DEP 302 SYSTEMS DESIGN

FUTURE OF ELECTRIC VEHICLES IN INDIA

Project Report

An academic project by
Atish Waghwase, Vanshaj Kumar, Zaid Khuram

PROJECT ABSTRACT

This is an academic project by Atish Waghwase, Vanshaj Kumar, and Zaid Khuram, students of IDC School of Design at IIT Bombay. The project began with an aim to study the electric vehicle ecosystem in India while also taking reference and understanding systems that have been implemented across the world.

With the help of primary research and extensive secondary research, the project focus was brought down to electric two wheelers in India. With two wheelers taking up 80% of the current automobile markets, along with the government expecting 80% of two wheeler sales to be electric by 2030, we felt it was a more realistic and grounded goal to achieve.

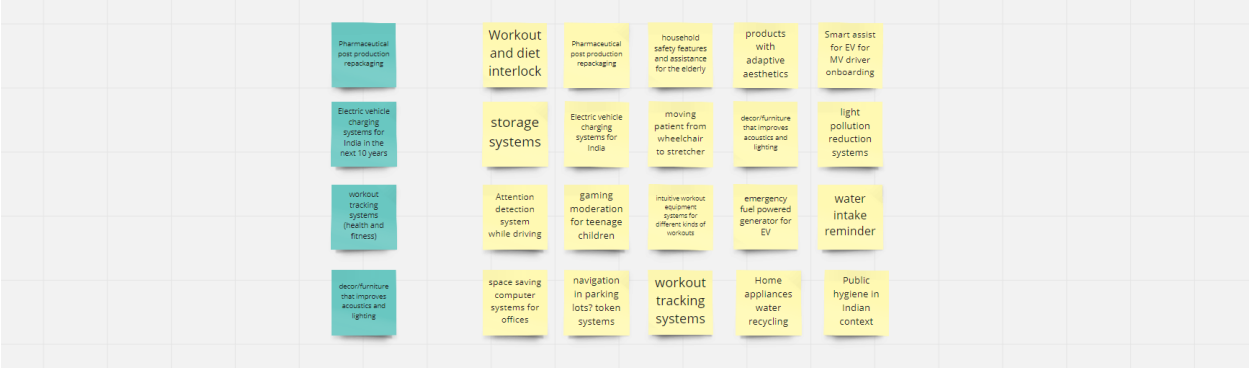
Continuing with further ideation and problem identification for this futuristic scenario, we came up with multiple subsystems that could be tackled within it. After evaluating our option, the project focus was further narrowed to the public charging ecosystem in India for electric vehicles, with extensive focus on electric two wheelers.

Through research and detailed review of the stakeholders in the system, the project had an outcome in the form of a business idea. ‘Navaaz EV Charging Solutions’ would be a business to business company that would help clients of all sizes set up charging stations at their locations. We also came up with an extensive set of guidelines for the work the company would do and execute.

INITIAL IDEA EXPLORATION

Idea Mapping

We started our journey by putting down any and all elements around us that each of us thought was a part of a bigger system or infrastructure we could work on. Our ideas ranged from interior office systems for work from home situations to public parking spaces, pharmaceutical industry supply chain to health and fitness notions people have.

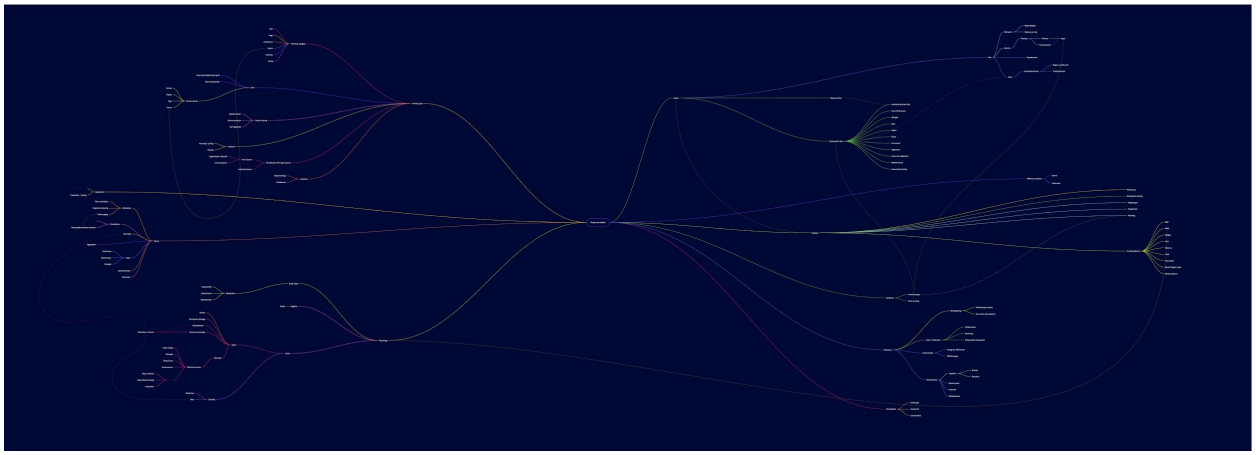


Sticky notes with spontaneous ideas

We narrowed down and selected four ideas that we felt had the most potential, as well as suited our interests. From our shortlist, the pharmaceutical supply chain idea was dropped due to a clash with another group, and the home office idea, we felt, did not have a large enough scope or system behind it for us to work in-depth on. We moved forward with two ideas; Health and Fitness, and Electric Vehicles adoption and usage in India.

Mind-Mapping

It was vital to understand the broader system around the initial ideas we had. To map out the subjects' interconnectedness and range, we noted down everything related to the topic and made connections between them. This helped us see the nuances that exist between the elements within the system as well as get a glimpse of perspectives the stakeholders in the system would have.



Wide view of the entire mind map, meant to show all the connections

We chose to divert away from the subject of Health and Fitness as it consisted of a lot of personal choices and preferences that stakeholders marketed and used. We didn't find the complete system around exercise to be as appealing as we had initially thought.

SECONDARY RESEARCH | Indian EV Industry

National Electric Mobility Mission Plan 2020

Published 2012 by Department of Heavy Industry (Govt. of India)

This paper summarises India's major first step towards being part of a sustainable world. The paper studies and puts forth why taking this step in evolving India's automobile industry is not only beneficial to the nation in terms of reduced pollution levels and higher energy efficiency, but also in growing India's economy and providing employment opportunities.

The paper briefly maps out the recent developments made in the electric market and moves towards initiatives the government of India can take towards their goal and the key challenges it may face. This plan that initiated in 2013 aimed to have sold 6-7 million electric (or hybrid) vehicles by 2020 was a preliminary and ambitious project but nonetheless very beneficial in paving the way for future policies.

Indian Automobile Market Overview

Published November 2020 by India Brand Equity Foundation

This presentation outlines the different segments within the automobile market; two wheelers, three wheelers, commercial vehicles and passenger vehicles. It explains the capacities of each market segment and analyses recent trends and strategies by the government and private corporations in moving towards an electric future.

The paper also talks about the future of India's market by analysing current purchasing patterns by consumers, and taking into account their incomes and spending patterns. By comparing these trends to actions taken by market leaders of each segment, this paper helps us to understand probable difficulties that could be faced in taking each automobile segment electric, and possibilities in overcoming them.

India's Electric Transformation

Published April 2019 by NITI Aayog (Govt. of India) and Rocky Mountain Institute

This paper gives an summary of the key policy and industry initiatives to support rapid adoption of electric mobility in India, analyses the impacts of FAME II with respect to emissions, oil consumption and overall EV adoption trends; and proposes possible actions that industry and government can take can take in continued support for the faster development of EVs.

Challenges for India for Achieving Target of Electric Buses and Cars

Published 2019 in International Journal of Electrical Engineering and Technology

This paper goes more in depth about government involvement in achieving the NEMMP 2020 target and the status of different states in adopting their vehicles to this initiative. It further outlines all the initiatives taken by the government as part of the NEMMP. The initiation of FAME I in 2015, its extension in 2017 and the launch of FAME II with a massively expanded budget in 2019.

The paper also creates very clear links with other elements in the EV system that are essential in making it work. It highlights the importance of the charging infrastructure as well as subsidies by the government, on both supply and demand sides, to make EVs more desirable.

Zero Emission Vehicles (ZEVs): Towards a Policy Framework

Published 2018 by NITI Aayog (Govt. of India)

This paper talks about the possibility of India becoming leaders in small and public electric vehicles and also how by doing so, we can reduce our oil import bills considerably. It also talked about the required innovations like new battery chemistries (focusing on minerals other than lithium), a policy regime that encourages access to latest technologies and a concerted effort by the Indian industry to achieve global competition through acquiring the necessary scale and using cutting edge technology.

KEY LEARNINGS

Are Electric Vehicles Really Sustainable

Up to this date, India's main source of energy is coal. Now the question arises, are electric vehicles powered by coal actually sustainable?

Recent studies show that even with India's main source of energy as coal, CO_2 emissions are seen to be 29% lower than the average emissions from both diesel and petrol. And by 2030, with more cleaner and renewable sources of energy, these emissions are expected to fall to around 50%. This indicates that EVs charged with India's electricity grid emit lowers lifecycle emissions already. As coal power capacity continues to shrink and the share of renewables increases, India's crude emission factor is expected to fall through the decade as well, in turn resulting in gradually decreasing overall EV emissions.

If looked at from an efficiency perspective, electric vehicles can convert about 59%–62% of the electrical energy from the grid to power at the wheels. Meanwhile, conventional petrol vehicles only convert about 17%–21% of the energy stored in petrol to power at the wheels. Means using electric vehicles will not only decrease the day to day running cost but will also help in reducing the carbon

footprint. EVs also have lesser moving parts compared to ICEVs making them less likely to have mechanical issues.

