LUND UNIVERSITY
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Electric Vehicle Charging Stations In India

The challenges and barriers being faced by charge point operators and a look at possible solutions

by

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The Paris agreement was the first time all 196 member states agreed to find solutions to fight global warming and keep temperatures 2 degree Celsius. Under the umbrella of the agreement, the Paris Declaration on Electro-Mobility and Climate Change called for action towards electric mobility. India is one country attempting to implement Electric vehicles and has set an ambitious target of reaching 100% electric mobility by 2030. However the country has not seen a great lift off in the sector with questions being asked as to what comes first the Electric vehicles? or the charging infrastructure? This thesis attempts to identify the barriers and challenges that are hindering the deployment of Electric charging stations while also looking at ways that the charging network can be catalyzed. The study used a qualitative approach using the system of innovation as its framework and obtained data from various experts involved in the EV sector. The results from the study showed how the deployment is hindered by unavailability of land, a stable grid connection and the goverments incompetency. Ride sharing companies and PPP's were identified as possible ways of catalyzing the infrastructure

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Table of Contents

1 Introduction

In 2015, the world saw an unprecedented step towards climate action with the signing of the Paris agreement. Under the agreement, 196 countries agreed to invest in a more cleaner economy and keep global greenhouse gas emissions under 2 degrees Celsius in the second half of this century (Wei *et al.*, 2016). The climate agreement not only requires for countries to shift away from fossil fuels in order to maintain the net zero emissions target - but called for investments into new infrastructure, technologies and production processes to increase energy efficiency (Wei *et al.*, 2016). According to the international energy agency (IEA) these investments can help reduce greenhouse emissions by 24 % by 2030 (Wei *et al.*, 2016). With different industries trying to reduce their emissions, one particular industry that's being driven by climate action is the Electric mobility sector (The World Bank, 2018). Under the umbrella of the Paris agreement, the Paris Declaration on Electro-Mobility and Climate Change & Call to Action specifically appeals for governments to push for electric mobility (UNFCCC, 2015).

According to a United Nations report (Sustainable Mobility for All Initiative, 2017) passenger vehicle numbers are estimated to double to 1.2 billion vehicles by 2050 - with a growing number in developing countries. Due to the sector's dependence on fossil fuels, the transport sector accounts for 23% of global carbon dioxide emissions (Wei *et al.*, 2016) and the number is estimated to reach 40% by 2040 if action towards E-mobility is not taken (Sustainable Mobility for All Initiative, 2017). One major concern however that is usually unnoticed is the number of deaths related to transport emissions. According to (Anenberg *et al.*, 2019) over 381,000 thousand pre mature deaths were related to tail pipe emissions from vehicles. Hence, there is an enormous opportunity for countries to tackle climate change, pre mature deaths or other negative externalities related to the use of fossil fuels in the transport sector by switching to Electric Mobility (e-mobility).

One country that has been tremendously working on E-mobility is India- the focus of this research. The country has 25 cities out of 50 in the world with the worst air quality in the world (IQAir, 2019) and 74,000 people lost their lives as a result of vehicle emissions in 2015 (Sustainable Mobility for All Initiative, 2017). One way to understand the severity situation is to examine the air quality index during and before the corona virus lockdown. For the first time in four decades, India witnessed a decline in carbon emissions thanks to low industrial and transport activity WEforum (2019).

The past decade has seen an increase in the number of initiatives launched by the government of India in order to push for electric mobility. In 2013 the National Electric mobility mission plan 2020 (NEMMP) was launched to deploy 6 – 7 million electric vehicles by the end of 2020 (GoI , 2013). Further schemes were also launched along the years to push and achieve the goals of the NEMMP such as the Fast Adoption and Manufacturing of Hybrid And Electric Vehicles (FAME) however the country has lagged well behind in achieving its desired goals (TERI, 2019). The FAME scheme comes in two phase. The first phase launched in 2015 focuses on providing demand incentives for consumers to buy a electric vehicle (EV) and had a budget of around $120 million (TERI, 2019). Realizing the need for charging infrastructure, the phase 2 of the scheme was

launched with ten times the budget and a focus on providing demand incentives especially for electric cars and building the required charging networks (TERI ,2019). However as of 2019, only 270,000 EV's are on the road with 60% being two wheeler bikes and the government is most likely not going to achieve its 6-7 million EV target by 2020 (TERI ,2019).

1.1 Research Problem

In spite of the incentives offered by the government to promote Electric vehicles, India is still struggling to get more electric cars on the road (Jhunjhunwala, Kaur and Mutagekar, 2018). One thing to note is that India's personal transport market is very segmented as compared to developed countries. The market consists of two wheeler bikes – the most common mode of transport, three wheeler rickshaws used for public transportation and Four wheeler cars and buses. The schemes launched by the government embrace all these modes of transport with the aim of bringing in more electrical variants to each of them. The NEMMP which is the backbone of the entire electrification process aimed at making India a leader in two and four wheeler electric vehicles by 2020 (GoI, 2013).

Success, however, has been seen much more for two- and three- wheelers – that too in a limited capacity as opposed to 4 wheeler vehicles (TERI, 2019) and could be attributed to the lack of charging infrastructure. In the 2 and 3 wheeler charging context, there is an alternative available in the form of battery swapping however in the case for four wheeler vehicles, the country faces the classic chicken and egg problem in trying to answer as to what comes first, the electric vehicles? Or the electric vehicle charging infrastructure? (Sheppard *et al.*, 2016). The charging infrastructure is still in its infancy in spite of the vision by the government hence this research aims to answer the following questions

What are the current barriers and challenges hindering the implementation of EV Charging stations?

How can the scaling-up of EV charging stations be catalyzed?

1.2 Aim and Objectives

The aim of the research is to identify the barriers faced by charging infrastructure operators and how they can be overcome in order to pave a smooth way for rolling out the infrastructure. By using the innovation systems theory, the research will aim to unveil the different institutional, networks and actors barriers being faced in the country that is making it difficult for the charging operators to diffuse there technologies. Currently there is limited research on E Mobility in the context of developing countries as the major push towards EV's is primarily seen in developed countries. Using examples from countries such as Norway, Sweden, Singapore the thesis will attempt to use and compare the findings in the developed countries and shed light upon the EV sector (primary the charging infrastructure) of India.

The findings from the research can help public and private parties in other developing countries understand the challenges that moving towards E-Mobility brings in a developing country and more importantly address the importance of the charging infrastructure. Furthermore private parties particularly foreign companies who are looking to invest in the EV sector of India can visualize identify the present scenario and the barriers that they will have to overcome.

1.3 Outline of the Thesis

Following the introduction and research questions, the thesis will look in to the relevant literature on the associated topics. The literature review will also cover the present conditions and environment of the transport sector of India. Thereafter the systems of innovation theory which is the theoretical framework being used in the study will be introduced under which the empirical data is analyzed.

The method section will discuss the methods used to collect the primary data and will discuss the limitations and problems of the methodological approach adopted in this study. The empirical analysis section will present the data collected in a systematic manner and attempt to answer the research questions that have been formed

The conclusion of the thesis will aim to summarize the entire thesis and offer a glimpse into ways this study can be used.

2 Literature Review

The literature review covers important findings from research papers and reports regarding the importance of electrical vehicle charging infrastructure. First an overview of the Indian transport sector will be presented in order to better understand the trends within the sector. The review will also cover studies that look into the challenges that charging station operators face in setting up a charging pod. A look into the case of public private partnerships (PPP's) for charging infrastructure in china will also be presented.

2.1 Present environment of India's Transport Sector

According to the UN (UN/DESA, 2017) India's population is expected to hit 1.65 billion people by 2050. The country also faces rapid urbanization growth and by 2031 up to 40% of the population will be living in urban areas (Deloitte, 2019). The growing population and urbanization has increased the need for personal vehicles and the government wants to pursue alternatives to internal combustion engine (ICE) vehicles to mitigate the effects of rising pollution as well as to reduce the country's rising oil import bill (Deloitte, 2019). With a growing economy, the transport sector is at the forefront of driving the Indian economy (GoI, 2013) contributing 7.1% of the entire GDP (Innovation Norway, 2018). At present, the automobile sector of India is the fifth largest in the world and by 2030 it is expected to be 3rd largest in the world (Innovation Norway, 2018). Primarily the industry is dominated by 2 wheeler motor cycles with nearly 20 million motorbikes on the road in 2017 (Innovation Norway, 2018). In terms of personal vehicles, there were around 3.8 million cars on the roads in 2017 (Innovation Norway, 2018). [1]

[1] Data reported in innovation Norway report is cited from the society of Indian automobile manufacturers (SIAM) – an apex national body representing the automobile industry. Data available directly from SIAM comes at a cost hence the figures chosen from the Norway report that explores the opportunities available for Norwegian companies by investing in the Indian electric mobility sector

