estimated figures in 2030

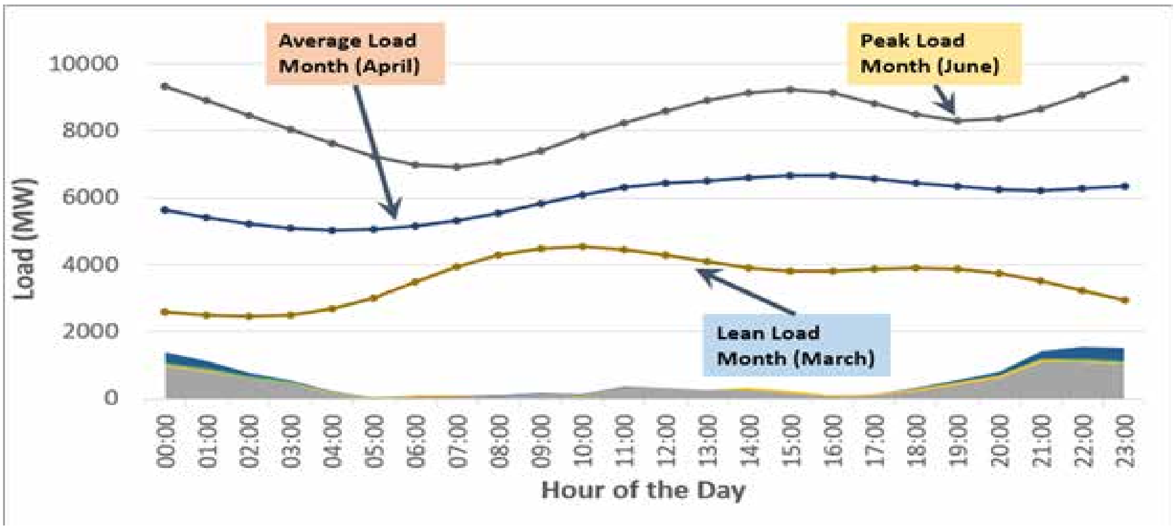
SNo.	Vehicle category	Total estimated count in 2030*	EV % in total vehicle count	EVs charged on a weekday**	EVs charged on a weekend**
1	EV 3W/ e-rickshaw	1,20,013	100%	1,20,013	1,20,013
2	EV 2W	14,93,632	34%	14,93,632	6,80,028
3	EV 4W (private)	6,97,935	30%	6,97,935	2,44,277
4	EV 4W (institutional)	51,862	41%	51,862	-

*IRADe estimates; ** Estimated count based on survey results

Source: IRADe Analysis

As can be seen from the above table, it is estimated that Delhi would have a substantial number of EVs by 2030, and hence their impact on the grid would also be significant. The Central Electricity Authority (CEA) estimates that for the year 2030, the peak load requirement in Delhi would be 11,575 MW. The estimated impact of different types of EVs on the Delhi grid on a typical weekday compared with the electricity load is shown in Figure 115.

Figure 115: Estimated impact of EVs on Delhi on Electricity Load* in 2030 on a typical weekday



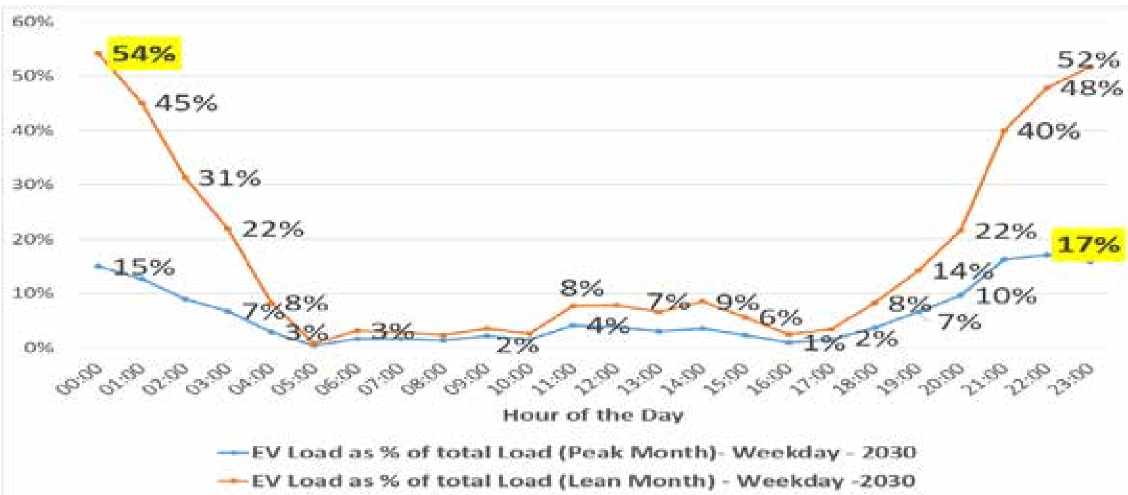
**without prospective EV load*

Source: CEA and IRADe analysis

It can be interpreted from Figure 115 that the substantial impact is due to the EV 4Ws. The additional topping up impact on the grid is made by EV 2Ws mainly due to their large numbers, as indicated in the figure. Comparing the effect in 2030 (Figure 115) with the one in FY 2019-20 (as shown in

Figure 113) shows a significant difference. This is primarily due to the estimated count of vehicles. Another important observation to be made is that the impact of 4W (institutional) vehicles is substantially subdued and the noon charging peaks that were seen during the analysis of the surveyed vehicles is dampened. This is because EV 4Ws (private) count is relatively high as compared to the EV 4Ws (institutional). Figure 116 highlights the impact of EV charging on the estimated hourly electricity load on peak and lean months.