India and the Global Automobile Market

India became the fourth largest auto market in 2019 displacing Germany with about 3.99 million units sold in the passenger and commercial vehicles categories. India is expected to displace Japan as the third largest auto market by 2021. This shows India's strength in this industry and with India's average income on the rise and young population on the horizon, the automotive industry is expecting to increase exports by five times by the year 2026. (2020, India Brand Equity Foundation)

With the Indian government aiming to make India a Research and Development Hub for not only EVs but the whole automotive industry, they have created changes in taxation towards electric vehicles as well as hugely increased funding for electric mobility startups to gain ground in Indian streets. This in turn, to an extent, has attracted international and domestic Original Equipment Manufacturers (OEMs) to set up new production facilities within the nation. This provides companies with cheaper components and plays its role within the 'Make in India' scheme.

The current automobile market in India can be divided into four segments; Two wheelers, Passenger vehicles, Commercial vehicles and Three wheelers. Two wheelers hold a major part of the market share with more 80% of total automobile sales in 2020 being two wheelers in India. (2020, India Brand Equity Foundation)

Government Initiatives

The National Electric Mobility Mission Plan 2020 (NEMMP) was India's first major step towards widespread adoption of Electric Vehicles in India. The vision of this initiative was to achieve fuel security by promoting electric and hybrid vehicles in India. This would be done through providing fiscal and monetary incentives to suppliers and consumers to kickstart this technology. This plan aimed to have sold 6-7 million electric (EVs) or hybrid eclectic (xEVs) vehicles by 2020.

Faster Adoption and Manufacturing of Electric Hybrid Vehicles (FAME I) was the first detailed policy issued under the NEMMP plan. With a budget of INR 1.4 Billion, It outlined in detail the incentives offered to OEMs, and consumers to purchase xEVs in India. While the government faced many challenges and reached a stalemate in a sense when companies asked the government to set up charging infrastructure before they could make vehicles and the government hoped to have vehicles before the charging infrastructure was put in place.

In hindsight, NEMMP 2020's goal seems like a very ambitious plan, but what was achieved through FAME I was far more important in taking this strategy forward. The government clearly understood that without a charging infrastructure it was going to be very hard to incentivise private companies to create vehicles. And without their production and development of new vehicles, creating competition and in turn lowering prices for the consumers was only a dream.

FAME II, initiative in 2019, as an iteration to FAME I but with a massively increased budget of INR 100 billion majorly focused on creating a massive charging infrastructure by 2030. The government sanctioned 2636 charging stations in 62 cities across 24 States/UTs.

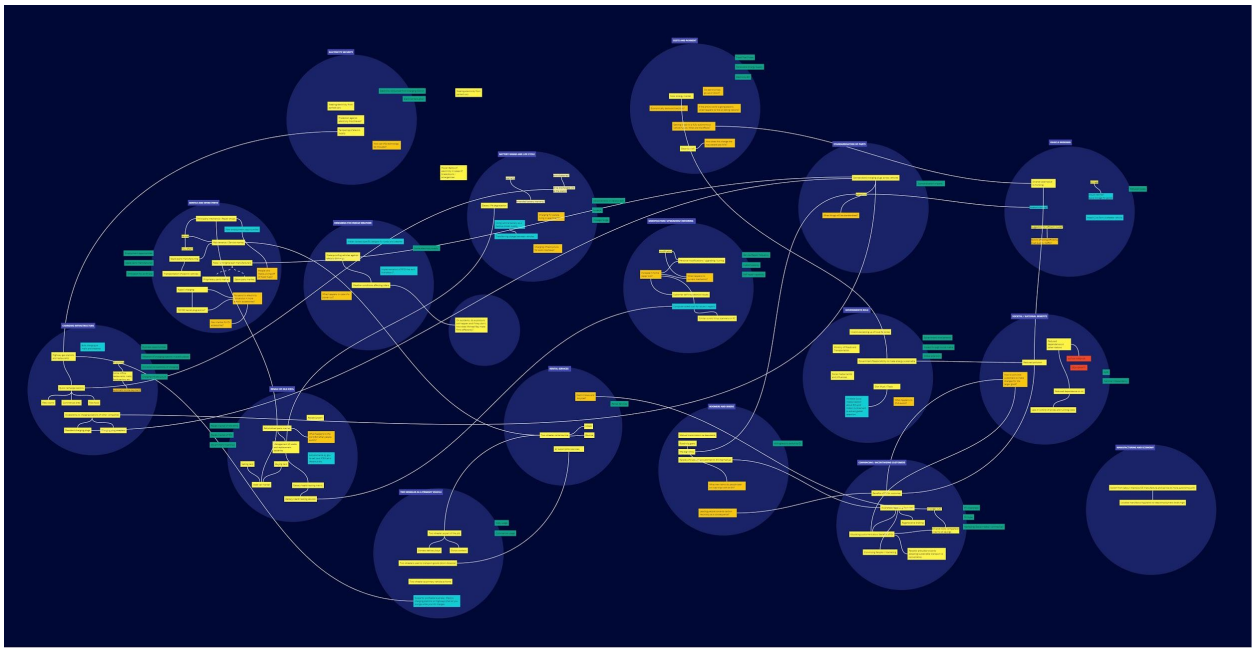
This massive budget increase also showed domestic and international corporations the government's eagerness and involvement in pushing the electric future in India. This in turn attracted investors and multiple deals were done. Toshiba, Denso and Suzuki have partnered together to open India's first Lithium-ion battery plant in Gujarat.

EV SYSTEM MAPPING

Mind Map

It was imperative to map out the system we spent many hours researching and attempting to understand. However, we did not want to create an inherent hierarchy by choosing to start with one aspect over the other. To counter it, we chose to create a generic mind map of the elements that are within or related in any way to the Electric Vehicle idea that we have.

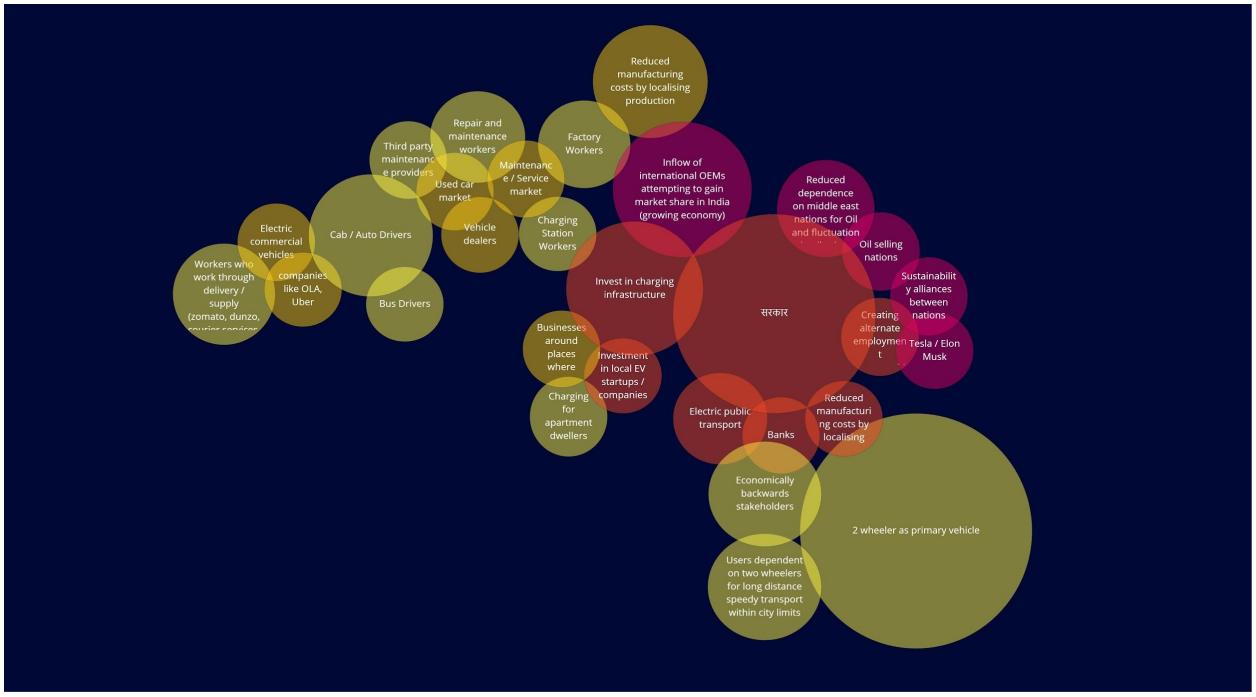
We then clustered them in groups, based on common ideas and then created links between individual elements to get an idea of the relationships that exist between them. This process helped us understand the interconnectedness and depth of the EV system and how it had ties with the government, global hype, local employment and consumer mindsets of electric vehicles. A very organised version of the mind map that we ended up with is shown below.



Initial mind map

Zonal Clustering

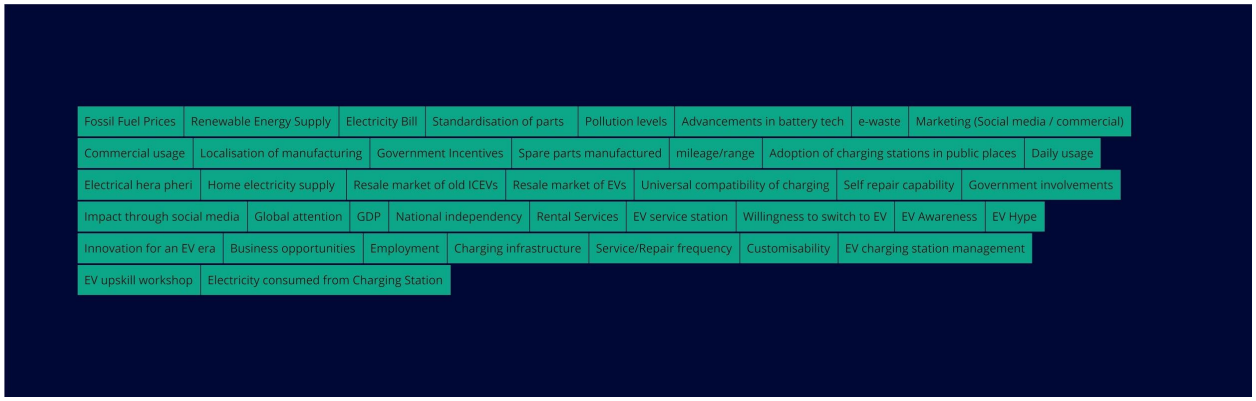
This step was experimental. In an attempt to create a visual depiction of overlaps and links between subsystems, we used circles to depict them, coloured differently according to their hierarchy in the stakeholder ladder and placed them on our canvas. This process helped us come up with new ideas and realise that we needed to dive deeper into what these connections were and how they affected each other. Shown below is our first attempt at showing systemic connections.