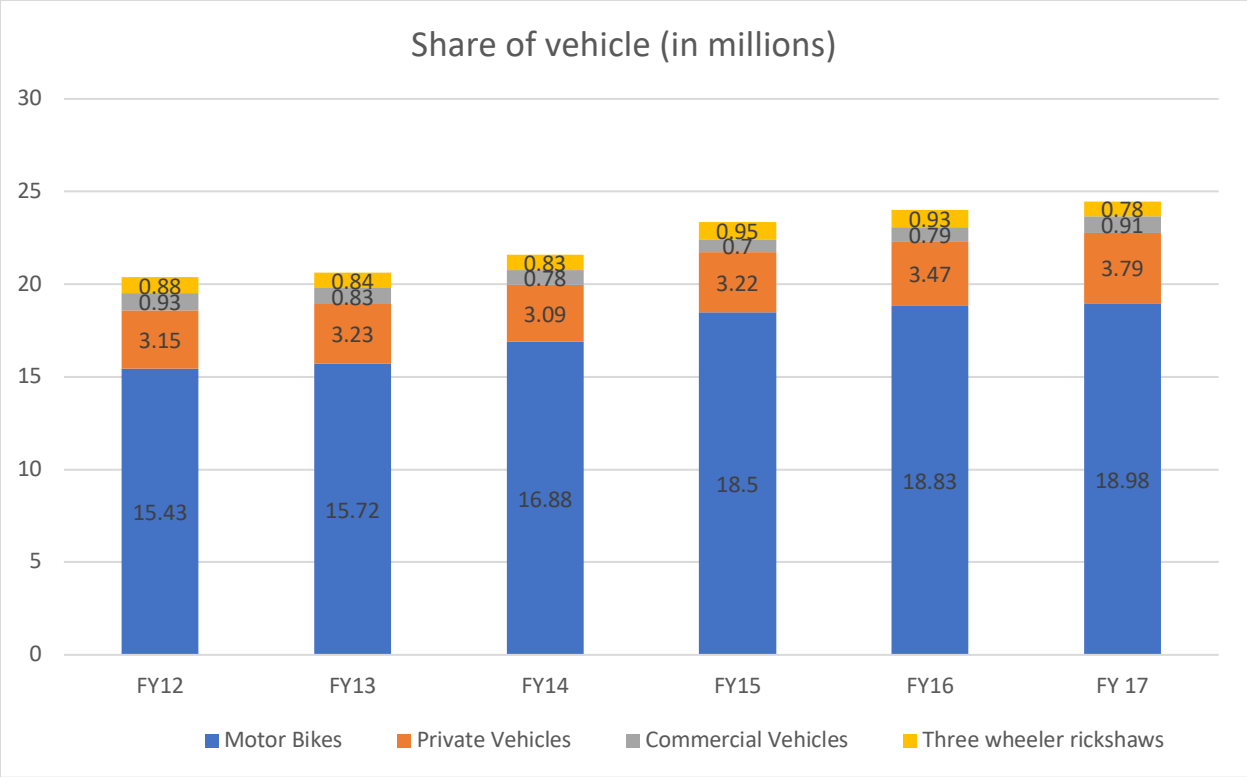

FIGURE 1 SOURCE INNOVATION NORWAY 2018

2.1.1 Electric vehicle charging infrastructure as a barrier to EV adoption

Several research papers and studies have reported the availability of charging infrastructure as a main barrier to EV adoption (Philip and Wiederer, 2010), (Rezvani, Jansson and Bodin, 2015). Over the past decade, Norway has been a leader in battery electric vehicle adoption with 18% share of the market belonging to EV'S (Figenbaum, 2017). (Figenbaum, 2017) suggests that the financial incentives offered by the Norwegian government to lower the cost of purchasing an electric car and privileges such as access to bus lanes and free parking e.t.c helped Norway achieve its position today. The policy instruments introduced by the government helped bring in a variety of electric vehicle models which became more price competitive compared to ICE vehicles (Figenbaum, 2017). In a study conducted on Norway, the authors, however conclude that both price incentives along with increased access to charging stations are the ideal policies to increase EV's on the road as had happened in the country (Mersky *et al.*, 2016).

Philip and Wiederer (2010) note that the lack of charging infrastructure is closely linked with range anxiety. Range anxiety is a massive concern with consumers afraid of being left stranded on the road without the ability to charge their vehicles particularly in long distance journeys (Philip and Wiederer, 2010) with (Lee and Clark, 2018) suggesting that even lower prices and better performance of EV'S will not attract consumers if there is insufficient charging stations on the roads. Addressing range anxiety issues are challenging as they require either an increase in battery capacity or reducing the minimum time to charge which are both economically unfeasible (Knutsen, 2013). A solution to this issue can only be done by increasing the availability and access to charging infrastructure. According to Knutsen (2013), there has to be more infrastructure for EV's to compete with ICE vehicles.

Despite the studies suggesting that public charging infrastructure is a pre-requisite of increased e-mobility, a study on the European union (EU) conducted by Mathieu (2018) deem public charging as having more of a psychological effect when deciding to buy an electric car. The study showed that only 5% of charging takes place in public charging points and a more mature market will further increase the demand for fast charging at home rather than on public sites (Mathieu, 2018). Public infrastructure acts more like a confidence booster for people to travel more (Bailey, Miele and Axsen, 2015) but the use of public chargers is still lower than home chargers. Moreover the technology involved in the EV sector is also rapidly changing - with improving battery's offering more distance range hence the decision to place more electrical charging points should be carefully planned (Knutsen, 2013). In Germany for example Funke and Plötz (2017) found that better battery performance will decrease the demand for charging infrastructure and the future possibilities should be taken into account when planning the infrastructure.

2.1.2 Electric charging Infrastructure in India

A recent consumer study conducted in India showed that 55% of people are willing or want to switch over to electric cars and the main reason for not buying one was due to the lack of infrastructure (AutoTechReview, 2019). One important aspect to note is that every city has a different pre condition on whether to have more public or home chargers. Cities which are more spread out and less dense will have preference for home charging as opposed to cities which are more urban and have people living in apartment buildings (Hall and Lutsey, 2020). Yet, many cities in India are very densely populated and severely over urbanized (Gupta and Saini, 2018) making fast public charging an important pre requisite for EV users. In the report by (TERI, 2019), it is noted that due to the high number of people living in apartment buildings in Indian metropolitans, public charging will be needed to meet the required needs. However the high costs of Land in the cities make it challenging to make a suitable business model for the charging business (TERI, 2019).

2.1.3 Barriers and challenges to deployment of EV Charging infrastructure

This section will present the major barriers being faced to large scale deployment of charging stations in general and in the context of India from various literature and studies. The perspective provided will be from the charging infrastructure providers in the difficulty they face in diffusing the charging technologies.

Lack of Demand

A major concern facing charging station providers is the lack of demand for EV's. A lower uptake of EV'S means the charging stations will be underutilized (Bureau of Energy Efficiency and Ernst & Young, 2019). In a policy analyses and recommendations provided by Philip and Wiederer (2010) for C40 Cities (96 cities taking strong actions towards sustainability and represent 25% of world economy) note that demand uncertainty is a main economic barrier for wide scale deployment of EV infrastructure. A minimum number of EV's are required to be on the road for there to be some financial feasibility in deploying the chargers (Philip and Wiederer, 2010). In Singapore for example, private sector charging providers were reluctant to invest in charging pods despite the availability of government grants as the lack of EV's make the investment very risky (Philip and Wiederer, 2010). Range anxiety also does not necessary mean there will be a demand for public chargers as people are just hypothetically afraid of the battery running out – not necessarily meaning they will recharge at public charging spots (Philip and Wiederer, 2010).

Weak Grid Infrastructure and Regulation On The Sale Of Electricity.

Charging Electric vehicles presents an immense power load on the electric grid particularly direct current (DC) fast charging infrastructure (Hall and Lutsey, 2017). Looking at India, (Nair *et al.*, 2018) found that the country will need 37% additional electricity form 2017 if it has 100% BEVS by 2030. Users want to charge their car as quickly as possible which is only possible with the use of DC chargers. Cities therefore have to invest in a strong grid that is capable of sustaining the load however as DC chargers use a high amount of power compared to home chargers (Hall and Lutsey, 2017). Another major concern is whether setting up a charging station should be treated as the sale of electricity or a service (Philip and Wiederer, 2010). This can be very costly and can effect proposed business models as resale of electricity is either not allowed or expensive as compared to offering it as a charging service (Philip and Wiederer, 2010). Hence a clear policy is required form the government on the regulation of electricity.