Figure 116: EV charging impact compared to the weekday estimated hourly electricity load in 2030 (peak month/lean month)



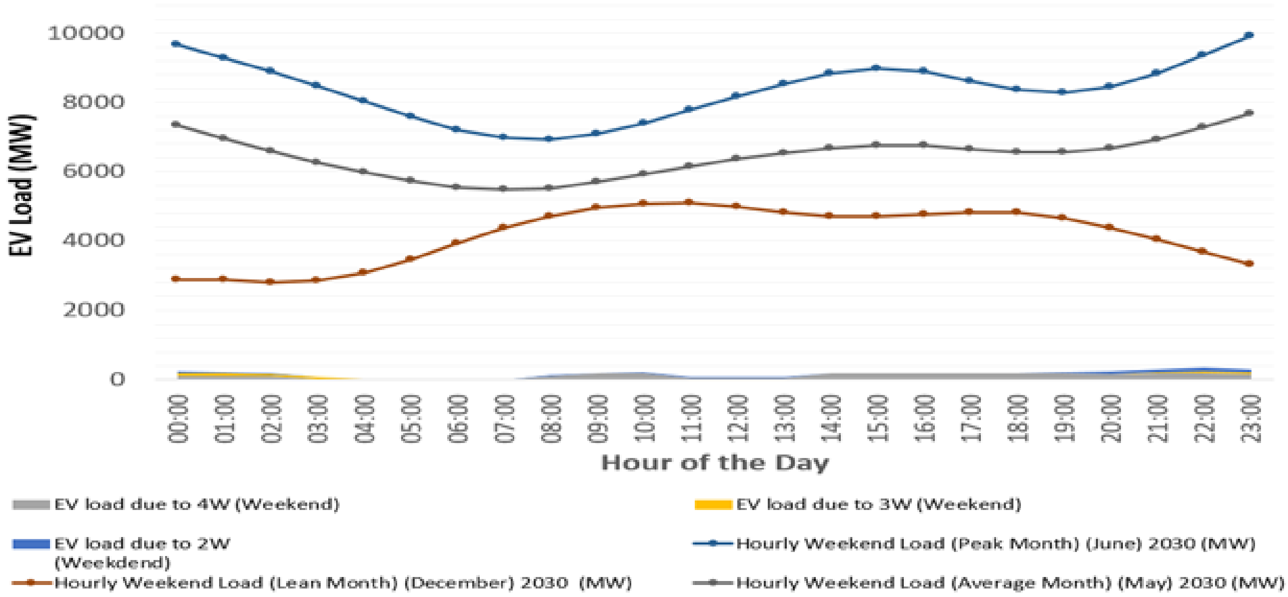
Source: IRADe Analysis

[18]Source: Baseline Scenario in CEA Long Term Electricity Demand Forecasting Report, Aug 2019

[19]The peak load month, average load month and lean load month curve is plotted based on peak load requirement (in MW) available for 2030 (Long term electricity load forecasting, CEA 2019) and offsetting the load based on FY 2019-20 actual data obtained from 'Energy Analytics Lab'- IIT-K CER Website https://eal.iitk.ac.in/ .

It can be inferred from Figure 116 that EVs in 2030 have the potential to contribute 17% over and above the peak month electricity load requirement. This contribution may increase to 54% of the total electricity requirement in the lean month. Hence, it is imperative for the distribution system to plan for EVs coming into the system. The load impact due to weekend charging of EVs is shown in

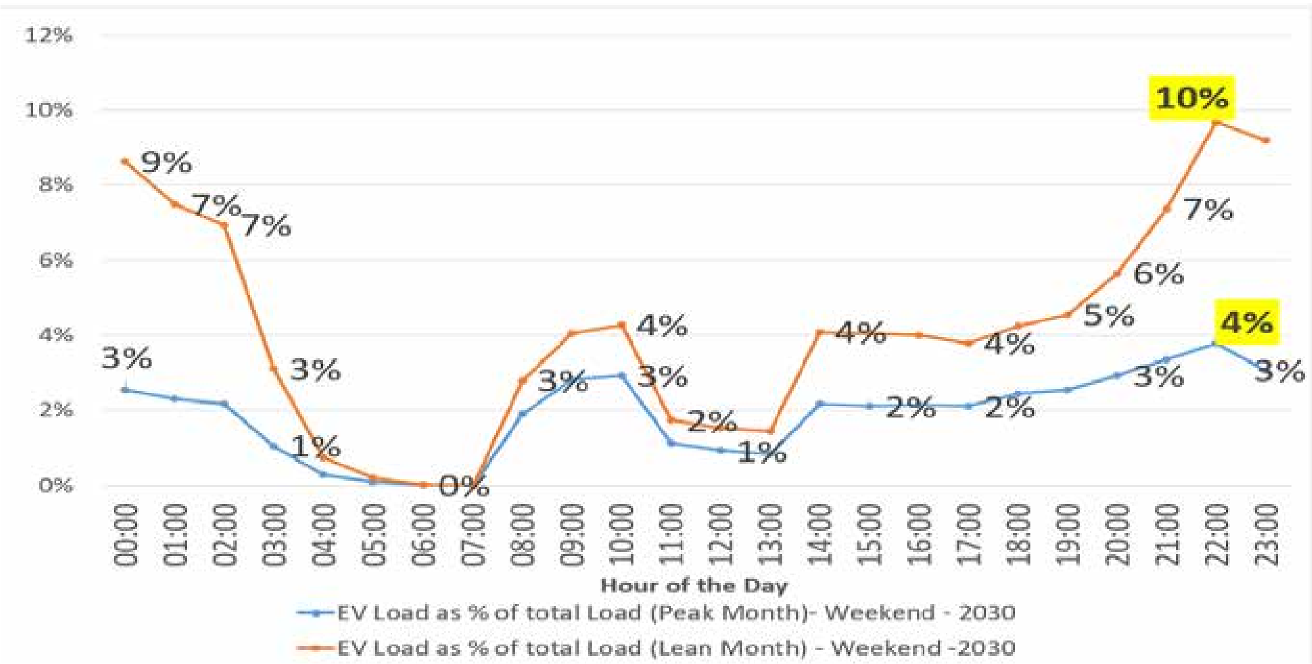
Figure 117: Estimated impact of EVs on Delhi's electricity load* in 2030 on weekend