Zonal clustering

Locating Variables

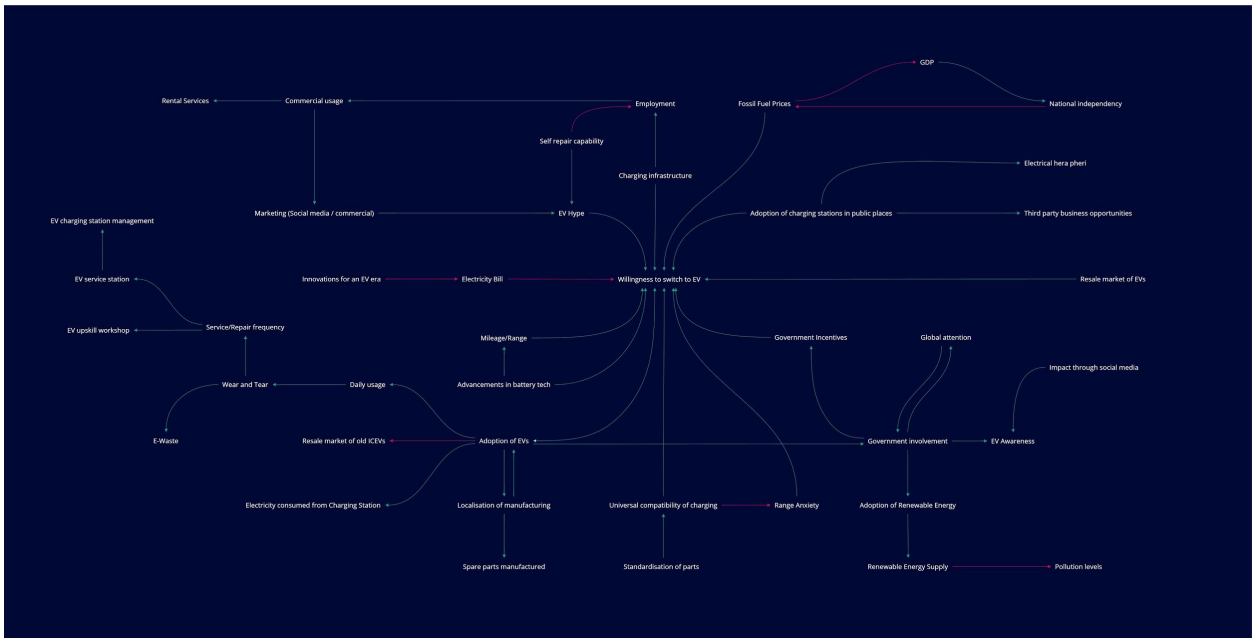
Since we had already attempted to map the system on our initial mind map, we derived variables from our first exploration. Variables were required to be neutral nouns to allow their flexibility of influencing or being affected positively or inversely. The list of variables we came up with at this stage are shown below.



A list of our variables

Mapping Variables

Here we started to map and draw lines between the variables to see how each of the variables affect another. Green lines show positive relationships while red lines show inverse relationships. We started with the variable ‘willingness to switch to EVs’ as it seemed a very central variable to our project. While we still did not start forming any systemic loops, this stage helped us question linear relationships and broaden our understanding of the systemic structure.

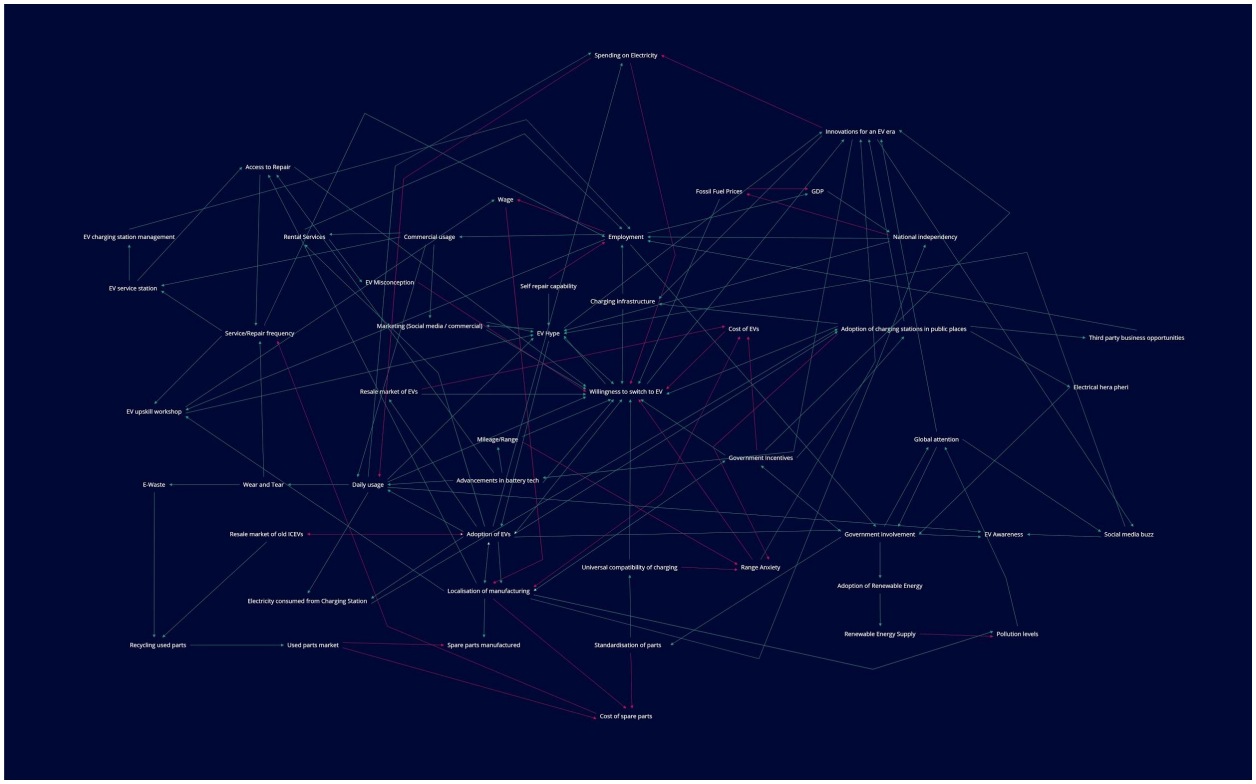


Primary connections map of variables

CAUSAL LOOP MAPPING

We did not hold back at this stage. By letting loose and thinking about the EV system at multiple levels from users and consumers to governments and global networks, we were able to map out a large number of the relationships within the system. We were able to come up with numerous variables through the process of mapping out linear relationships that in turn were only a small part of a systemic structure.

We started to locate reinforcing loops; loops that have a positive relation with each other so if one increases the other will increase and in turn feed back into that same. And balancing loops; where relations between variables work in opposite directions and maintain a relatively steady rate. By identifying these loops, we were able to see how interference in one variable in the system can affect multiple things, making it a more complex process to create change. The final, but not complete, version of our Causal Loop Diagram is shown below.

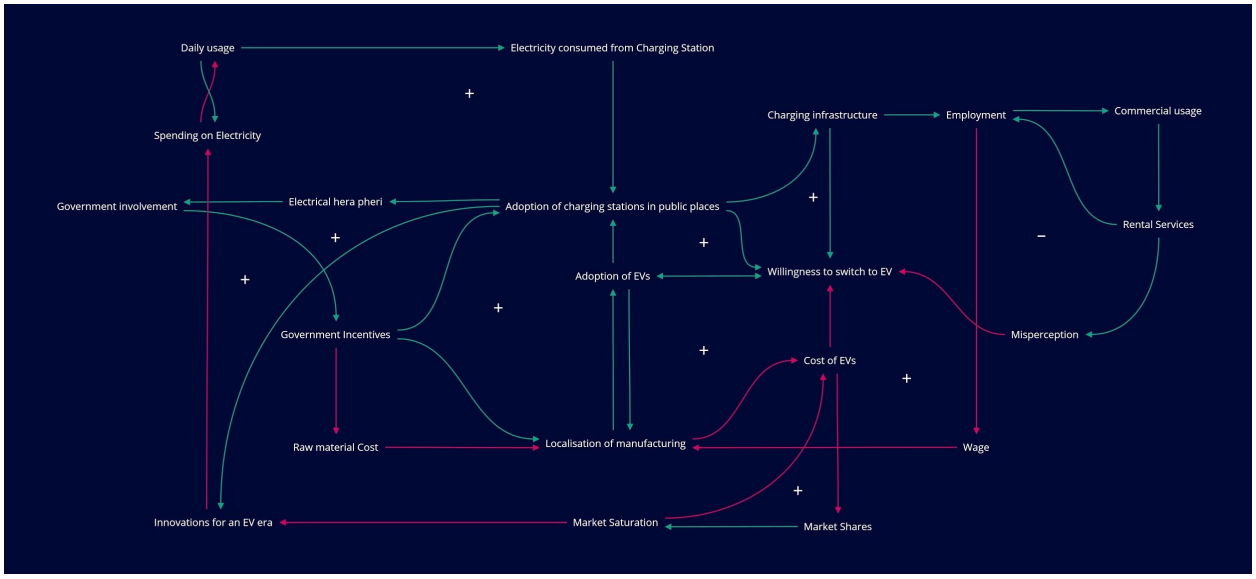


Complete causal loop diagram

EV Adoption

Our initial ideas of transitioning to widespread EV use only included investment and marketing. Through this loop we understood that EV adoption is connected to larger contexts like electricity production which further leads to questions of are the sources of electricity sustainable? EV adoption in turn could cause a vast range of new issues alongside the benefits that we attempted to anticipate like electricity theft and perception of leaving cars to charge in public spaces.