Cost of set up and government support

Despite technical innovation leading to lower costs of charging stations, setting up a station still requires significant expense's on getting a permit , installation and purchasing the land to operate on (Hall and Lutsey, 2017). The government can play a crucial role in providing subsidies or allocation of land to improve the economics of setting up the infrastructure (Philip and Wiederer, 2010). Furthermore there is also the challenge of obtaining a permit to set up the station which according to (Philip and Wiederer, 2010) " is cumbersome, time-consuming and expensive". A streamline and smoother process is required with several cities already working on making it easier to obtain a permit (Philip and Wiederer, 2010).

Technology Transitions

Due to the rapidly changing battery and charger technologies, there is a degree of uncertainty amongst investors on whether to invest in a risky charging business (Bureau of Energy Efficiency and Ernst & Young, 2019). There needs to be standardization before the wide scale deployment (Philip and Wiederer, 2010).

Barrier / Challenge	Description	Sources
Lack of Demand	Lower number of EV's are on the road make investment in EV's charging stations very risky	(Philip and Wiederer, 2010), (Bureau of Energy Efficiency and Ernst & Young, 2019)
Weak Grid infrastructure and regulation on the sale of electricity	A strong grid required to support the enormous demand from EV charging. Fast charging can use anywhere between 240-400 kw of power	(Nair *et al.*, 2018), (Philip and Wiederer, 2010)
Cost of Set up and government support	Setting up a station involves several costs including rent, charging equipment and the need for a permit	(Bureau of Energy Efficiency and Ernst & Young, 2019), (Philip and Wiederer, 2010), (Hall and Lutsey, 2017)
Technology Transitions	Rapidly changing battery designs with more capacity makes it challenging to set up stations in strategic locations.	(Philip and Wiederer, 2010)
Standardization of Chargers	Lack of standardization of charging equipment/ connectors and the what power or voltage is to be used	(Hall and Lutsey, 2017), (Philip and Wiederer, 2010), (Nair *et al.*, 2018)
Business Model Complexity	Different business models i.e PPP's, urban bodies or grid operators providing the infrastructure that needs to include number of stakeholders	(Bureau of Energy Efficiency and Ernst & Young, 2019), (Hall and Lutsey, 2017).
Land Unavailability	Difficult in finding land particularly in dense cities to set up the charging stations	(Bureau of Energy Efficiency and Ernst & Young, 2019)

Figure 2 Summary of findings from related literature

2.1.4 Types of Chargers

An EV' requires either a AC or DC power to recharge. In countries where there is a low chance of installing private charging facilities, it is important to determine what type of charger will be required. AC chargers convert AC current into DC current via a converter in the car and are much slower than DC chargers. Both these charging types have 3 different levels of power. To provide an example on the different type of chargering levels the charging levels of the standards used in the United States are presented.

AC charging Levels

Table 1 ADAPTED FROM (Un-Noor *et al.*, 2017)

Level 1	Suitable for overnight charging and can take anywhere between 0.5 to 12 hours to fully charge. A charger can simply be connected to a normal 110 V home outlet to recharge the car
Level 2	Uses an onboard charger and a direct connection from the electric grid. Has a maximum voltage of 240 V and is the most common charger being used
Level 3	Uses dedicated power supply specifically for EV charging and can charge an EV battery in 30 minutes, maximum electric supply of 600 V

DC charging levels

Table 2 adapted from (Un-Noor *et al.*, 2017)

Level 1	Has voltage between 200-450 V and maximum power of 36kW
Level 2	Has the same voltage as level 1 but the maximum power is more than double at 90kW
Level 3	Has a much higher voltage between 200-600 and 240kW of power

Despite the level 3 charging speeds of AC chargers, they still do not come under the category of fast chargers (Un-Noor *et al.*, 2017). DC chargers offer much more power and have exclusive powerlines and installation dedicated for DC equipment. Since the power Supply is in DC, most charging stations automatically adjust the voltage according to the car and battery capacity (Un-Noor *et al.*, 2017). DC public charging can be more beneficial for megacities, where there is difficulty in obtaining land as it allows EV's to be charged faster - in most cases under 30 mins and hence allow a wide coverage of charging service (Funkea, et al., 2019).

2.1.5 Determinants of Public and Home chargers

According to (Funkea, et al., 2019) countries where there is a less chance of having a private home connection will be in the greater need of a public charger. This can be seen in the case of the Netherlands where there is a low availability of home charging due to fewer detached houses as compared to California where a high number of detached houses allows for more private charging (Funkea, et al., 2019). To allow for overnight charging, AC chargers can be installed on the streets or in parking lots for consumers living in apartment buildings where as DC chargers can be installed in public places i.e. malls or city centers to allow for faster charging.

Some of the main determinates on whether to have public or home chargers are:

Housing patterns: According to Hall and Lutsey (2020), housing patterns is one of the main reasons that determines the location of chargers. Where there are more apartment buildings, it will be difficult to access private chargers and public chargers will be a necessity (Funkea, et al., 2019). (Funkea, et al., 2019) also note that's countries that have megacities will need DC public chargers so that the maximum number of people can benefit from the service.

Mileage. A city where people commute more and travel in between cities will need more public chargers to meet the demand of their driving patters (Hall and Lutsey, 2020). Moreover (Funkea, et al., 2019) suggest that DC public charging will be an important factor in allowing for long distance travel as users will need to charge there vehicle as quickly as possible

Commuting patterns and public transport : According to Hall and Lutsey (2020), cities which have less public transport which results in a high number of people driving to work e.t.c can have EV users benefit from work place public charging.

2.1.6 Public Private Partnerships in electric charging infrastructure

There is still no general agreement as to how to define a PPP however according to the EU (Europe, 2017) a PPP " is one of the governance mechanisms available for the public authorities to perform their statutory tasks, revitalization included". It is a partnership between the private and public sector that aims to provide services that normally the public sector has the duty to provide. Under the Eu Framework a PPP is where:

"*A form of cooperation between public and private sector*

A scheme of executing tasks or providing services traditionally procured by the public sector

An undertaking where both parties are capable to execute their tasks more efficiently than the other party

An economically effective formula for building infrastructure and providing public services

An undertaking that brings benefits to both involved parties proportionally to their involvement"(Europe, 2017).

In the past, PPP's were solely meant for financing of projects, such as a highway road and initially were more of a private- finance initiatives rather than partnerships (Sadka, 2006) but nowadays they have become a lifeline around the world for the efficient construction/ operations of infrastructure and sharing of risks between the public and private sector (Sadka, 2006). Although PPP models have been used for transport infrastructure such as roads and rails, the concept has not been as widely used for electric charging infrastructure (Wang and Ke, 2018). One reason for this is that the government is not responsible for putting up the stations and the duty lies with the private sector to put up public chargers (Wang and Ke, 2018). Nevertheless, Installing Public charging stations still requires coordination between various stakeholders e.g. municipalities, grid operators and there is a high initial investment required for setting up and maintenance (Wang and Ke, 2018). According to (Deloitte, 2019), private operators are unable to operate feasibly and cannot recoup their investment based on selling the service alone. There needs to be government support for a good business model.

Recently, China has been working on a PPP model in Anqing with the aim of installing 20,000 chargers in the city (Wang and Ke, 2018). The country had been facing numerous issues with regard to diffusing charging stations – including the acquisition of land and opted to have a PPP model for implementing the network (Zhang, Zhao and Kan, 2019). Analyses on the project showed that the PPP model will significantly reduce the financial burden on the government and will ensure a very efficient and strong charging network with the inclusion of the private sector (Zhu, 2017).

In its report, the (Bureau of Energy Efficiency and Ernst & Young, 2019) notes that a PPP model will be ideal for India to develop public charging infrastructure and achieve 100% electric mobility by 2030. However a feasible project must reduce the risks to the private sector (Bureau of Energy Efficiency and Ernst & Young, 2019) which is the main reason for having the PPP model (Sadka, 2006). The public sector through municipalities and the state transport authorities can help private players to identify suitable land and create a demand for EV'S (Bureau of Energy Efficiency and Ernst & Young, 2019) with the government leveraging from private sector experts to run efficient charging stations (Deloitte, 2019). The (Bureau of Energy Efficiency and Ernst & Young, 2019) has come up with 2 PPP models that can be utilized in India. They include:

PPP between private investors and municipal corporations - As land is difficult to obtain, municipalities in this model will be the ones responsible to provide land to private parties on lease. The revenue between the private and public sector will be shared with income streams from the charging service itself, advertising and co-branding. This private sector will be responsible for creating the demand of the station and raising the required capital for the project.

PPP between private investors and state transport utility: In this scenario the transport utility will be responsible for the land as well as raising demand for the charging service. Private investor will not be charged for the land however there will still be a revenue sharing mechanism between the private and public parties. One major benefit of this model is that the risk of having low demand is transferred to the public sector and the public sector is safe from any risks if there is no demand for the service.