** without prospective EV load) Source: CEA and IRADe analysis*

It can be inferred from Figure 117 that compared to a weekday, the impact of EV charging on a weekend, although not as significant as weekday charging, still has the potential to be 4% of the hourly load in the peak month and 10% of the total electricity load in the lean month of 2030. This is shown in Figure 118.

Figure 118: EV charging impact compared to the weekend estimated hourly electricity load in 2030 (peak month/lean month)



Source: IRADe Analysis

5.4 Conclusion

There are various conclusions to be drawn from this chapter which segregates the vehicular impact of each category of vehicle surveyed along with the mode of charging (slow/moderate) wherever applicable. The analysis also estimates the cumulative load due to the EVs in FY 2019-20 as well as in 2030, highlighting the major factors affecting the grid load a decade ahead. Summarisation of the learnings is mentioned below.

Note: The study's survey spanned over only two months (Sep-Oct 2020) and hence the seasonal variation in EV charging behaviour, if any, does not show in the outputs.

A. Key learnings from Surveyed Vehicles

1. E-rickshaws are primarily plugged in for charging in the late evenings (around 8 pm) and hence their impact on the grid load is from such time till early morning. As per the survey, very few e-rickshaws top up in the afternoon and hence their impact too is minimal. E-rickshaws also have very small batteries, so their impact is only profound when the numbers plying are very high. The charging pattern for this category of vehicle is similar on weekdays as well as the weekend.

2. EV 2Ws, like e-rickshaws, are plugged in for charging in the evenings (around 7 pm) and hence their effect on the grid is from late evening to early morning. As per the survey, only 46% of EV 2Ws are charged in the weekend as compared to weekdays and hence their impact on the weekend is comparatively subdued. Very few vehicles see a top-up in late morning/noon, but there is no significant impact on the load due to that.

3. Surveyed vehicles for EV 4Ws, which are privately owned, shows that only 35% of vehicles are charged during weekends compared to weekdays. This sharp reduction might be due to the very less number of office goers on Saturday and Sunday. This impacts the load as the weekend impact is non-significant with a plateaued load curve. The weekday load of EV 4Ws (private) impacts the grid during the late evening to early morning hours as most vehicles are plugged in at around 7 pm. This category of vehicle also sees top-up of charge at noon and the surveyed people confirmed that this charging is done in and around the office complex or in parking spaces.

4. Among the surveyed EVs, EV 4Ws used by institutional organisations or are rented comprised the major portion of the survey count. A moderate charging pattern was noticed for EV 4Ws (institutional) and hence their increased impact was noticed in survey results as multiple peaks during the day, primarily due to top-ups. The slow charging impact of this category of the vehicle was similar to EV 4Ws (private) with evening plug-ins adding to the load in the evenings to night hours.

B. Estimated vehicular impact

1. The impact of EVs (individual or cumulative) on the grid is very minimal due to the very low number of EVs plying on the Delhi roads in FY 2019-20. Comparatively high e-rickshaw numbers are also not impacting the grid much because of very small batteries used in such vehicles.The impact of EVs in 2030 is profound and is provided below.

    a. EV load share in 2030 estimated hourly demand (without EV load) on weekdays.

        i. Maximum of 17% at 00:00 hrs in peak month.

        ii. Maximum of 54% at 22:00 hrs in lean month.

    c. EV load share in 2030 estimated hourly demand (without EV load) on weekend.

        i. Maximum of 4% at 00:00 hrs in peak month.

        ii. Maximum of 10% at 22:00 hrs in lean month

C. Interventions for load management

A few of the critical interventions that can be undertaken for management of the increasing EV load is discussed below:

1. Time of Day (ToD) tariff:

Price economics is an essential consideration while deploying Time of Day (ToD) tariff. ToD is a tariff that is charged based on the time in which load is connected to the system (in this case, EV charging time). A higher tariff is charged from consumers if the load is connected during peak time of distribution utility while a rebate is given if the load is connected at lean hours. This is done such that non-essential loads can be shifted to non-peak hours so that load management becomes easy and economical for a distribution utility. As shown in the analysis, the surge loads of EV in the noon and early evening hours can be shifted to off-peak hours of late-night by utilising ToD tariff for a price-sensitive consumer.