More ideas of the role of the government and the private sector in easing EV adoption was key in understanding the influencing factors. Reinforcing loops like if the government subsidise manufacturing facilities, it would reduce the cost of parts and in turn of the EV, making it accessible to a large consumer base. Adoption of EVs will also only be possible in places of reliable electricity supply which cannot be said has been achieved throughout the Indian subcontinent at the moment. Below is the map of the EV adoption subsystem.

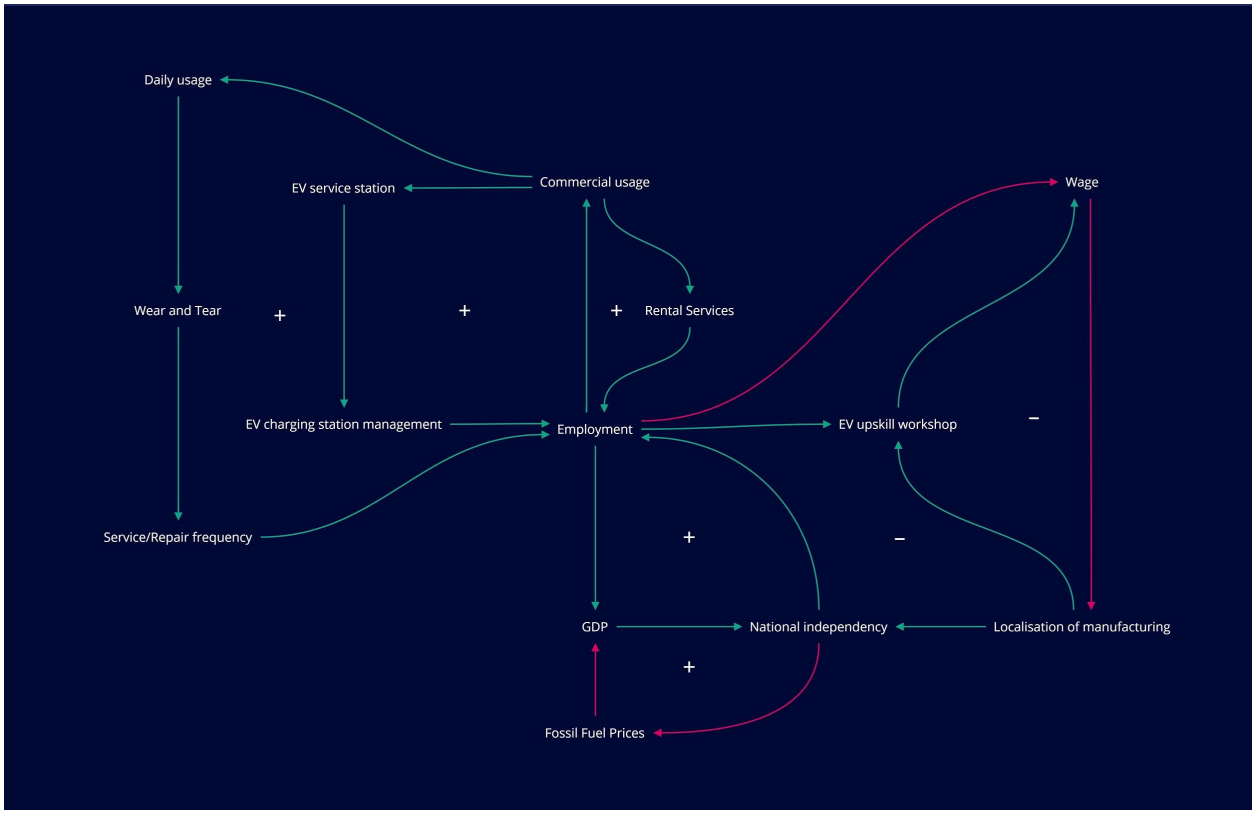


EV Adoption subsystem

Markets

If we continue to anticipate what would happen with growth in EVs in India, it was important to clear out how businesses and markets would connect to the system. As for any automobile, the vehicle service and maintenance was a major part of our exploration. The connections we made showed that while the market of ICEV maintenance might lower, the EV service market will definitely rise since it is a new technology and consumers would not be as aware of the smaller issues. However, this would also require workers to relearn their trade, which may not be ideal for all. We hope to dive further into this reinforcing loop later on in our project.

We also explored how global variables like fuel prices and international treaties would affect India's transition. If localisation of industries would happen, fuel prices would affect India's economy less and in turn make them more independent and possibly even exporters for some specific parts. The map of the Market subsystem is shown below.



Markets subsystem

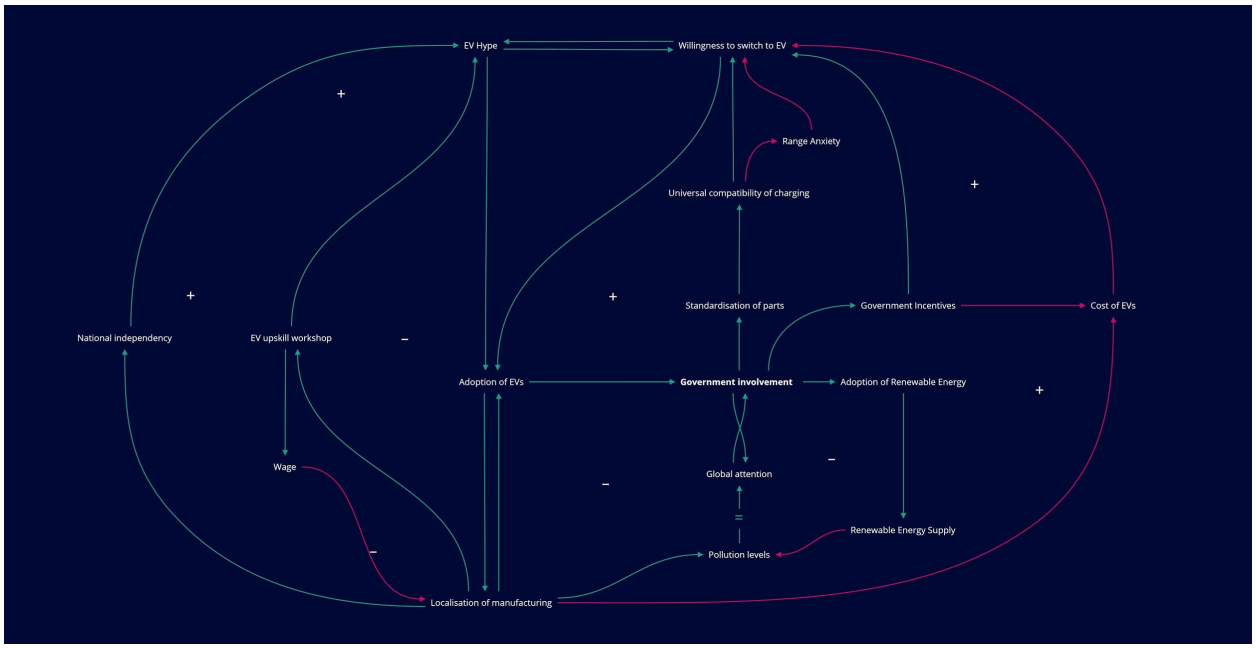
Government

Governments and influenced by global attention and in turn do receive global attention sometimes for steps they take towards cleaner and sustainable alternatives. This reinforcing, but slightly delayed, loop shows one aspect that influences change. While it was understood that government intervention in tackling the early transition period of EVs would be essential, through the causal loops, we were able to gain understanding of how much of intervention would be needed.

China's EV industry grew rapidly in the last decade making other countries invest in this green future as well, however, their market relied heavily on this regular subsidies and incentives. It was not sustainable. In 2018, when the government pulled back on a few subsidies, EV market sales dropped making it clear that the government needed to rethink their policies. Through this loop, we identified the many elements that are affected, in a form of a domino effect, which would eventually make it easier to pinpoint where government intervention would be most effective. We hope to get back to this a little later in the project.

The government's influence on consumer mindset is also not to be underestimated in India. The connection between EVs, localisation and in turn national independence could work as a major factor

in influencing people to switch to EVs. India has already taken steps in this direction which we highlighted in our report last week. The map for the subsystem is shown below.