2.2 Theoretical Framework

This research will be viewed through the lenses of the systems of innovation framework. There is still no clear definition of the concept with each author having a different view/ approach of what the system actually refers to (Chaminade and Edquist, 2005). The main concept is based on the works of Christopher Freeman who defines the system as

"*systems of innovation are networks of institutions, public or private, whose activities and interactions initiate, import, modify, and diffuse new technologies"* (Freeman, 1987)

The important feature of the system is that firms do not innovate alone – but work together with different organizations in a given environment (Edquist, 2009). In his work (Edquist, 2009) defines the system as

"all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations".

As such there is not such factor that solely determines the innovation process will take place hence it is important to bring in every single factor in the process (Edquist, 2009). The sole purpose of the system is to successfully achieve the development, diffusion and use of the innovation (Edquist, 2009)

The main features of an innovation system include.

***Institutions*:** (Edquist, 2009) Notes that institutions are what controls the relationships between various actors involved in the innovation process and their role is strongly required in the innovation processes. The institutions are "sets of common habits, norms, routines, established practices rules or laws" that effect the way innovations are developed or used (Malerba, 2005). Formal institutions such as the government can implement laws and policies that can set the direction of the innovation (Malerba, 2005).

***Organizations / Actors and Networks*:** Every sector has various organizations and individuals that help determine and shape up the innovation process. These can include both the public and private sector such as users, banks, universities or the government whose contribution in terms of finance, research or regulations e.t.c help to develop and diffuse the innovation (Malerba, 2005). There is a continuous learning process within the system with different agents interacting and communicating with each other to exchange knowledge related to the innovation (Malerba, 2005). In more simple terms, it is the behavior of these agents using the knowledge they have that leads to technological development.

Knowledge and technologies: Every sector has a specific knowledge base and technologies attached to it which determine the behavior of firms (Malerba, 2005). A major source of knowledge is feedback at the production and demand level which can benefit in improving the technology further (Malerba, 2005).

The system of innovation approach's main strength lies in having placed learning and innovation at the core of the system and encompassing both produce and process innovations (Edquist, 2009). The approach has been widely by the EU, OECD and other international organizations to form policies surrounding a countries innovation capability (Edquist, 2009). The approach takes into account every single factor- be it public or private that determines the innovation process from development to diffusion and helps identify the relationship between the innovating firms and other organizations that might hinder the innovation process (Edquist, 2009).

No system however is perfect and the system of innovation does have some weaknesses. (Edquist, 2009) notes that there's no uniform meaning given to "institutions" as some authors attach organizations to it while others term it to be the laws, rules or patents involved. There is still divided opinion on the system - with lack of "empirical regularities" categorizing the system approach as a framework rather than a theory (Edquist, 2009).

3 Methods

The section below will provide an overview of the methods used for this research and how the topic was approached. As the EV sector is relatively new in India compared to European countries, there is little research particularly in the area of charging infrastructure. Since the Indian . government and relevant transport authorities do not provide the data free of charge, a qualitative approach was adopted for the research with various interviews conducted with relevant individuals. Another reason for using interview was that during the review of literature, there were limited views of different stakeholders involved in the EV sector.

3.1 Topic choice and Preparation

Initially a literature review was conducted on the general state of the EV sector around the world and the challenges the sector faces. The extensive review brought forward the classic chicken and egg problem - the question of what comes first, the Electric vehicles or the charging infrastructure.

The literature on India presented the ambitious plan by the government of India to have 6 to 7 million vehicles by the year 2020 and this thesis helps to explores the degree to which this project proved successful.

Taking into account the charging infrastructure problem found from the existing literature, an extensive research was done on the situation in India. The research was conducted by using various reports from international agencies such as EY, Deloitte, reports from Indian government agencies such as NITI AYOG and Society of Indian automobile manufactures. Information was also taken from foreign government reports of Norway and Sweden that were identifying the potential of the India's EV sector and the benefits that EV related companies can have by investing in the sector. Articles from online newspapers and automobile websites were also read to get a grasp of the Indian EV sector. This led to the suitable identification of players who are involved in the sector and from whom their input would be insightful for the purposes of this thesis.

3.2 Interviews

After understanding the environment surrounding the Indian EV sector, there was the hope of getting interviews from charging station investors, utilities operators, and policy makers thus gaining the perspective from every angle. The parties involved were identified from the government reports and almost 40 people were contacted via LinkedIn and company emails. In total only 6 potential interviewees replied with 4 interviews taking place. The interviewees however were among those who were directly involved in the sector and had deep insight and understanding of the EV sector. The table below provides lists the interviewees, their role and the work their organizations does.

Interviewee	Organization	Position	Area of work	Organization background
Shyamasis Das	Alliance for an energy efficient Economy (AEEE)	Principle Research Associate & lead – Power utility and electric mobility	Electric Vehicles and Distributed Energy Resources; Renewable Energy and Energy Efficiency Investments	The organization is a leading think tank and currently the only one working on creating awareness for energy efficiency. It is a policy advocacy and energy efficiency market enabler with a not for profit motive and is provides research and offers data driven and evidence based policies. The focus of AEEE is the interlinkages of power utility and electric mobility. electric tariffs and grid integration.(adapted from aeee.in and interview)
Anonymous	Energy Efficient Services limited	Deputy Manager	Electric vehicle and infrastructure deployment	The company is part of the government of India and works under the ministry of power. The company has been leading the way for wide spread adoption of EV's and trying to establish the charging infrastructure (adapted from interview)
Harsh Jain	Ernst & Young	Senior Consultant	management consultant on electric vehicles, mobility solutions, battery storage	One of the largest professional services firms in the world
Srujana Patnaik	Cellerite Systems	Chief Executive Officer	Electric mobility and infrastructure	Deep tech company working on providing charging infrastructure mainly for two and three wheelers (cellerite.com)

Before the interview a comprehensive list of common questions were made for each individual. The interviews however were semi structured to allow the buildup of follow up questions and gain detailed insights (Creswell, 2014). One benefit of semi structure interviews is that they provide more useful data when the number of interviewees are small (Pathak and Intratat, 2012). In order to come up with meaningful questions, a literature review was conducted to get a glimpse of the global and Indian EV infrastructure. A set of 15 questions were written down, however during the interviews some of the answers were overlapping for each question hence not every question was asked as information was already being provided for those specific questions.

Furthermore, the respondents were offered the chance to remain anonymous and one of the individual – due to his links to the government chose to use this option. The respondents were also made aware of how their input will be used and that they will get a copy of the research to make sure nothing goes against what they said.

3 of the interviews were conducted on WhatsApp call while one through cisco's webex meet. Due to the lack of option of recording a WhatsApp call, the information from those interviews were noted down word by word. The fourth interview was recorded and later transcribed. each interview lasted between 60-90 minutes, which allowed for a deep insight into the present situation of the EV sector with each respondent also offering continuous help after the interview.

3.3 Data Analysis

3 of the 4 interviews had only been written down and the 4th interview with the government official was transcribed. After the transcription, the information from the interview was divided into 2 categories – the commonalities and dissimilarities in terms off the barriers were laid out. These were later compared and contrasted to the findings from the literature review and new information that could be attributed to India were singled out.

3.4 Limitations

The main limitation was getting a higher number of people to interview. Even though they were around 40 invitations, they were only 6 respondents. The present corona virus situation also made it difficult for some people to do an interview as they were working from home. There was an interview organized with a individual from NITI AYOG, a policy think tank of the government of India that is doing considerable work on the EV sector. However due to a person becoming infected with the virus, the office had to close down and the interview subsequently could not take place. If time had allowed more actors involved in the EV sector could have been interviewed. Time constraint was another issue as firstly it took considerable amount of time to pick the topic. The interviewees also had to be identified after doing a comprehensive literature review and from their own writing a personal email to 40 people took a lot of time. Furthermore conducting and setting the dates of the interviews also took considerable time, as some of the interviewees were busy which left the author in a loop with no information.

Another major issue was that there was no straight off data available from government websites. Some of the information was irrelevant and not well collected while data from the society of Indian automobile manufactures came at a cost. Hence data regarding numbers and future growth of the sector were taken from external resources such as EY and innovation Norway.

(Millward & Brewerton, 2001) note that there can be considerable bias if there comparisons are made using the data during the interviews. As interviews with independent officials was done first, the author feels there could have been some bias when doing the interview with the government official. This was as result of follow up questions against the goverments role being asked to the government official.

However, the relevant organizations and individuals interviewed were all well established in the EV sector and had a very deep insight and knowledge in the area which is why the author is confident that the information gained from the interviews can produce reasonable results. The interviewees had years of experience in the energy and transport sector and had a keen interest in the EV sector.

4 DATA ANALYSIS

4.1 What are the current barriers and challenges hindering the implementation of EV Charging stations?

4.1.1 Lack of demand and awareness

A major problem associated with the EV sector around the world, the experts noted that India is also having trouble in having an answer to the chicken and egg problem. Charging operators are unwilling to invest in an infrastructure that has too many risks attached to it as the number of electric vehicles on the road are too few. Furthermore, there is still a high level of uncertainty surrounding the future behavior of consumers regarding EV. From the interviews, one reason for the low adoption of electric vehicles is price.