2. Smart charging/ Managed or controlled charging:

Smart charging is another intervention that has been deployed successfully in various parts of the world and in a fast-evolving market like Delhi, may provide an innovative solution to the load management problem. Smart charging involves integration of vehicle with the grid and hence also broadly given the name, Vehicle-Grid Integration model. In Smart charging, charging can be initiated, stopped or regulated for an EV or multiple EVs based on remote functionality.

For example, renewable energy (RE) generation, especially solar, starts generating substantial power and because of must run status of the same, forces coal generation plants to ramp down and operate inefficiently at partial loads. Smart charging may initiate charging of connected EVs and coincide its load drawl in conjugation with the operation of a photovoltaic solar plant. This may lead to better management of the grid and avoid costly system augmentation which otherwise might be needed to support peak load charging of EVs.

Smart charging can be unidirectional or bi-directional. Uni-directional is a case as mentioned above while the bi-directional, in theory, is the usage of charge available with vehicle batteries to support the grid in times of urgency to dampen the load curve of distribution utility. Benefits of Smart charging, non-exhaustive, are listed below:

a. Reduction of bills for the consumer by efficiently using time of usage tariff and alternately avoiding high demand charges, which would otherwise be imposed on the consumer.

b. Deferral of distribution system upgrades/augmentation costs.

c. Better integration of RE.

d. Reactive power support in management of energy imbalances.

5. Smart transitioning of EV load:

Delhi, as well as India, is moving towards a grid with an increasing share of RE in its energy mix primarily dominated by solar power that peak during the day. In the upcoming decade, the availability of infirm cleaner power in the grid during the daytime will be higher and cheaper than power in the evenings and nights. Hence, the charging of EVs may need to be accommodated during the daytime using suitable mechanisms that inspire the charging behaviour of EV owners.

5.5 Way forward

This study gives few crucial points to ponder in the expected dominance of EVs in the next decade, primarily due to added impetus by the government to promote it as a sustainable means of transport through subsidies and rebates, as ever-increasing IC engine fuel prices burn holes in the price-sensitive customers' pockets. The analysis undertaken in this chapter could pave the way for future studies that may be undertaken by Discoms to better understand the impact of EVs on their systems. Some of the suggested areas for the Discoms are the following:

1. Policies for shifting charging time needs to be explored based on the demand-supply pattern of electricity.
2. Sensitivity of charging time with the price of electricity needs to be explored.
3. Augmentation of the existing network to manage grid efficiently considering the share of EV load at certain hours of the day.
4. Preparation of a road-map for the Capex and Opex for system augmentation related to EV integration into the system.
5. Effective management of high RE as well high EV integration into the Discom system.
6. Identifying location for EV charging stations considering the system's existing capacities and potential for future augmentations.
7. Injection of harmonics by EV charging systems into the grid.
8. Identifying individual substation/transformers that would either need upgrade or a new sub-stations establishment, requirement for feeder segregation etc.
9. Demand management policies for shifting charging time needs to be explored based on the demand-supply pattern of electricity.
10. Exploring sensitivity of charging time with the price of electricity for consumers.

5.6 Limitations for Analysis

The study is limited in its scope since it captures the consumer behaviour based on the surveys conducted for a limited number of vehicles for all the three segments of customers, viz., 2Ws/3Ws/4Ws.

1. The charging system in Delhi still employs DC moderate charging as its best charging mode, with 15kW of charging speed (Bharat DC_001) being the fastest charging option available for customers. As faster charging options are made available in Delhi , the instantaneous load impact on the grid may be even higher.
2. Few vehicles, especially 4Ws (institutional), are mentioned as being charged thrice in the same day, which might not be the case for every weekday and hence its impact might be a bit skewed.
3. Some of the vehicles surveyed are now discontinued, viz., Mahindra e-Verito (4W), Okinawa Ridge (2W), etc. and hence further addition of these vehicles would not take place although similar or better models are expected from the manufacturers.
4. The surveyed vehicle dataset does not include some latest car models such as the Hyundai Kona. The additional newer models may bring batteries of higher capacities as technology evolves and range anxiety is addressed. This would not only mean a higher load on the grid, but a faster charging rate of newer vehicles would also have a notable impact on the slope of the electricity load curve.

Annexure I

Technological Profiling - EV 2W

Two-wheeler conventional vehicles comprises two-thirds of all the vehicles in Delhi and causes the maximum pollution amongst all other conventional vehicle types. In order to reduce air pollution, conventional vehicles are substituted by electric vehicles. The Delhi government has aimed to register at least 5 lakh electric vehicles by 2024 in the national capital region which will mostly include 2Wsand commercial vehicles. There are 23 2W EV models under the Delhi's EV policy across seven manufacturers (Economic Times, 2019). All these models are eligible for purchase and scrapping incentives across the seven manufacturers. The top brands which manufacture electric scooters and bikes are Revolt, Bajaj, Ather, Hero Electric and TVS. The factors considered for this profiling is range, battery charging hours, availability of fast charging, battery type, battery capacity and price of the EV 2W. Two battery types are available in the market for 2W EVs which are Li-ion and Lead acid.