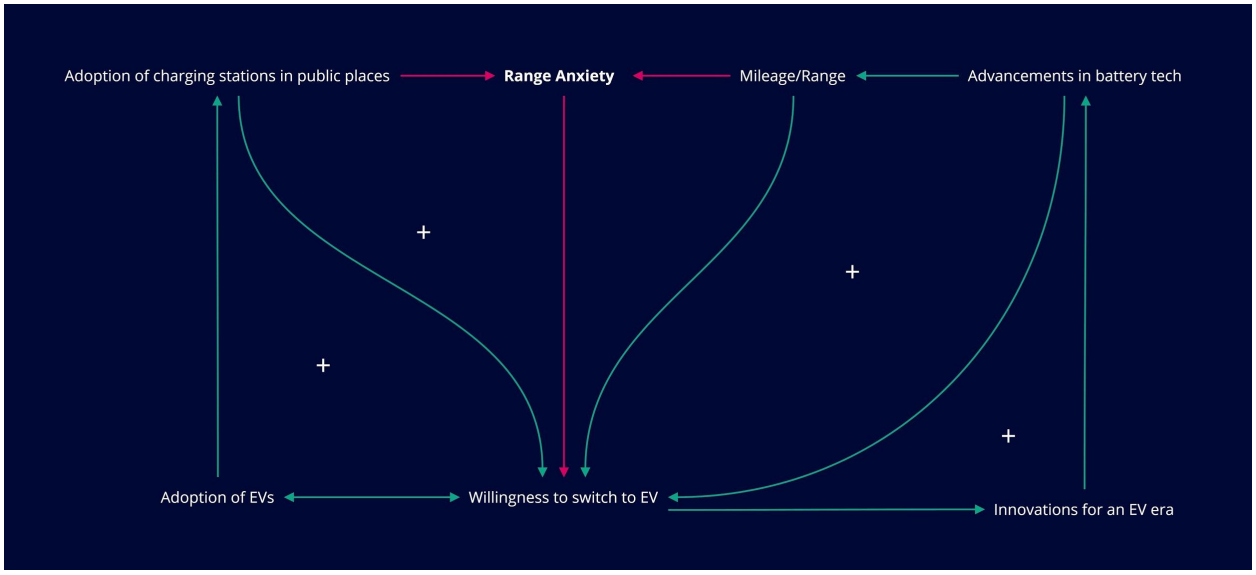


Government subsystem

Range Anxiety

The most common phrase thrown about when talking about why EVs aren't yet the future, range anxiety. We wanted to understand what causes this feeling and how it affects other things.

Range anxiety decreases people's willingness to buy EVs. This is more specifically caused by the lack of charging infrastructure compared to fuel stations along with battery technology still not being adequate enough to be compared with ICEVs. While recent breakthroughs have allowed companies to provide competitive range, it is still fairly new, which means it may take some time before it becomes the mainstream idea.

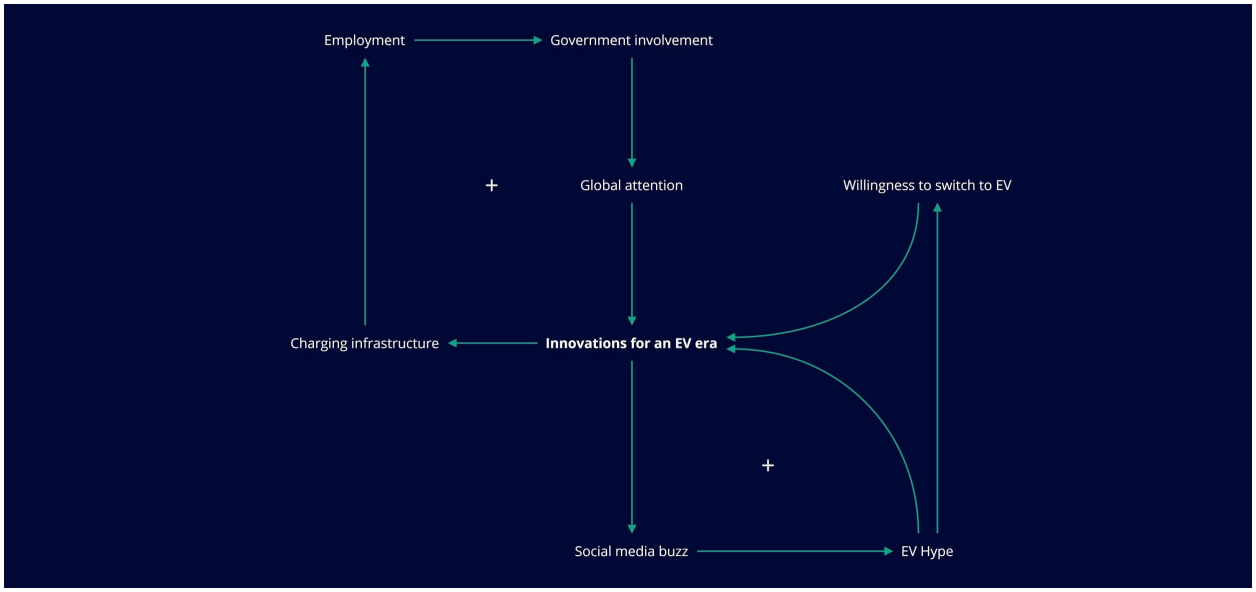


Range Anxiety subsystem

EV Innovation

The idea of EV innovation along with investment in R&D in India was part of many other subsystems. However, it was important to identify variables in relation with Innovation as it plays a major role in planning for a EV growth in India that is sustainable over a period of time with minimal government intervention. The idea of charging infrastructure being central to this growth only grew in significance through this subsystem as it not only helps create employment, but helps change people's mindsets of EV adoption.

EV innovation is also connected to social media hype which not only pushes private companies to make change, but offers a new light to the electric future in India. Business innovation such as Yulu (covered below) and electric bicycles to be used as an option for last mile connectivity pushes the idea of an electric future further to consumer minds, which has already started happening in metropolitan cities in India.

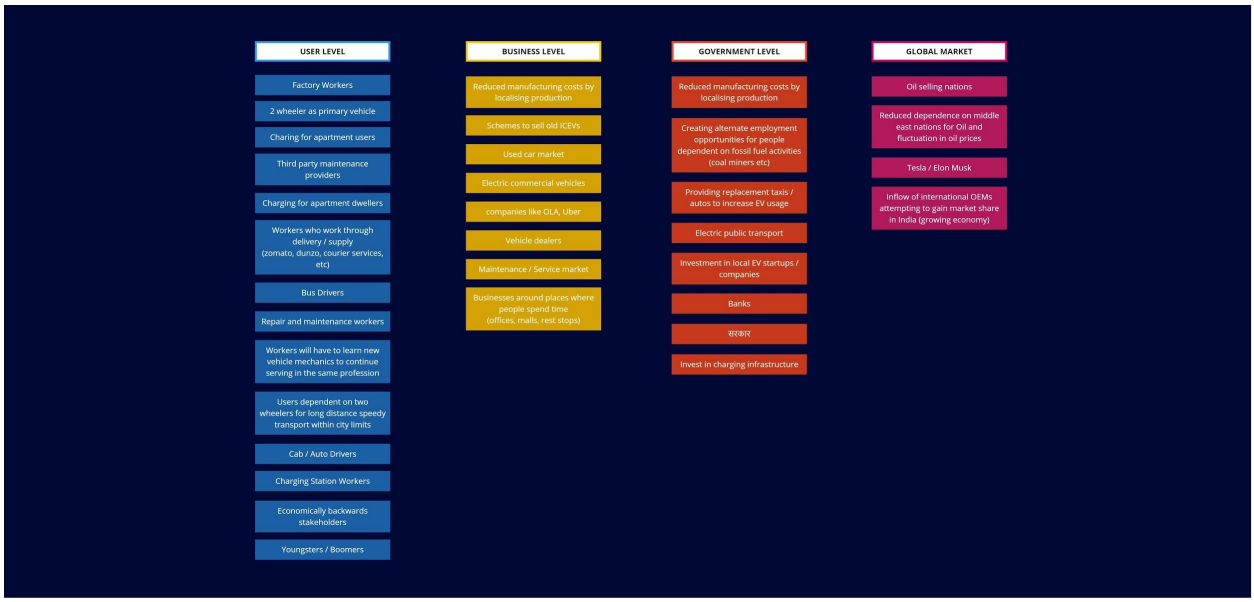


EV Innovation subsystem

STAKEHOLDER MAPPING

The Multiple Levels

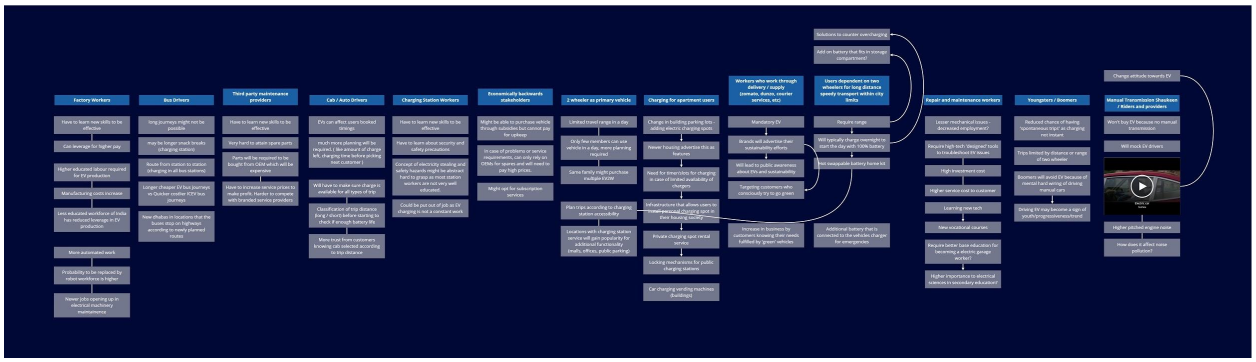
We came up with an exhaustive list of all the stakeholders we thought would be affected by the introduction of EVs and then categorised them according to four levels - Consumer level, Business level, Government level and Global Level



Stakeholder mapping across various levels

Consumer Level Deep Dive

We started with the consumer level, and got sucked in. We attempted to cover as many aspects for each type of consumer and at the same time anticipate problems that may rise, or business that could be developed. From our Causal Loop Diagram, we realised that while many jobs may be created, many jobs in the ICEV industry may also be destroyed, and to ensure a net surplus in a country like India, where labour is abundant is imperative.



Deep dive at the consumer level

We came up with a range of ideas and probable issues and business that could emerge from the rise of E.V culture in India. A few of them are listed below -

1. *Shifting to electric public transport*

   Adoption of EV buses might lead to longer snack breaks to top up the bus's charge. All stations might need to have charging stations and this might give rise to *dhabas* along existing bus routes that were previously unnecessary.

   If electric transport becomes cheaper, people will have the option to opt for cheaper and longer journeys v/s quicker and more expensive journeys.