". It is a very price sensitive market India and you have to give a price edge over an ICE engine to an electric vehicle so people can come out and purchase" (interview with EESL)

Several factors were attributed as the reason behind the high price of EV's. The technological landscape of battery's hasn't developed much in India and battery prices remain high in the country with components being imported rather than being manufactured in India (AEEE). Furthermore the battery's that do exist do not have sufficient capacity for long distance drives.

"For four wheelers the current battery sizes are not that big with the average size being around 22KW. This is good enough for city mobility and not long distance. If you want to go out of the city, it will be impossible as the battery wont help to reach another city… and if you go for a higher capacity battery the cost of the EV will go up" (interview with AEEE).

From the interviews, there were two unique characteristics of India that were not found in previous literature. Firstly there is no competition in the market despite the government offering financial

incentives in the form of subsidies to help bring in a variety of models as car manufactures are unwilling to further invest and scale up the EV segment.

"The goverments has not been able to make the OEM (original equipment manufacturers)take the whole project more seriously and the OEM's are taking the government for granted. The OEMS which consist of 60% big manufacturing car companies are against electrifying and assert that hybrids are the way to go however hybrids have already been in the market for a long time. Last year we had just 3400 EV's sold and 3600 this year" (interview with EY consultant).

Secondly, there is a complete lack of awareness about Electric vehicles with consumers not aware of the benefits of owing an EV. As India is a price sensitive market, consumers behavior is mainly effected by the price of the vehicle and not the benefits the EV's possess e.g. lower operating costs and environmental friendliness.

*"We did an analysis and found there are a few problems (in the sector). First there is the high cost of EV and second is that there is no charging infrastructure in the public. Third is there is no demand and awareness and people do not see the benefits of an EV" (*interview with EESL).

For charging infrastructure operators, these are the primary challenges being faced in trying to recover their investments. There has to be a high number of EV's on the road for charging operators to turn in some revenue and eventually profit however the current environment is completely unfavorable for a charging station investor to enter the charging business.

4.1.2 Lack Of Land

A major concern that was noted in all the interviews is the lack of land available for setting up the infrastructure. The early adopters of EV's in the country are expected to be in Urban area (interview with EESL). Urban cities in India however are heavily urbanized and over populated and as a high number of people live in apartment buildings, there will be a need of public charging instead of home charging. This creates the issue of land availability which makes it difficult to obtain and set up the infrastructure,

"Another big problem is unavailability of land. Our cities are very dense and compact and do not have any spare land. Most of people live in apartment buildings and there is no concept of having a garage to park the car" (interview with EY consultant).

"In the analysis with charge point providers, finding land and placing the charging pod is very important. However it's a very big issue as cities in India are very dense and compact cities. finding land is a major challenge and since land is scare, the rent of land is very high which drives up the cost of public charging station" (interview with AEEE).

It was also noted that municipal cooperation's are unwilling to provide land for free (for a certain period) or at a low rate to private entity's as the public will not be acceptable for such a decision (interview with AEEE).

4.1.3 Electricity Grid Infrastructure

Every interview respondent noted that having electric vehicles on the roads will mean a great increase in electricity consumption for charging the vehicles in the country. India however faces several challenges in incorporating a suitable and stable electric grid to charge the vehicles. From the interviews it seems that the challenge of having a stable grid will be difficult to overcome and will take considerable time.

As mentioned before there is the challenge of finding suitable land and most charging will be done using public chargers. From the interview with AEEE, just as it is around the world that consumers want to charge their EV in a short time (Deloitte, 2011), it was mentioned that Indians as well are very time conscious and want to have their Vehicle's recharged as quickly as possible meaning the public chargers will have to be DC fast chargers. Though they can charge the vehicle very quickly they also require a strong electric grid and high capacity transmission. The utility companies are responsible for this however they are not in the capacity to provide any help.

"There needs to be a grid and transformer capacity for charging the pods to work. In India's case, the distribution companies are already making losses in billions of dollars every year and do not have the money to invest in the infrastructure hence the charge point operators themselves have to invest in the grid system" (interview with EY consultant)

"the destination grid has to be resilient to meet the demand and if there is a short fall of capacity the grid will become unstable. the electricity distribution companies are hesitant to provide connections which are not adequate for fast chargers. they need upgradation of grid which is a major cost" (interview with AEEE)

The lack of a proper grid infrastructure is further adding to the Risk of the charge point providers. The operators themselves will have to invest in the necessary infrastructure i.e transformers, wires however that too could cost as much or even more than setting up the station itself(interview with AEEE). It was also noted that some areas lack a grid infrastructure such as major highways and although there is the option of extending the grid however this is very time consuming and can take up to 6 months just to get the permission (interview with AEEE). The risk to investing in the grid is further intensified for both the utility company or the charging operators as the number of vehicles are too few and the recovery of the investment will take considerable time

"to develop a station for a normal charger if we have 4-5 chargers it will require 150-200 kw so for such a load we need a transformer and high tension lines and also initially there will not be any revenue generation because there are no vehicles available" (interview with EESL)

The challenge being faced hence in terms of the electric infrastructure is immense. However there does seem to be work being done by the government to provide a stable grid connection.

"for the grid operators or the distribution companies it's (EV infrastructure) a new revenue stream for them. it is like adding a new consumer in their base. there is a value for the companies…grid management available to cut out the peak demand. grid management they will be able to do in a proper manner, the system operator or the distribution company do not have any problem. and since most of these charging stations will be coming in urban areas, the infrastructure in the past five has improved a lot. There are central and state plans in changing the entire infrastructure of distribution company in major cities" (Interview with EESL).

4.1.4 Government capacity

A major theme highlighted from the interviews was the role the government is playing which is having both a negative and positive impact.

Some of the positive steps taken by the government include:

1. Delicensing the charging business which means operators do not need a license from the government to set up the charging pods (interview with EESL)
2. Amending the electricity bill and allowing third parties to sell electricity to EV owners as a service and not as the resale of electricity (interview with AEEE)
3. Offering 70% capital subsidy for setting up the charging infrastructure (interview with EESL
4. Lowering the import duty of key components that make up the chargers from 18% to 5%.

Even though the government is trying to make a positive impact, there was considerable critism towards the capacity of the government even to some extent by the official. Firstly it was noted that the government plans of having 6-7 million cars by 2020 was way too ambitious and the government launched it at a time when the market was not ready to adopt such vehicles (interview with AEEE).

Another thing to note is that both the private sector and the public are trying to implement the chargers in the country. The government however has been more in favor of public companies rather the private sector companies.

"there are 3 main issues. One is in terms of the government's handling of the subsidies. Out of 10000 (approximately $1.3 billion) crores issued, a 1000 crores (approximately $130 million) are specifically towards EV charging infrastructure. The government has delicensed this sector and allowed private sector to participate however in the first round of subsidies ,the subsidies were only provided to public companies and non to private ones. That in itself means there is no level playing field for private companies… The government agencies end up taking the low cost approach which are very less flexible meaning the approach may put up more chargers however they will be in places which have no demand of electric vehicles. Some of the chargers are not in the ideal locations and people like charging their vehicles in places such as malls, restraunts" (interview with EY consultant).

Further problems attributed to the government is not having competent people to deliver a technological advanced project such as electric mobility

"Institutional aspect it is lacking . there is a structure and the guideline is that all states have to designate agencies to install public charging stations. However there is lack of capacity of experience of state officials. it's a new sector and as a state government official who is a bureaucrat and not aware of the new technology there will be problems" (interview with AEEE).

In the interview with the government official, it was found that the subsidies introduced in the FAME 1 scheme were not properly utilized and despite the scope there is still a lot of improvement needed from the goverments side.

4.1.5 Access to Finance

As noted previously much of the subsidies went to government owned agencies and not to private parties. Private operators face numerous financial problems as there is no project financing involved (interview with AEEE). Furthermore local financial institutions are also unwilling to provide financing in EV infrastructure projects as there are too many risks associated with the projects.

"for banks and other financial institutes they are not yet comfortable enough to invest in the infrastructure given the reason that for 4-5 years there wont be any revenue generation and it is also not certain that there will be a great influx of EV in the market" (interview with EESL).

Summary of Research question 1 What are the current barriers and challenges hindering the implementation of EV Charging stations?