Table 65: Technological Profiling of EV 2W

EV 2W	*Range (km/ charge)	**Battery charging hrs.	Fast charging	Battery type	Battery capacity (kWh)	Ex-showroom price (INR)
Hero Electric Flash	65	4 to 5	No	Lithium Ion	1.34	39.9 k-52.9 k
Hero Electric Optima LA	50	6 to 8	No	Lead Acid	0.96	44990
HERO ELELCTRIC MAXI	70	7 to 8	No	Lead Acid	1.15	29,990
Hero Electric Cruz	70	4 to 5	No	Lithium Ion	1.15	37390
Revolt RV300	180	4.2	Yes	Lithium Ion	2.7	84,999
Revolt RV400	150	4.5	Yes	Lithium Ion	3.24	1.03 lakh
Ather 450	70	4.18	No	Lithium Ion	2.7	1.13 lakh
Okinawa I Praise	160	3 to 4	No	Lithium Ion	3.3	1.12-1.14 lakh
Bajaj Chetak	95	5	No	Lithium Ion	3	1-1.15 lakh
TVS iQube Electric	75	5	No	Lithium Ion	4.5	lakh

**Range of the vehicle is the total distance covered per charge.*

***Battery charging hours is the total number of hours required by the vehicle to completely charge its battery depending on the battery capacity installed in the vehicle.*

The technological profile of some of the popular models in Delhi has been tabulated (Zigwheels , 2021). Two types of charging options are compatible with EV 2Ws, slow and fast charging. As can be observed from Table 1, electric bikes like Revolt 300 and Revolt 400 have fast charging options available. However, fast charging infrastructure is not yet available to EV 2W consumers. All the other factors for profiling EV 2Ws vary from model to model.

Annexure II

Technological Profiling – Existing E-Rickshaw (3W)

Eighty-eight thousand registered e-rickshaws are running in Delhi, but the actual count of e-rickshaws that includes unregistered e-rickshaws is above 1.5 lakh (consists of both owned and rented e-rickshaws). Currently, e-rickshaws already comprise fifty % of the three-wheeler sales in Delhi. All these provide an opportunity to understand the profile of existing EV users, their preferences, charging pattern, and thus anticipate the future behaviour pattern of EV consumers. The factors considered for technical profiling are range, battery charging hours, availability of fast charging, battery type, and battery capacity of e-rickshaws.

Table 66: Technical specification of e-rickshaws in Delhi

S. No.	Standards	Existing e-rickshaws in Delhi
1	**Vehicle dimensions:** • 2700*1000*1750 mm • (Max width 1000mm & max length of 2800mm)	2700*(900 to 1000) *1750 (varying sizes are available in this range)
2	**Capacity:** • Four passengers + 1 driver and load capacity of 450 kg	4 or 5 passengers + 1 driver and additional luggage (average occupancy is more than four passengers in Delhi which is due to lack of enforcement. Carrying more than four passengers is overloading and violation of rules)
3	**Battery specifications:** • Four batteries • 100 Ah or more battery capacity	4 Lead-acid batteries each with the standard capacities of 100/120/140Ah.
4	**Charging time and range:** • Charging for 7 to 8 hours • Range of 80 km to 100 km	Charging for 8-10 hours depending on battery life. The average range of 77 km
5	**Speed:** • Speed restriction of maximum 25 kmph	Speed ranging from 20 kmph to 40 kmph
6	**Electricity consumption**	6-7 units per day
7	**Life of e-rickshaw: 2-3 years**	Life of an e-rickshaw depends on the operation. It may range from 2 years to up to 8 years for some e-rickshaws if maintained from time to time. Parts of e-rickshaws have to be replaced from time to time (batteries in every 9-11 months, tyres in 12-15 months, etc.)

Source: ICAT, ARAI website, ICLEI SA

Types of e-rickshaws

A range of e-rickshaws is available. E-rickshaws of various models have either Lead-acid or Li-ion batteries fitted in them.

1. **Passenger rickshaws** are used for ferrying people from one point to another. As per the Delhi survey, 100% of e-rickshaws used for ferrying passengers are presently running on Lead-acid batteries. Among all the available types of e-rickshaws, passenger e-rickshaws cater to the maximum number of the population and have been in huge demand.

2. **Load carriers** are used for carrying loads varying from 500 kg to 1000 kg. The motor power is higher in this case. These are used more frequently at places like airports, shopping malls, railway stations, etc. These can be used for short distances also. The maximum speed ranges from 20 to 25 kmph and the battery requires charging for 9-10 hours.