   Commercial cabs will have to develop a system to be allotted rides based on charge left and will have to develop a system to hot swap batteries as they need to run all day

2. *EV services*

   As electricity itself is subscription based, it could give popularity to EV subscriptions services. Since the expected life of a vehicle is dependent on it's battery longevity, subscription services might benefit from renting pre-serviced vehicles.

Limited range might also generate new ways to plan trips, which would be based on charging station location. Travel companies might leverage this nature to their advantage.

3. *Charging for apartment users*

   Housing societies will advertise EV charging in their parking lots which will also increase EV awareness and adoption. Public charging stations might need to be fitted with security systems such as locking mechanisms to prevent people from plugging their own vehicle in until one's vehicle is charged to the desired level.

4. *Daily use*

   Brands that make EVs mandatory for their employees will advertise their efforts towards a greener future, to strike a chord with the public's beliefs of trying to go green. Employees as well as the general public who use EVs for long distances on the same day will require systems similar to battery swapping. This will lead to innovations that allow spare batteries to be carried in the same vehicle.

5. *Attitude towards EV adoption*

   Enthusiasts who prefer manual transmission over automatic transmission will resist switching to EVs. Citizens with possibly decades of conditioning of driving manual transmission will also have a hard time rewiring their brain to be able to drive automatic transmission. Switching to EVs might become a sign of youth/progressiveness.

   Emulated manual transmission could be one solution to onboard such users.

CASE STUDIES | EV Transition in other countries

China's Government Sponsored Growth

China's growth in EV over the past decade has been substantial and leads the world in sheer size of its EV market. This has influenced many countries to invest and be part of this 'EV race' that is commonly understood as being the future.

China offers many subsidies for EV along with strict rules and regulations on streets that highly incentives consumers to make the switch. ICEVs are just not allowed in many city centres across china. The government also charges about $1200 for a number plate for an ICEV, a fee that is waved off for an

EV. These strict regulations have allowed China to maintain a steady growth in this market over the past decade.

However, an incident in 2018 where China decided to reduce subsidies, ended up reducing the number of EVs sold by over 10%. This showed the reliance of this whole market on constant government funding. It was important to note that this is possible partly due to the nature of China's government. It would be much harder to implement such strict regulations in a country like India. This pushed us to identify aspects that would lead to sustainable and natural growth, rather than put up a facade with government backed funding.

The Rise of EV Bicycles and the Bicycle culture in Europe

"The use of e-bikes is an important part of active mobility in Europe. E-bike sales continue to grow rapidly and e-bikes are fast becoming the option of choice for millions of commuters, travellers and recreational cyclists. The European Cyclists' Federation (ECF) actively promotes the increased adoption of e-bikes not only as a sustainable and healthy means of transport and leisure, but as a viable alternative to trips by car." - Jill Warren, ECF co-CEO

"2019 has been a positive year for the EU Bicycle Industry thanks to the continuous boom of e-bikes as well as the increasing production of bicycle parts and accessories in Europe" - Erhard Büchel, CONEBI President

According to the latest market report from CONEBI, one of European Cyclists' Federation (ECF's) partners in the bicycle industry, more than 3 million electric bikes were sold in the EU, a substantial increase of 23% compared to the year before. Not just this but e-bike has also made seniors significantly more mobile in recent years.

The e-bike boom also created a strong positive effect on jobs. This is due to the fact that the production of pedal assist e-bikes in Europe was growing at a fast pace: from 2018 to 2019 the surge in units produced amounted to almost 60%, after growing already by 66% the year before. This increased the number of direct jobs in the EU in 2019 to a total of more than 60,000, with another 60,000 indirect jobs created upstream and downstream, the total increment was around 120,000 jobs. This increased the growth rate by a bunch: 14.4% job growth in comparison with 2018, and 32% in comparison with 2017.

MOVING FORWARD WITH ELECTRIC TWO WHEELERS

Reasons Electric Two Wheelers are the Future in India

1. Market domination

'Rome was not built in a day.' The idea of making India's road powered completely by electricity cannot happen overnight. With two wheelers having an 80% market share in 2020, it seems fitting to take first steps in this segment and slowly move on to the rest.

The context and usage of two wheelers in India only adds to its probability in succeeding and becoming a true viable and more sustainable alternative to existing ICE two wheelers.

2. Charging v/s fuel refilling

The current, conventional way or refuelling a vehicle involves going to the gas station and filling the fuel tank. This process takes less than 10 minutes and provides the user with an almost total range with almost no worries of where or when the tank could get empty since a petrol station is very easily accessible through the road network in India.

Electric two wheelers, unlike electric four wheelers, require a minimal amount of charging time. As seen in the Ather 450X, it can provide upto 15 kms of range with a 10 minute charge. This refuelling/recharging scenario is much closer to the conventional system, making it a more achievable first step in moving towards an electric future.

3. Catalyst to the charging network

The rise of any electric vehicle segment could incentivise the government and private corporations to invest in creating a charging network. This could potentially break the 'chicken and egg paradox' of whether EV's should come first or a charging network.

Difference Between Electric Two Wheelers and Four Wheelers

Comparison of the two latest EVs as of 2021, the Ather 450X (an electric scooter) and the Tata Nexon EV (an electric car) -

	Ather 450X	**Tata Nexon EV**
Range	116kms	312kms
Charging at home	0 to 80 in 3.5 hours 0 to 100 in 6 hours	0 to 80 in 8 hours 0 to 100 in 10 hours
Fast charging at station	0 to 100 in 1.25 hours	0 to 80 in 1 hour
Battery	2.61 kWh	30.2 kWh

Price (as of March, 2021)	₹1,60,000 (approx.)	₹14,00,000 (approx.)

We also realised that the usage expectations of a two wheeler is very different from that of a four wheeler, regardless of whether it's electric or uses an Internal Combustion Engine (ICE). In fact, given the current state of technology, people will hold ICE vehicles as the benchmark to evaluate EV performance. Below are some of the key differences.

Two Wheelers	**Four Wheelers**
Average distance travelled <50kms/day	Distance travelled can be >600kms/day
Used for commuting within a single city, typically used to run quick errands	Expected to be able to travel to other cities, go on road trips while providing leisure and comfort, and travel within a city as well
Since it does not leave the city, charging can happen overnight at home. Doesn't need to rely on charging infrastructure.	Since it is expected to travel far from home, overnight charging can't be the only method of charging. Required charging infrastructure at and on the way to the destination.
More value for money for the average consumer	Less value for money for the average consumer

SECONDARY RESEARCH | Perception of EVs

We wanted to understand what psychological reasons drove people to purchase EVS or what reasons they had to hold back from doing so. The papers we studied are listed below along with key learnings from each of them.

Customer Perception towards Electric two-wheeler Innovation

By Dr. J. G. Sankar and Mr. H. Kumar G. published in the Journal of Contemporary Issues in Business and Government Vol. 26, No. 2, 2020

This paper brought forward a reality we so far were kind of moving away from. It clearly states how 'people's perception towards the product (Electric two-wheelers) is negative,' but also makes sure to point out that 'support coming forward from the Central govt. and ever-increasing prices of petrol, sooner or later the electric bike industry is going to grow dramatically.'

The study conducted by these researchers in Chennai, Tamil Nadu reinforced the learnings we had in our more primitive study we conducted. People's purchase perception is primarily influenced by

charging time, followed by the number of models and then their environmental concern and the range of the vehicle.

It also gave us a perspective on electric bicycles and their growing popularity in the metropolitan cities in the south of India. Being accessible to a wider age group and can be used to travel long distances along with the rise of health concerns, it has scope to grow and become a phenomenon.

Electric Vehicle Adoption: Environmental enthusiast bias in discrete choice models

By B. Smith, D. Olaru, F. Jabeen, and S. Greaves

This paper informed us on the effect environmental enthusiasm can have on the market. A very minimal one. While it does help create hype for the movement which in turn does motivate users to make purchases, the main factors for making such purchases are more material and functional. EV Infrastructure is what would drive the market towards change which can be classified as a form of 'new technology,' according to the authors, since it requires a systemic change through multiple levels of planning.

Through research done, the paper reiterates how EVs are the future. The young generation already prefer purchasing biofuel vehicles over petroleum vehicles and soon, with the EVs becoming more accessible, the switch is inevitable.

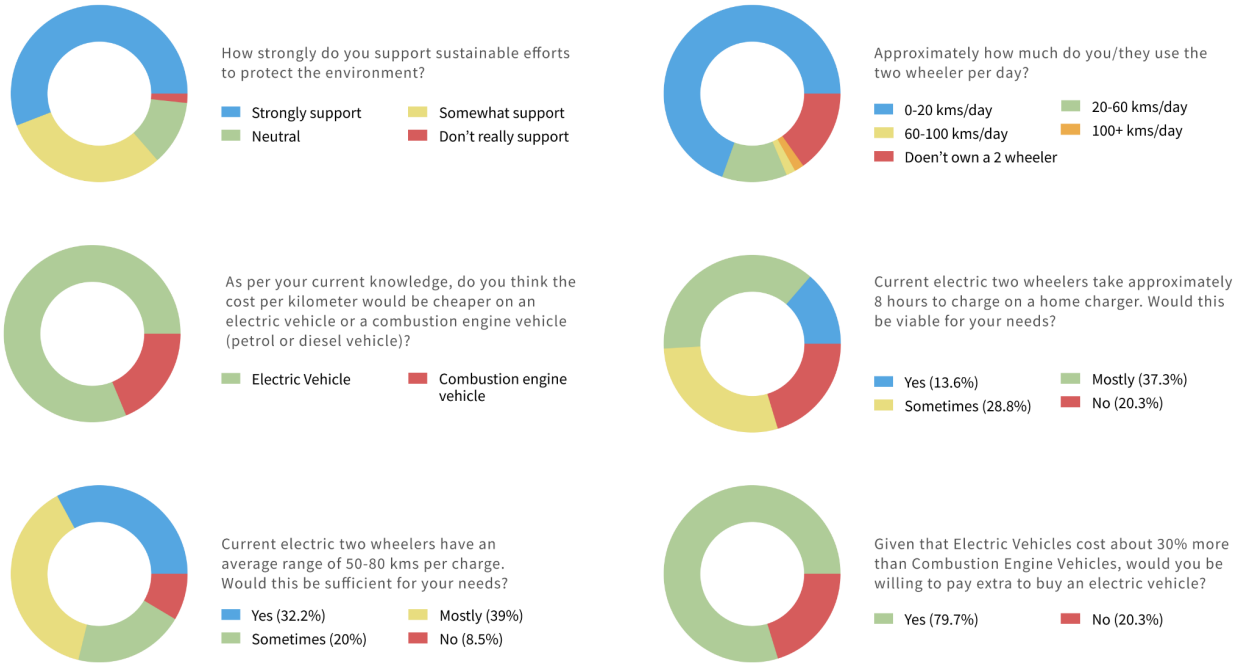
You are what you drive: Environmentalist and social innovator symbolism drives electric vehicle adoption intentions

By Lee V. White and Nicole D. Sintov

This paper provides a new perspective and the social effect EV adoption can have. Material wealth and choices are already seen as a judgement of lifestyle and character, especially with growing social media presence around the world. The use of EVs to show the character of environmental concern would be a trend that is predicted to grow significantly.