The electric vehicle sector in is still in its infancy in the country and a lot of technological research and development is required especially on the case of the battery's which are not able to power the vehicle for a long distance. For a charging infrastructure business model to work there has to be more electric vehicles on the road so that potential investors can recoup there investments. Hence the biggest challenge is to pick up the demand for the vehicles and get manufacturers to produce a variety of models. Furthermore there is great hinderance from the goverments side. The government is providing the necessary funds however favoring public agencies over private ones is now allowing for the private sector which is more efficient to enter the market. Municipal cooperation's are also not providing or identifying suitable land hence the government support is only limited to the financial side and not for overcoming the other hurdles involved. Furthermore the government, even though it has an ambitious project in the pipeline – does not have the qualified or knowledgeable people who can push through a 21st century project of electric mobility. Also, the lack of a proper grid infrastructure that is required for the Indian market is putting off investors from investing in a project that is already not going to have any revenue generation for a number of years. Utility companies who are in severe debt have not provided any solution to incorporate EV charging on the grid. Lastly, acquiring finances from local banks or institutions is difficult due to the nature of the project not guaranteeing any return for the intimal period.

Barrier / Challenge	Example
Lack of Demand/awareness	Consumers not aware of the benefits of an EV. Very price sensitive market
Lack of Land	No cooperation from municipal bodies to identify suitable land
Electric Grid Infrastructure	Utility Companies unwilling to invest in a stable grid required for DC fast charging
Government Capacity	Incompetent individuals / favoring public companies over private
Access to finance	Difficulty obtaining loads from banks and other local financial institutions

4.2 How can the Scaling of EV charging stations be catalyzed?

This section will address the research question above. It will look at the role the government is playing and various solutions presented during the interviews.

4.2.1 Role of government:

In the previous section it was mentioned how the government is in some way coming in the way for developing the EV infrastructure especially for private players. However the government is also playing a major role in trying to develop the EV charging stations. The government is trying to create awareness of EV and has done this by attempting to adopt EV for the entire government fleet. The government agency EESL is overlooking the entire EV project of India and is currently trying to convert the present government fleet of 500,000 cars into electric ones

"*we did a study and found there are half a million cars being used by goverments departments. Essentially these cars are being supplied by 3rd party vendors. and a vendor gives the car with driver, car maintenance and it is being used by the govt officials to go around in their cities. These half a million cars can be converted into EV and they have to be parked in one place, being used for 10hrs a day, have a set daily routine where they are used… with this we developed our business model and we converted into a lease model (for government fleet) with EV manufacturer. I (EESL) being a government company was providing an EV with a charger and driver to the government department who was willing to convert ICE engine to EV and right from the prime minister's office, to defense office and finance ministry and all the higher govt officials were using our vehicles. Around 2500 electric vehicles we were able to deploy out of 10,000. this created a buzz in the market and there were a lot of seminars (on EV'S) e.t.c and people were considering an EV as one of the option" (interview with EESL).*

The government procurement of the EV's is sending out a message to the consumers to also switch to an EV (interview with EV). More cars on the road will mean more EV charging pods. As noted before having a low number of EV's on the road is putting off investors from investing charging infrastructure. The goverments adoption of EV's is – though at a small number is putting EV's on the road which can stimulate the set-up of charging pods. Though the government is setting up the charging infrastructure within its own premises and only government owned EV's can be charged, it's still creating awareness due to their visibility and hopefully will change the consumer behavior (interview with EESL).

With regards to the tariff, the state level government has also issued a notification that charging stations will be charged a lower tariff than the commercial tariff to further provide a financial edge to the operators (interview with AEEE). However the government needs to come up with further regulations such as peak tariffs time and a smart grid infrastructure to allow for a smoother roll out of the network (interview with EY consultant).

Furthermore, municipality bodies are only collaborating with the government companies to identify land to set up the chargers – that too for government EV'S. Hence the urban bodies need to work with private players to set up stations which the common person can also use (interview with AEEE).

Lastly, one problem that was noted was that the companies involved in the EV sector have to deal with various government offices i.e. the department of heavy industries, ministry of power, ministry of urban development e.t.c which is slowing down the process of obtaining licenses or planning permissions (interview with EY consultant). One solution to overcome this problem was the formation of a Nodal Agency- an agency that incorporates all the work of the various offices involved resulting in companies involved in the EV sector having to visit just one office rather than each individual one.

"In terms of institutional framework what needs to be done is there needs to be nodal agencies at state government levels which can coordinate across all levels. If you need to do planning of the grid you need to really work with the fleet operators (companies owing a large proportion of cars - for rental or taxi service) and with the transport department" (interview with EY consultant)

4.2.2 Ride sharing companies

From the interviews it was noted that ride sharing companies are playing a major role in developing the charging infrastructure. Companies such as Ola, Uber and blue smart are making investments to convert their fleets into Electric ones (interview with EESL). India has an expanding ride sharing eco system, with new startups entering the market and backed by major investors who are trying to bring innovation to the EV sector by working with the OEMS (original equipment manufacturer) and government agencies to establish charging stations (interview with EESL). Commercial adoption of EV's is increasing through ride sharing companies and the major reason is that running a EV in a ride sharing company brings down the operating costs and electricity is much cheaper than petrol in the country (interview with AEEE).

More notable, India is the only country in the world which has a ride sharing startup "blue smart" with 100% electric vehicles with 900 vehicles (interview with EY consultant). The company is not only provide services to the everyday user but also has contracts with multinationals such as google and Microsoft to provide their employees with a taxi service from home to work (interview with AEEE).

The small startups are using in house charging at the moment, however major companies such as OLA are investing in public charging stations to be used by ordinary consumers as well (interview with AEEE). The government is also pushing for the ride sharing companies to convert their fleet's into electric ones hence the reason for the investment into EV's and public charging stations by the major companies (interview with EESL). At the moment the ride sharing companies are contracting with malls and leasing parking places to set up the EV pods (interview with EY consultant).

4.2.3 Access to finance

As gaining finance is a challenge, the interviews highlighted the role the government can play in making access to finance easy.

"The challenge is also of getting finances. affordable lending is a very big challenge and since EV is a new sector the risk perception is very high. The goverments can actually do some work with banks and provide lending at affordable rates. The Government has control on the banks and can help reduce risk and debt" (interview with AEEE). With the private companies being left out of bulk of the subsidy's, the government should - through the banks help private players gain access to the finance to set up there charging business.

4.2.4 Public Private Partnerships

Due to the level of risks involved in the EV sector, public private partnerships were highlighted as a major solution to the problems. Currently however PPP in charging infrastructure is still in its infancy. The models are already being applied in the country where the private distribution companies are working with charging operators and municipalities to identify land and setup public charging stations however at a very small scale (interview with EESL). However for PPP'S to work there needs to be an ease in raising finances for the projects - something which the government can easily do by leveraging their control over the banks and financial institutions (interview AEEE). The potential in PPP is great and if done at a large scale in the country, it can lead to rapid development of EV infrastructure (interview with EESL).

5 Discussion

The aim of this study was investigate the barriers hindering the implementation of Electric charging stations in the Indian context and have a look at the ways the infrastructure can be made widely available. The section will provide a discussion on the results and a linkage to the literature and theory.

5.1 Barriers hindering the deployment of EV charging infrastructure in India.

Most of the barriers found in this research were line with findings from the literature. For instance a major reason from the research attributed to EV stations not being deployed is the low number of vehicles on the road. Investors were not willing to invest in a project that will not guarantee revenue for a number of years. One note was that private sector companies did not get the subsidies while government agencies did which is why the government has been attempting to deploy the stations (limited for the government fleet only) while the private companies haven't. This however could be true to some extent. In Singapore for example, private charging operators – despite getting government grants, did not find any value in investing in the charging business while presenting the argument that a large number of cars are needed to gain investor confidence (Philip and Wiederer, 2010). Lowering the costs of the EV's and creating an awareness campaign can help reach the optimum number required on the roads. Awareness of the benefits of EV's are lacking in the Indian consumer base and studies do highlight the fact that lack of knowledge about EV's put off potential consumers from purchasing the vehicle (Rezvani, Jansson and Bodin, 2015). It may be argued that an awareness campaign might lead to more EV adoption in India and subsequently the charging network.

One thing that was expected in the findings was the difficulty in obtaining land. Indian cities are tightly packed together and people do not have access to home garages hence the need for public chargers. Such importance of public charging is also noted in the cities of Amsterdam and Beijing where people mostly live in apartment buildings (Hall and Lutsey, 2020). In the interviews, the role of the municipalities bodies was highlighted and how the bodies are unwilling to help identify and provide land to set up the charging stations. Their importance of urban bodies, however should not be underestimated and attempts should be made to leverage the access to land that urban bodies hold. In Stockholm for example, city authorities provided free access to parking places for companies to set up charging stations resulting in 108 charging points being set up ('ELECTRIC VEHICLE CHARGING Guidelines for Cities', 2017). Though Indian cities are much larger than Sweden ones, a lot of learning can be done from the Stockholm case to utilized the potential of city bodies and find the accessible land.