3. **Vegetable/fruit cart/garbage e-rickshaws.**

Table 67: Technological profiling of e-rickshaws in Delhi

E-Rickshaw Models	Range (km per charge)	Battery charging hrs.	Fast charging/ slow charging	Battery Type	Battery capacity	Input voltage	Battery charger	Max. speed kmph
Hero Electric	100	8 hrs.	Only slow	Lead acid	100 Ah	48 V	48 V 15 Ah	25
Kinetic Green	80-100	8 hrs.	Only slow	Lead acid rugged battery	100Ah	48 V	48 V 15 Ah	40
Mahindra Electric	85-130	2hrs. 30 min to 3hrs. 50 min	Both	Lithium-ion	3.69 V-7.37 V	48 V	48V 15 Ah	24.5-55
Jezza Motors	100	8 hrs.	Only Slow	Lead acid	100 Ah	48 V	48 V	25
Atul Auto Ltd.	80	8 -10 hrs.	Only slow	Lead acid	100Ah	48 V	48 V 12Ah	25
Udaan E-rickshaws	75-125	8 hrs.	Only slow	Lead acid	100Ah	48 V	48 V 12Ah	25
Skyride E-rickshaw	100	8-9 hrs.[20]	Only slow	Lead acid	100 Ah	48 V	48 V 12 Ah	25
Gayam Motor Works	60-90	5-6 hrs.	Only slow	Lead-acid	120Ah	48 V	48 V 12 Ah	25
Lohia Auto	70-80	8 hrs.	Only slow	Lead acid	80 Ah/100Ah	48 V	48V - 12A three stage	<25

The Lead-acid batteries need to be replaced every 8-9 months, whereas the Li-ion batteries have a life of up to 5 years. Moreover, the Li-ion battery's life cycle is over 3000 times or more compared to just 400-500 cycles in Lead-acid.

[20]Under Certain Test Conditions
Depending upon Charger and Battery Capacity, Site & Product Conditions

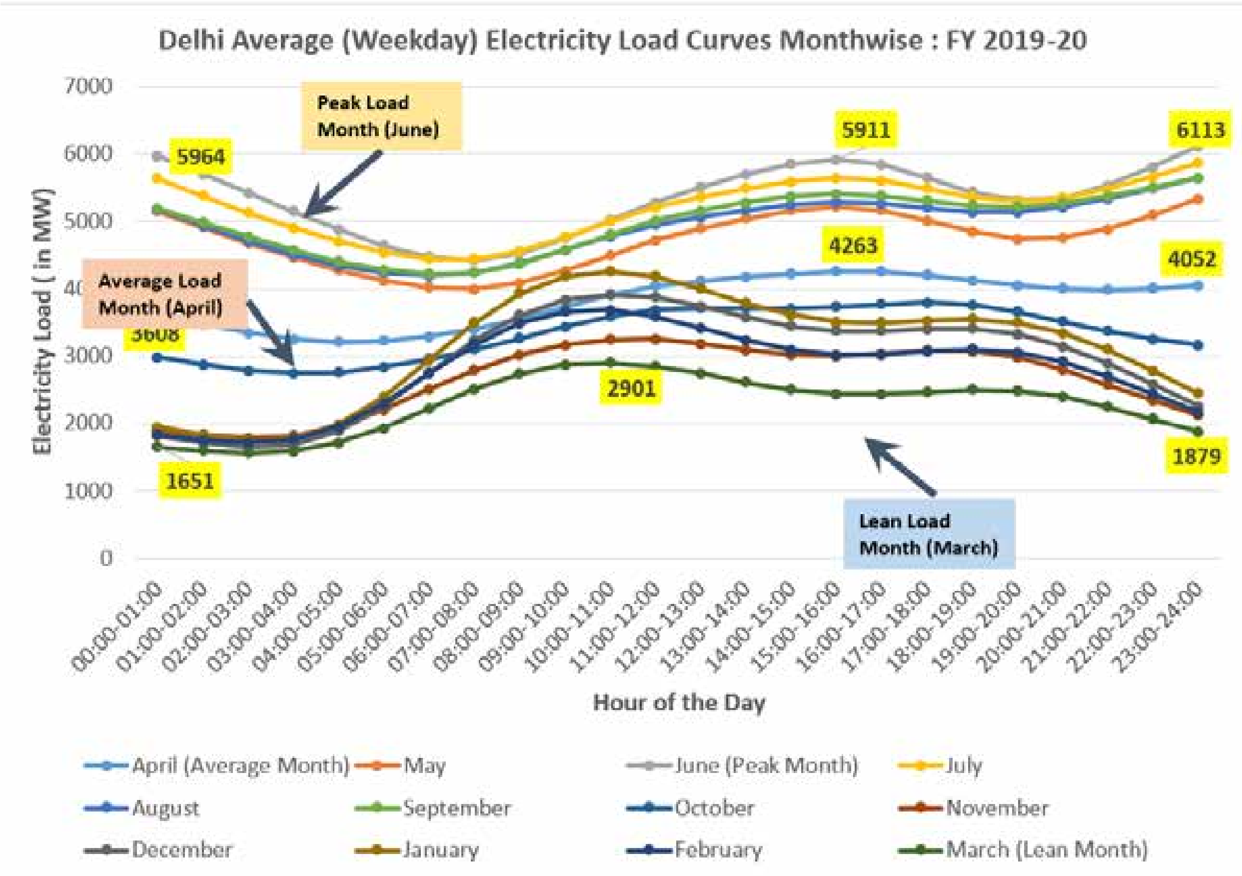
Annexure III

Electricity Load Pattern in Delhi

The per capita electricity consumption in Delhi is 1574 KWh[21] (FY 2016-17) and has seen its load requirements grow consistently over the years. The maximum demand met in FY 2019-20 was 7409 MW. In the current context of understanding the EV load impact on the grid, it is essential to analyse the hourly load pattern in Delhi. It is also vital to segregate the hourly loads on a weekday/weekend basis because the charging behavioral impact of EVs (which we would later analyse in this chapter) would vary substantially over a typical working day and weekends.