PRIMARY RESEARCH

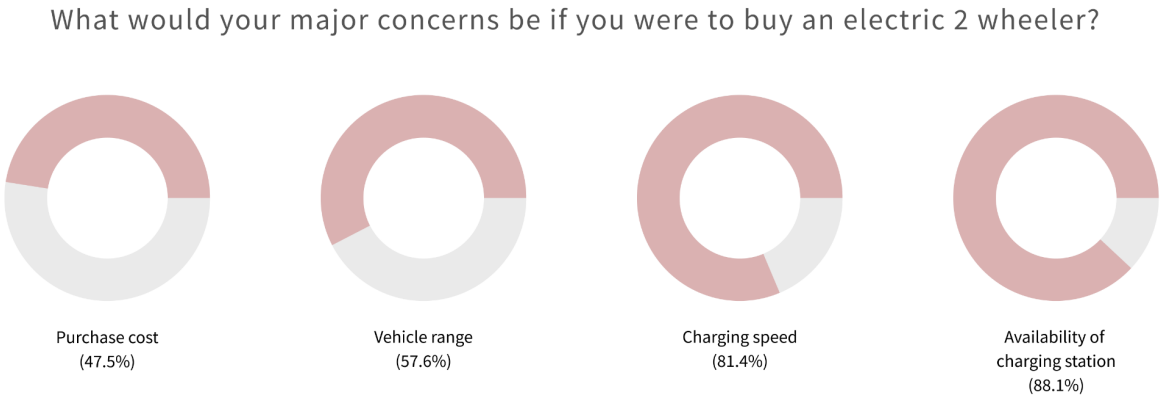
In an attempt to understand the perception of electric two wheelers, and electric vehicles in general, we designed an online questionnaire using google forms and sent it out to friends and relatives across social media. The responses helped us understand the ideas people have about the transition to electric vehicles and why they feel that way. The total responses were 59 and the age group was 16 to 25 year olds. The questions we asked are listed below. The results are shown below.



Our primary research findings

Key Insights

1. 47.5% of our respondents said their primary means of commute was a two wheeler
2. 86.4% of respondents said at least somewhat support sustainable efforts
3. 81.4% of respondents said that they drive less than 60km per day, which is under the average range of an electric two wheeler on a full charge
4. 72.2% of respondents agreed that electric two wheelers taking 8 hours to charge fully was mostly viable for their needs
5. Charging speed and availability were the top concerns among our respondents, both of which issues are minor if one uses a home charger and charges the EV overnight



Concerns among the respondents

SCENARIOS

We imagined scenarios in the future to help identify details in the project. This helped us address 'what if' questions from different perspectives, along with coming up with ideas. A few of the more distinct scenarios are listed below.

1. Overcrowded parking lot with cable clutter
2. Slums with multi storey houses
3. Teenager that does chores for the family and attends classes
4. Delivery-persons of supermarkets and restaurants
5. Using of E2W for reaching the last mile from public transport hubs
6. Middle class commuter who does spontaneous short trips
7. People who carry heavy items on a two wheeler
8. Online delivery services like Zomato that use E2W throughout the day

PROBLEM IDENTIFICATION

Our project area was unique in the sense that we were mapping and designing for a system that we anticipate and predict for in the future. By studying trends in other fields, we were able to get a vague idea of what the future would hold. Moving forward it was important to get to the details and therefore we chose to frame as many 'what if' questions as possible to challenge ourselves to come up with possible solutions to the problems we anticipate. A visual summary is shown below.

Addressing all the 'What ifs'

What if...

1. There is a power cut?
2. There is no charging station nearby?
3. The charging cable is on the other side of the charging port?
4. The user cannot park the vehicle close to their residence; how will they charge it?
5. Petrol becomes more expensive and people can't afford EVs?
6. A user gets locked out of a 'smart vehicle?'
7. A user reaches a charging station but it is fully occupied?
8. A user wants to make a long journey ASAP?
9. A user cannot afford a battery after its life has deteriorated?
10. Third-party businesses are not willing to invest in EV chargers?
11. Users are overly cautious about overcharging and battery health?
12. The destination is farther than the vehicle's range?
13. OEMs are not willing to invest in EVs because of competing sales from ICEV counterparts?
14. The power of EVs is insufficient for certain people's needs?
15. People don't believe that EVs are more sustainable than ICEVs?
16. A user cannot remember if they have plugged in their EV?
17. A user forgets that the EV is plugged in and rides off?
18. Used EVs are too risky to buy?
19. Climate conditions affect battery life and range isn't as estimated?
20. Battery longevity isn't as advertised?
21. Chargers at a charging station aren't compatible with a user's EV?

22. A user wakes up and realizes there is no charge in their EV?
23. There is no authorized service station nearby?
24. The battery gets damaged in an accident?
25. A certain area has non renewable electricity supply?

Key Insights

We came to realise how different the system around EVs can grow compared to the existing refuelling system. Electricity is much more accessible than petrol or oil which require pipelines or tankers to deliver. This opens the door to individuals to set up charging stations, reducing the dependence on oil companies and taking away the power they hold in the market. The same idea would incentivise leaders in that space like Shell, Indian Oil and Bharat Petroleum to stay ahead of the market and invest in charging infrastructure before they are deemed useless.

Another scenario that helped us realise the different economic groups we will need to take into consideration, for example, people living in unorganised settlements where not each house has access to a path or road where a two wheeler can fit through. This will make it very difficult to rely on home charging. We thought of ideas ranging from battery renting services, to allowing users to submit applications for companies to set up semi-private charging stations in localities with such issues.

Looking at India as a whole, we also need to understand everyone's circumstances. Not all people have access to reliable electricity supply. If EVs were to become the main form of transportation, it would probably give rise to private companies in this same space who could leverage their guarantee of electricity in areas that face such challenges.

Other business opportunities such as certification of battery health to in turn help increase confidence in second hand EVs would probably be a must since the Indian automobile market depends heavily on second-hand dealers of vehicles to reach the masses. Service and assistance on the road if batteries run out of charge, along with battery rental shops that would always have charged up batteries would be a lifesaver in cases where people have unplanned trips.

Brainstorming

Addressing all the 'What if' questions helped us identify issues that could come up with the EV transition. We have listed the important ones below.

1. Parking lots will be cluttered with wires if everyone gets EVs
2. Public charging stations might not be trustworthy
3. Shared residential parkings will run out of chargers for all EVs to be parked at once

4. Since batteries are very heavy (10-20kgs), how will the ergonomics of the EV be to afford regular replacement?
5. Batteries tend to lose charge when idle for long periods (standby time)
6. Regular overcharging will tend to degrade battery health
7. Battery recycling plants aren't localised and are very rare
8. Existing garage workers need new technical knowledge
9. Automobile enthusiasts will resist switching to auto transmission
10. Buying used vehicles will be risky since battery health cannot be guaranteed
11. A lot of places are prone to power cuts
12. Batteries will discharge quicker in very hot or very cold climates

Our map of all the problems and their possible solutions

NARROWING DOWN

The problems we identified were all over the place. We realised we needed to narrow down and dive deeper into a specific area rather than cover everything at a surface level. We went through all the problems we identified and ideas we came up with to make a list with areas we would be interested in working on.

- Haptics and sound simulation for MT enthusiasts.
- Battery renting and swapping.

- System to increase adoption of public chargers by third party businesses and private investors.
- Book and pre-booking system for public chargers.
- Battery health and charge monitoring system.
- Making home charging convenient and easy to use.
- Installation and repair of Home chargers.
- Environment design for public chargers.
- System for battery buyback, exchange, and recycling.
- Battery changing mechanism with minimum obstruction.
- Removable battery ergonomics for battery swapping.
- Rental services for last mile connectivity. Reinforces public transport use.
- Incentives to increase EV transition.
- Remote EV monitoring and control.
- Regulation in public spaces for EV transitions.
- Redesigning public infrastructure for an EV era.

Evaluation

After listing out all these ideas, we needed to evaluate them to make sure we selected one that we can work with. We used the real-win-worth method to do this. Each of the ideas would be scored a 1, 3, or 9 on the three parameters; how realistic the idea is, do we think the idea is winnable, and will the outcome be worth the effort.

Idea	**Real**	**Win**	**Worth**	**Total**
Haptics and sound simulation of MT for enthusiasts	1	9	1	11
Making Home Charging convenient and easy to use	9	3	9	**21**
Installation and repair of Home chargers	9	3	9	**21**
Removable battery ergonomics for battery swapping	9	3	3	15
System for battery buyback, exchange and recycling	3	1	3	7
Incentives to increase EV transition	9	1	3	13
Public chargers business workflow (space design)	9	9	3	**21**
Redesigning infrastructure for an EV era	3	3	3	9
EV mechanism for minimum obstruction	3	9	3	15

Battery renting and swapping	9	3	3	15

The three ideas that came out on top had one thing in common. They were all related to charging infrastructure. We still felt we could narrow down further and finally ended up public charging infrastructure as our final area. We put together a design objective to keep us on track through the rest of our project.