Furthermore, One barrier that will prove a considerable challenge for deploying EV infrastructure is the electric grid. In the interviews it was noted that the early adopters of EV's will be based in urban areas. As mentioned before, urban cities of India are very dense and compact and consumers do not have a home garage as in the case of countries such as Norway or Sweden. This will mean the use of public chargers, more specially DC chargers which charge at a faster rate but consumer enormous amount of electricity. All the interviews highlighted the need to upgrade the current electric grid in order to provide a stable electric connection to the charging points. This importance was also highlighted by (Hall and Lutsey, 2020) who found that that DC fast charging has a disproportional large impact on the grid and that large investments will be required to upgrade the standards of the grid. The main challenge in India is that who will carry out this duty. As stated in the findings, Utility companies are already in debt and the enormous investment to upgrade the infrastructure will most likely not attract investment from private players with (Hall and Lutsey, 2020) mentioning that it doesn't make sense for a private party to invest in the grid due to the substantial costs. Furthermore local financial institutions in India are reluctant to provide financing for EV infrastructure further raising the question as to how the electric grid can be improved to pave the way for charging points.

Lastly the role of the government is crucial for expanding the EV's and EV charging network. In the literature the main highlights of the government roles were related to incentives, polices and land allocation (Hall and Lutsey, 2017). In the indian context apart from these roles, there was the argument regarding the need of competent people – who are aware of the potential of EV's to be involved in sector at the government level. Not having competent people makes it difficult to have a practical and well researched policy. its impacts can be seen in the indian ev sector for example in the case of subsidies which were handed to public companies and not private ones, and the governments contuing revision of its policies regarding the E Mobility sector.

5.2 Catalyzing EV charging infrastructure

A major finding from the research was the goverments active role in procuring EV's and developing charging networks. This according to the interview with the government official is expected to create awareness in the market and kick start adoption of EV's in the country. Despite the positive steps by the government, there could be a chance that the government investments are putting off private players from investing in the infrastructure. (Philip and Wiederer, 2010) note that public competition can make the EV charging business unworthy of investment from private sector companies and as noted from the interview with EY, the government is taking a low cost approach and placing charging stations where they are not even needed. Rather than attempting to provide the charging networks, it could be better for the government to provide financial incentives to private parties who can help run a better charging network. These can considerably reduce the costs of setting up and tax breaks could also reduce operating costs.

One finding that stood out was the role of ride sharing companies in adopting EV's for their fleet and expanding the charging infrastructure. The investments by ride sharing companies such as Uber and Ola could lay a perfect platform for raising the number of EV'S on the road as well as the charging network. (Batra, 2017) also notes that there's a great potential in ride sharing to significantly push for EV adoption. It could be argued that EV ride sharing companies can also

play a big role in reducing carbon emissions with EV's as they cover more mileage and are mainly used in cities, where more fuel is consumed due to lower speeds.

With regards to PPP, the findings from the interviews only briefly mention that PPP models can be beneficial for setting up the infrastructure and at the moment are being applied at a very small scale in India. Several reports including the (Bureau of Energy Efficiency and Ernst & Young, 2019) report and (Deloitte, 2019) suggest that PPP models in India can help expand the charging infrastructure and reduce the risks involved. However as noted in the literature review, PPP in EV charging infrastructure is a new phenomenon and hasn't been applied widely. In order to give a glimpse of the benefits, China's use of a PPP model in EV charging infrastructure will be used as an example. The government of china acknowledged the efficiency of private firms regarding the construction and quality of public chargers that they can provide (Zhu, 2017). One of the projects is the Anqing project which is known to be one of the best practices of PPP implementations in the country and a model being used to deploy 20,000 chargers in Anqing city (Wang and Ke, 2018). The project has seen partnerships and coordination across different levels – from urban planners, power companies to municipal bodies in making an effective plan (Wang and Ke, 2018). The findings from the interviews conducted on India brought up a lot of risks associated with the investing in charging infrastructure. A main concern was not enough revenue being generated. In the Anqing project, the PPP model removed this concern. The private sector is financing the project however the government is funding the gap between the revenue and the costs as initially there won't be enough EV's to raise enough revenue (Wang and Ke, 2018).

Moreover the government is absorbing the risk of pricing changes especially in the case that the utilization of the chargers fall (Wang and Ke, 2018). Furthermore the Anqing government is holding the responsibility for identifying and providing suitable land for the infrastructure construction (Wang and Ke, 2018). In the context of India, several lessons can be learned from the Anqing project, especially the method of reducing the revenue risk which was a major concern brought up. Though there needs to be a study on results of the PPP model in 2020, the project was nominated as a national demonstration project meaning it is an example of the best practice of PPP (Wang and Ke, 2018).

Looking at the barriers and catalyzation of EV charging stations through the lens of the innovation system framework, it can be argued that the network of institutions and organizations involved are hindering the development and diffusion of the charging infrastructure. The main function of the innovation system is to "pursue innovative processes" through the network of public and private institutions (Edquist, 2009). In the case of organizations, the activities of public bodies i.e. utility companies, financial institutions are standing in the way for the diffusion of the EV infrastructure. Private companies require finances which financial institutions are not willing to provide due to the level of risk while utility companies are not willing to invest in the upgrade of the power grids. There is a uncertainty around the availability of a land to set up the charging stations and municipal urban bodies are unwilling to help find suitable land or offer land at low lease. In the interview with EESL it was mentioned that it is not the role of the government to install the charging infrastructure even though the government agencies were handed the subsidies and not the private parties. Despite the subsidies. the government is not only limiting itself by setting up the charging infrastructure for its own fleet but preventing private providers from coming in the market through the actions of the national bodies such as the utility and financial institutions. However new and established actors specifically the ride sharing companies i.e OLA are working with local

manufacturing companies to stimulate the demand of EV's and increase the number of charging stations.

6 Conclusion

The Paris Declaration on Electro-Mobility pushed for countries across the world to switch to Electric vehicle and keeping this in line, India has set a very ambitious target of reaching 100% electric mobility by 2030. The governments ambition was to have 6-7 million vehicles by 2020 however the country's EV sector is still in its very infancy and a lot of research and development is needed in the sector. A common question is what comes first , the EV's? or the charging infrastructure? Having highlighted the importance of the charging infrastructure, this thesis attempted to highlight the main barriers and challenges hindering the deployment of the EV charging stations in India and a look at the ways that the network of chargers can be made widely available. Overall the research shed light upon the barriers in a developing country context and revealed the goverments role, availability of land and a stable electric grid as the main barriers that investors have to overcome. Furthermore a PPP model in China was presented that could be modeled in India to reduce the risks involved for both private and public parties, while the role of ride sharing companies in stimulating EV's and charging networks was also brought up from the findings. There is a lot of potential for India to switch to Electric mobility, however this will take a considerable amount of time given the scale of the number of vehicles and people in the country.

6.1 Practical implications and future research

The research from the thesis could be used by other developing countries who are in the stage of developing their own Electric Mobility Sector. Furthermore the current stakeholders involved in India could also benefit from the research by drawing upon the comparisons of India and developed countries. As for further research, it would be beneficial to conduct city exclusive research and compare the different problems that lie within each city and not in general terms.

7 References

Anenberg, S. *et al.* (2019) 'A global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015', *International Council on Clean Transportation*, p. 55. Available at: https://www.theicct.org/sites/default/files/publications/Global_health_impacts_transport_emissions_2010-2015_20190226.pdf.

Auto Tech Review (2019) *Auto Tech Review consumer survey*, *Auto tech magazine*. Available at: http://oreilly.com/catalog/errata.csp?isbn=9781449340377.

Bailey, J., Miele, A. and Axsen, J. (2015) 'Is awareness of public charging associated with consumer interest in plug-in electric vehicles?', *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 36, pp. 1–9. doi: 10.1016/j.trd.2015.02.001.

Batra, R. (2017) 'Standing up India's EV ecosystem - who will drive the charge?', p. 20.

Bureau of Energy Efficiency and Ernst & Young (2019) 'Propelling Electric Vehicles in India - Technical study of Electric Vehicles and Charging Infrastructure'. Available at: https://beeindia.gov.in/sites/default/files/press_releases/2019 - EY to BEE - Technical study on EVs %26 Charging Infrastructure.pdf.

Chaminade, C. and Edquist, C. (2005) 'From theory to practice: the use of systems of innovation approach in innovation policy', *Innovation Studies*, pp. 1–47. Available at: http://www.circle.lu.se/upload/CIRCLE/workingpapers/200502_Chaminade_Edquist.pdf.

Deloitte (2011) 'Unplugged: Electric vehicle realities versus consumer expectations', p. 32.

Deloitte (2019) 'Recharging India's electric vehicle ambition by electrifying public transport', *Future of Mobility*, (February).

Edquist, C. (2009) 'Systems of Innovation: Perspectives and Challenges', *The Oxford Handbook of Innovation*, (April). doi: 10.1093/oxfordhb/9780199286805.003.0007.

'ELECTRIC VEHICLE CHARGING Guidelines for Cities' (no date).