Figure 119: below shows the month-wise hourly load variation of Delhi on a typical weekday.

Figure 119: Average Hourly Weekday Load Curve of Delhi in FY 2019-20 (Month-wise)



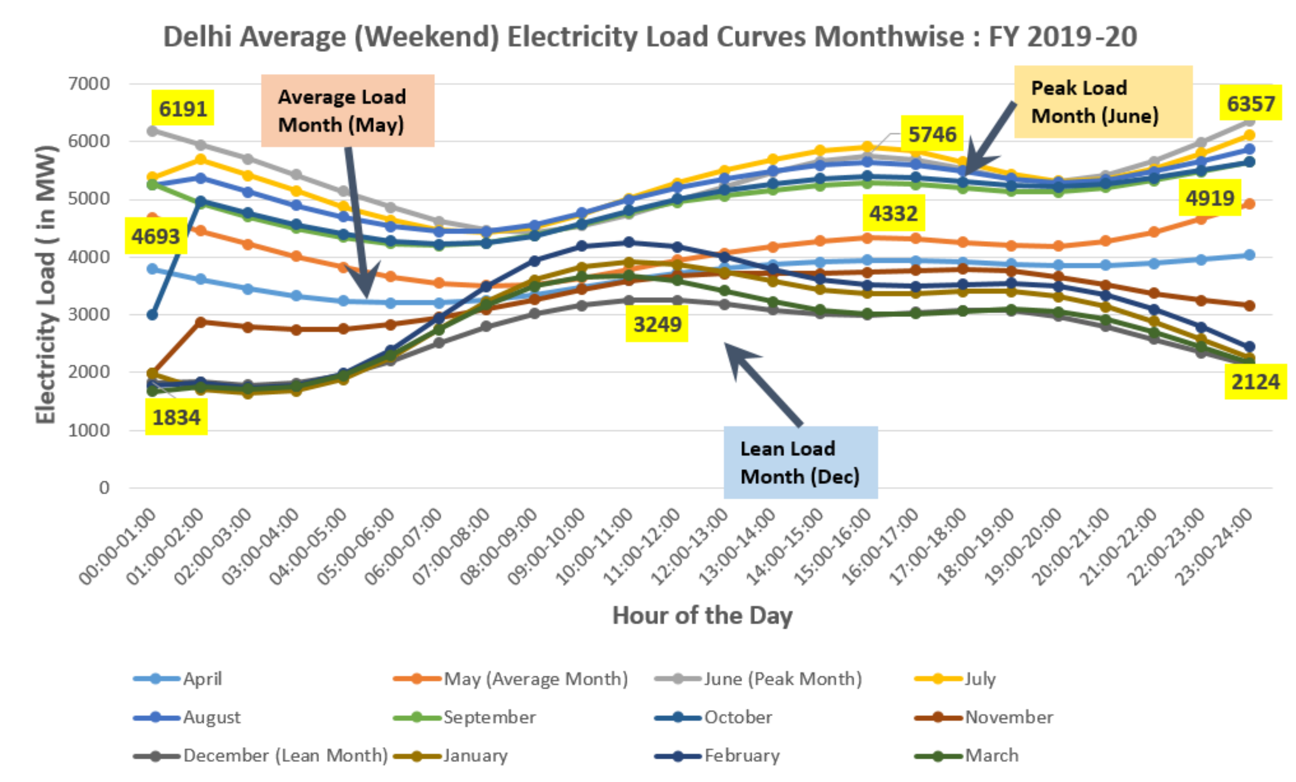
Source: IIT-K CER and IRADe Analysis

[21]Source: NRLDC Annual report 2019-20

As can be seen in the above figure, there is significant seasonal variation in the hourly load. As indicated in the figure, the peak load month FY 2019-20 for weekday load was June, while the lean load month was March. The graph also clearly depicts that the peak load hour in the day for a peak month was at around 00:00 hrs – 01:00 hrs while the same for a lean month was at around 10:00 hrs to 12:00 hrs. April can also be considered as an average month in terms of hourly load.

Figure 120 below shows the month-wise hourly load variation of Delhi on a typical weekend.

Figure 120: Average hourly weekend load curve of Delhi in FY 2019-20 (month-wise)



Source: IIT-K CER and IRADe Analysis

As can be seen in the above figure, there is significant seasonal variation in the hourly load. As indicated in the figure, the peak load month FY 2019-20 for the weekend load was June, while the lean load month was December. The graph also clearly depicts that the peak load hour in the day for a peak month was around 00:00 hrs – 01:00 hrs while the same for a lean month was at around 10:00 hrs to noon. May can also be considered as an average month in terms of hourly load.