Europe, I. C. (2017) 'Handbook on Public Private Partnership (PPP) in Built Heritage Revitalisation Projects', p. 56. Available at: http://www.interreg-central.eu/restaura.

Figenbaum, E. (2017) 'Perspectives on Norway's supercharged electric vehicle policy', *Environmental Innovation and Societal Transitions*. Elsevier B.V., 25, pp. 14–34. doi: 10.1016/j.eist.2016.11.002.

Funke, S. A. and Plötz, P. (2017) 'A techno-economic analysis of fast charging needs in Germany for different ranges of battery electric vehicles', *European Battery, Hybrid and Fuel Cell Electric Vehicle Congress*, 14(March), pp. 1–7. doi: 10.1016/j.enbuild.2014.12.047.

GoI (2013) 'National Electric Mobility Mission Plan 2020', *Ministry of Heavy Industries & Public Enterprises, Government of India*, pp. 0–186. doi: 10.1017/CBO9781107415324.004.

Gupta, S. and Saini, P. (2018) 'Electric Mobility in India : Potential and Policy Imperatives', 2018, pp. 1–10.

Hall, D. and Lutsey, N. (2017) 'Emerging Best Pratices for Electric Vehicle Charging Infrastructure', *ICCT White Paper*, (October). Available at: http://www.ivl.se/download/18.5922281715bdaebede9559/1496046218976/C243+The+life+cycle+energy+consumption+and+CO2+emissions+from+lithium+ion+batteries+.pdf.

Hall, D. and Lutsey, N. (2020) 'Electric Vehicle Charging Guide | ChargeHub'. Available at: https://energypolicy.columbia.edu/research/report/electric-vehicle-charging-china-and-united-states%0Ahttps://energypolicy.columbia.edu/sites/default/files/file-uploads/EV_ChargingChina-CGEP_Report_Final.pdf.

Innovation Norway (2018) 'India EV Story, Emerging Opportunities', *Https://Www.Innovasjonnorge.No/Contentassets/815Ebd0568D4490Aa91D0B2D5505Abe4/India-Ev-Story.Pdf*, pp. 1–74. Available at: https://www.innovasjonnorge.no/contentassets/815ebd0568d4490aa91d0b2d5505abe4/india-ev-story.pdf.

IQAir (2019) 'World Air Quality', *2019 World Air Quality Report*, pp. 1–22. Available at: https://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2019-en.pdf.

Jhunjhunwala, A., Kaur, P. and Mutagekar, S. (2018) 'Electric vehicles in India: A novel approach to scale electrification', *IEEE Electrification Magazine*. IEEE, 6(4), pp. 40–47. doi: 10.1109/MELE.2018.2871278.

Knutsen, D. (2013) 'A study of electric vehicle charging patterns and range anxiety'.

Lee, H. and Clark, A. (2018) 'Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption', *SSRN Electronic Journal*. doi: 10.2139/ssrn.3251551.

Malerba, F. (2005) 'Sectoral systems of innovation: A framework for linking innovation to the knowledge base, structure and dynamics of sectors', *Economics of Innovation and New Technology*, 14(1–2), pp. 63–82. doi: 10.1080/1043859042000228688.

Mathieu, L. (2018) 'Roll-out of public EV charging infrastructure in the EU', (September). Available at: www.transportenvironment.org.

Mersky, A. C. *et al.* (2016) 'Effectiveness of incentives on electric vehicle adoption in Norway', *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 46, pp. 56–68. doi: 10.1016/j.trd.2016.03.011.

Nair, S. *et al.* (2018) 'India's charging infrastructure - Biggest single point impediment in EV adaptation in India', *2017 IEEE Transportation Electrification Conference, ITEC-India 2017*, 2018-Janua, pp. 1–6. doi: 10.1109/ITEC-India.2017.8333884.

Pathak, A. and Intratat, C. (2012) 'Use of semi-structured interviews to investigate teacher perceptions of student collaboration', *Malaysian Journal of ELT Research*, 8(1), pp. 1–10.

Philip, R. and Wiederer, A. (2010) 'Policy options for electric vehicle charging infrastructure in C40 cities', pp. 1–95. Available at: https://www.innovations.harvard.edu/sites/default/files/1108934.pdf.

Rezvani, Z., Jansson, J. and Bodin, J. (2015) 'Advances in consumer electric vehicle adoption research: A review and research agenda', *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 34, pp. 122–136. doi: 10.1016/j.trd.2014.10.010.

Sadka, E. (2006) 'Public-Private Partnerships: A Public Economics Perspective', *IMF Working Papers*, 06(77), p. 1. doi: 10.5089/9781451863376.001.

Sheppard, C. J. R. *et al.* (2016) 'Cost-effective electric vehicle charging infrastructure siting for Delhi', *Environmental Research Letters*. IOP Publishing, 11(6). doi: 10.1088/1748-9326/11/6/064010.

Sustainable Mobility for All Initiative (2017) *Global Mobility Report 2017*, *Global Mobility Report 2017*. Available at: https://sum4all.org/publications/global-mobility-report-2017.

TERI (2019) *FASTER ADOPTION OF ELECTRIC VEHICLES*, *FASTER ADOPTION OF ELECTRIC VEHICLES IN INDIA: PERSPECTIVE OF CONSUMERS AND INDUSTRY*. New Delhi.

The World Bank (2018) 'Electric Mobility & Development', *The World Bank*. doi: 10.1007/s38311-018-0161-1.

Un-Noor, F. *et al.* (2017) 'A comprehensive study of key electric vehicle (EV) components, technologies, challenges, impacts, and future direction of development', *Energies*, 10(8). doi: 10.3390/en10081217.

UN/DESA (2017) 'World Population Prospects 2017 – Data Booklet (ST/ESA/SER.A/401)', *United Nations, Department of Economics and Social Affairs, Population Division*, pp. 1–24.

UNFCCC (2015) 'Paris Declaration on Electro-Mobility and Climate Change & Call to Action', *PARIS2015 Un Climate Change Conference*, p. 1. doi: 10.1007/s10640-015-9890-4.

Wang, K. and Ke, Y. (2018) 'Public-Private Partnerships in the Electric Vehicle Charging Infrastructure in China: An Illustrative Case Study', *Advances in Civil Engineering*, 2018. doi: 10.1155/2018/9061647.

Wei, D. *et al.* (2016) 'The paris agreement: What it means for business'. Available at: www.newclimate.org.

Zhang, L., Zhao, Z. and Kan, Z. (2019) 'Private-sector partner selection for public-private partnership projects of electric vehicle charging infrastructure', *Energy Science and Engineering*, 7(5), pp. 1469–1484. doi: 10.1002/ese3.367.

Zhu, L. (2017) 'Research on the application of PPP model in the Chinese construction and operation of new energy vehicle charging facilities', *AIP Conference Proceedings*, 1839(May), pp. 20031–20034. doi: 10.1063/1.4982398.

Appendix 1

1. Do you think that the EV infrastructure is slowing the adoption of EV in the country?

[My research topic focuses on EV Charging Infrastructure and exploring avenues for its proliferation. What is in your opinion the biggest hurdle in adoption of Electric Vehicles in India?

2. [Development of EV charging infrastructure for increased adoptions of EVs poses the classic chicken and egg problem: do you think consumers would be more inclined towards EVs if they see a rise of charging infrastructure?]
3. [And on the same point, how critical is Govt. support in development of the charging infrastructure in a country like India. Can this be left entirely to the whim of the private sector?]
4. India has a low uptake of 4 wheelers as opposed to 2 wheelers and 3. With battery swapping being common [in 2 -3 wheelers, would you say that the rollout of battery swapping is easier than having charging pods, and would that subsequently pave way for quicker adoption of 4 wheeler EVs in the market]
5. What investment potential do you see in EV charging stations? [Question needs clarity]
6. [With the government actively looking to introduce EVs in the market] What barriers are being faced in setting up the EV charging infrastructures.
7. [In the present market,] what are the major risks associated with investing in EV charging infrastructure [and has the Government announced any investment policy for the same]?
8. The Fame scheme focuses on charging infrastructure. How well do you think this scheme has been in fulfilling its goals?
9. What segment of the market is being targeting as each has different requirements (2wh, 3wh, 4wh, cv?
10. [Who are the major investors in charging infrastructure at the moment, and do you think their motive, in addition to profitability of course, is to further the green cause?] What investment criteria is being looked at to invest in charging stations?
11. What role do you think ride sharing companies or other start ups can play in expanding the EV charging infrastructure, and are any companies / start ups?
12. What support does the government offer to EV charging station developers?
13. How successful has the institutional and regulatory framework been to launch the EV sector in India, investment in charging stations?
14. How big of a role do subsidies have?
15. Is there some impact from the electricity mix? Does the government aim or prefers to subsidise only projects which have higher shares of renewables in the portfolio?