Annexure IV

Sample Size of Surveys and Reliability

The survey undertaken in this report covered more than 500 respondents in four distinct segments: current private users of EV 2Ws and EV 4Ws, EV 4Ws (institutional), e-rickshaws and prospective EV consumers. Thus, there are 5 different surveys with around 123 sample points each for the surveys of EV 2Ws, EV 4Ws (institutional) and e-rickshaws, 140 sample points for prospective consumers and only 21 sample points for the survey of EV 4Ws (private). Compared to usual travel surveys, the number of sample points included looks low. But the objective is not to conduct a travel survey but rather a survey of electric vehicle users in the fashion of travel surveys, although, ideally, a larger sample would have reduced sample variance and improved precision. However, at the time of the project, the market penetration of EV was very low and hence Shakti Sustainable Energy Foundation (SSEF) felt that having a large scale survey would not yield any improved result. But Discoms needed some initial assessment of the impact on the grid due to EV charging for their planning. Hence, it was decided to conduct small surveys for cost and time considerations.

The smaller sample size neither makes the estimates unbiased nor less precise. A statistical explanation to support the credibility of the sample estimates is provided below. The survey data is used to compute various average values of variables and ratios of interest. Firstly, the computed sample averages and proportions are unbiased estimates of the actual population averages and proportions. For theoretical proof, see chapter 2, theorem 2.1 in Cochran (1999)[22] which states that the sample mean is an unbiased estimate of the population mean. This is independent of the sample and population size. The variance of the estimated sample average $\bar{y}$, denoted as $V(\bar{y})$, and estimated sample proportion p (possessing a particular characteristic) as $v(p)$ is given by

Where S^2 is the variance of the population distribution, N is the population size and n is the sample size; see Theorem 2.2 in Cochran (1999).

$$V(\bar{y}) = \frac{S^2}{n} \cdot \frac{(N-n)}{N}$$

Where p is the estimated sample proportion of people having a characteristic of interest in the total sample and q=1-p. See Theorem 3.3 in Cochran (1999).

$$v(p) = \frac{(N-n)}{(n-1)N} pq$$

The target population for the survey in this report is EV users and prospective buyers of EVs for which the numbers are very low compared to the whole vehicle stock. Hence the population for the survey in consideration is finite.

The factor, $\frac{(N-n)}{n}$, is called the finite population correction (fpc) which tends to 1 as population size N tends to infinity. Thus, quoting Cochran (1999) section 2.6, "Provided that the sampling fraction n/N remains low, these factors are close to unity, and the size of the population as such has no direct effect on the standard errors of

[22] William G Cochran (1999), "Sampling Techniques", Third Edition, John Wiley & Sons, 1999

the sample mean". Cochran further adds, "In practice the fpc can be ignored whenever the sampling fraction does not exceed 5% and for many purposes even if it is as high as 10%. The effect of ignoring the correction is to overestimate the standard error of the estimate $\bar{y}$".

For an estimate of the size of population, we consider the total registered EVs by mode in Delhi. This is shown for the total registered from 2015-16 to 2019-20 in Table 68.

Table 68: Estimated population size through registered EVs in Delhi

	2019-20	Total registered from 2015-16 to 2019-20	Sample size as %age (FPC) of total
			For EV early adopters
Adapted Vehicle	0	5	
Agricultural Tractor	0	0	
Ambulance	0	0	
Bus	1	1	
Construction Equipment Vehicle	0	0	
Crane Mounted Vehicle	0	0	
Cash Van	0	0	
Educational Institution Bus	0	0	
E-Rickshaw (P)	19710	85997	0.1%
E-Rickshaw with Cart (G)	2229	3907	
Fire Fighting Vehicle	0	0	
Goods Carrier	0	26	
Luxury Cab	0	0	
Maxi Cab	0	1	
M-Cycle/Scooter	956	1743	5.7%
M-Cycle/Scooter-With Side Car	0	0	
Mobile Workshop	0	0	
Moped	9	47	
Motor Cab	577	915	10.9%
Motor Car	202	658	3.2%
Motorised Cycle (CC > 25CC)	0	3	
Private Service Vehicle (Individual Use)	0	0	
Omni Bus	0	1	
Recovery Vehicle	0	0	
Three Wheeler (Goods)	0	0	
Three Wheeler (Passenger)	0	0	
Three Wheeler (Personal)	0	0	

Source: Vahan Database for Delhi, sourced on 21/01/2022

The finite population correction (fpc) calculated for the sample collected for the report is shown above. The fpc for early adopters is shown as % of the total registered stock. The fpc for EV 2Ws, EV 4Ws, EV 4Ws (institutional) and e-rickshaw are 5.7%, 3.2%, 10.9% and 0.1%. In the case of prospective buyers, the population is large and infinite and hence n/N is almost zero. Therefore, even though the target population for the surveys is low, the fpc based on the survey is below 10% and therefore the variance of the estimated sample average is

$$V(\bar{y}) = \frac{S^2}{n}$$

And the estimated sample proportion 'p' is

$$\nu(p) = \frac{1}{(n-1)N} pq$$

Thus, sample variance depends only on sample size and not on the size of the population under consideration. In statistics, a sample of size n>30 is generally considered to be a large sample and since all sample sizes are greater than 100, except for EV 4Ws (private), we can consider the sample variances as a close approximation of the population variances and the sample estimates as reliable.

Several studies in the past also have used small sample surveys for important project surveys. An example of a past study by RITES using a small sample size is the study, "Environmental Impact assessment for Phase-II corridors of Delhi Metro". It uses only 94 sample points (see Table 3.16, page 58/120) (http://www.delhimetrorail.com/otherdocuments/EIADMRCIdors.pdf).

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