"To create a future proof and complete EV two wheeler public charging system."

UNDERSTANDING CHARGERS

Before we went forward, we needed to understand all the types of chargers and charging connectors that are there. According to the Indian government, there are three levels of charging speed that are present.

1. AC Regular Charging

An AC regular charger is what is usually installed where time is not a high concern. This includes spaces like home and offices where users would stay at the location for a long time, allowing the vehicle to charge up.

The power rating is usually limited to 2.5kW to 3kW. The range provided per hour charged is relatively low of 5 miles per hour, but usually gets the job done for the context. This type of charger juices up an electric 4 wheeler to 80% in 12-16 hours.

2. AC Fast Charging

This type of charging is relatively faster. They are relatively cheaper to DC chargers but still provide a decently fast alternative. These chargers are appropriate for homeowners who have high use or in public spaces within city limits.

The power rating ranges from 7kW to 22kW. The range provided per hour is 12 to 25 miles depending on the rate of charging. This charger would take an electric 4 wheeler upto 80% in 3-4 hours.

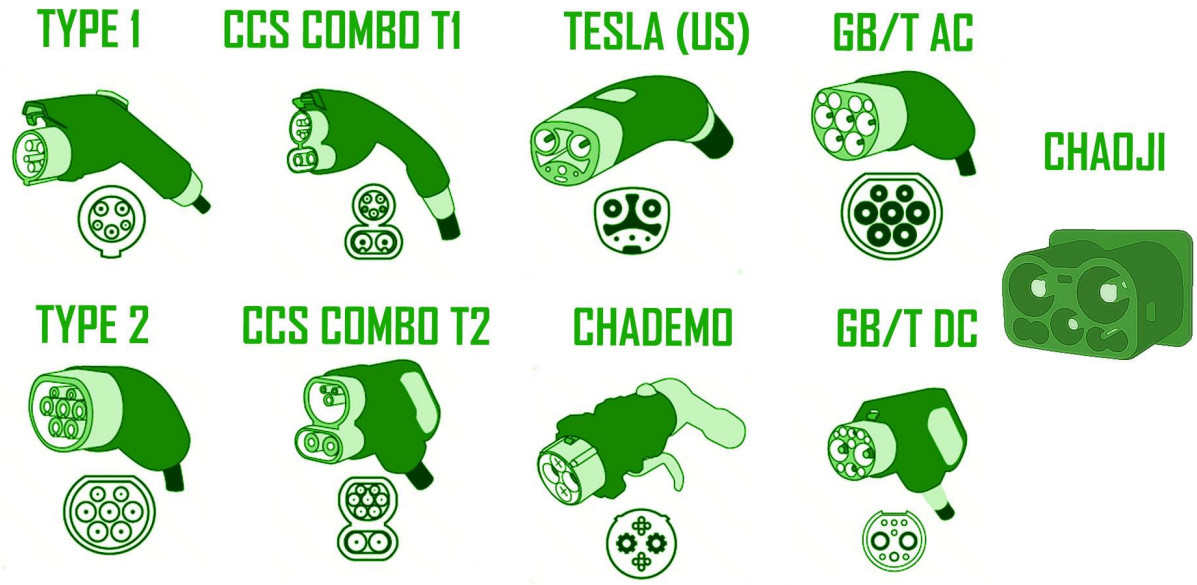
3. DC Charging

This is the fastest type of charging available in the market right now. Most vehicles today do come with DC compatible charging ports making it a possible alternative where required. Since the cost to set these up are relatively high, they are limited to where they

are needed, such as highway stations where users need maximum range in the least amount of time.

The power rating of DC chargers can start as low as 10kW and go as high as 1000kW. They provide a range of 100 miles or more within an hour of charge and can juice up an electric 4 wheeler to 80% in less than 30 minutes.

In the current global environment, there are multiple types of charging connectors available as well. Within the two wheeler segment in India itself, each vehicle has its own proprietary connector. It would be unnecessary to detail out each model. We were able to locate a few standards of charging connectors that is summarised in the infographic below.



Types of connectors on the market (Source: Interchargers)

SYSTEM IDEATION

The public charging system was still a vast space. We started to come up with possible guidelines informed by our research and discussions. We then divided them up based on subsystems they were part of. All of the initial guidelines we came up with are listed below.

Charging Station Design

- All parking spaces with EV charging features must be **strictly reserved for EVs only.** An increase in these spaces (especially in high traffic areas) will help create awareness of EVs and possibly become a factor for its purchase.
- Parking space organisation such that a single EV charger can reach multiple parking spaces.
    - With the help of manual management (valet persons), charging can be queued and efficiency of charger optimised.
    - An algorithm could be developed to execute the installation of such stations based on space available and configurations.
- With limited parking spots inside the city and the constant demand throughout the day in the city centre, introduction of facilities like **valet charging services** or **multi-story EV car parks** would be effective to cater to high traffic and demand.
- Rules for places that don't have a proper parking, chargers should only support E2Ws or else people wanting to park EVs in the correct orientation will cause a commotion of the road.
    - Make there is sufficient area for a E4W to park and go back without disturbing the road traffic before setting up charging spots and other facilities
    - If there isn't sufficient area to ensure well organized charging, demarcate a charging space using markers beforehand, and make sure it complies with the local transport rules. Give preference to fast chargers.
- Charging Stations should be located in **well lit areas and preferably slightly populated.** This will make users feel safe in leaving their EV to charge while they use the facilities.
- The **height of a charger** should be such that it is visible even if another vehicle is parked in front of it; one should be able to know the total number and location of all chargers in a parking space easily.
- Charging Stations should have an **emergency electricity supply**. This will make sure that a few dozen vehicles will be able to charge even after an electric power cut.
- Encourage people to put the charger back in place after the charging is done. Cable management should be easy enough for people to keep it such that it is not lying on the ground.

User Lifestyle

- If a vehicle is used for **daily commute**, users can pick an E2W since charging can happen at home and there is no need to rely on public infrastructure.
- If daily distance travelled is **less than 60kms** (average E2W range) for daily commute, users would be **more likely to use home charger**s that would top up the battery overnight. Can use slow chargers as well as fast chargers.
- If daily distance travelled is **more than 60kms** (average E2W range) for daily commute, users will be dependent on **charging during the day** and would then have preference for fast chargers. Look for fast chargers in your locality or at your workplace.

- With increase in home charger and E2W, **electricity usage during the night** will increase massively for the charge of electric vehicles. This could be handled by directing power towards residential zones of the city from the industrial or office areas, catering to the growing user base naturally.
- Indian public in general would be skeptical about leaving vehicles to charge in public. Some form of safety features like **locking mechanisms** or a **security service** while being charged would be highly effective to gain trust.

Charging Connector and Speed

- Type 1 chargers (with relatively slower speed) would be common for home chargers. Type 2 and Type 3 chargers can be sold to third party businesses as a **commodity / features** to attract customers as well.
- **Plugging in** your EV to charge will always be an option. This would be enough for casual users who can work within the max range of the vehicle.
    - Type 2 and Type 3 chargers will only increase convenience with speed.
- Development of Type 2 and Type 3 public charging stations is recommended as it will also attract third party business to be set up in its vicinity. **Real estate value** around fast charging stations is likely to increase.
- Any **private investor can set up public charging stations** (level 2 or level 3) as a new business venture.
    - Would be recommended to set up smart chargers to reduce maintenance cost of attenders by allowing them to be fully automated.
- Users would not mind **Type 1 chargers at their homes** as charging would most probably happen through the night after which they would be topped up for the day. Not networked (or dumb) chargers would make cost even lesser for private chargers.
- **Battery Swapping** would be ideal for users who use the EVs throughout the day and have minimal time to plug into charging outlets. It would also be a much quicker task than to wait to top up using a plug in charger.
- For users that travel more than 60kms per day (average E2W range), such as delivery agents, **battery swapping subscription** would work out faster, cheaper and more convenient
    - Suppose a person has subscribed to the battery swapping subscription then he'll not have to replace the battery after 4-5 years, but for this the cost of swapping batteries can be slightly higher then recharging the dedicated one.
    - A user can subscribe to this while buying a vehicle so they don't have to spend extra money on the dedicated battery.
    - If one has already bought an EV with a battery and wants to switch to a swapping subscription then your dedicated battery would be returned to the company and based on its condition the user would be discounted for the subscription.

Station Locations

- Public charging at all **transit hubs** i.e metro stations, central bus stations should have type2 or higher chargers available.
    - Possibility to make charging at these stations free will help stimulate the use of public transport for longer travel as well.
    - Will encourage the use of EVs for last mile connectivity
- Users should have the ability to **apply for a new charging station** location based on demand. This would be helpful for users who do not have a private parking space or have more demand for chargers in some neighbourhoods.
- Public Charging Stations should **not be more than 1.5kms** away from any area inside the city. This would be especially important for lesser developed areas of the city (slums, unorganised housing) where home chargers would be very rare.
- Charging Stations should be located at **main roads or hotspots** (crossroads) to increase visibility and accessibility. People would be less likely to drive into smaller lanes to access a service.
    - This would also make sure that the area could handle the increased traffic of vehicles due to the charging station
    - If the parking is near a commercial area then people will be able to spend their time doing chores while their vehicle is charging

User Interactions

- Charging stations would be accessible to a wider range of the Indian public by having human assistants or **attendants to help first time users,** disabled or senior citizens in charging and making the transaction.
- **Visual stimulus for connection made** and charging has initiated. Will help users avoid any misconnections.
- **Prepaid payment systems** for public chargers would allow for faster movement of traffic and completely automated transactions. For rare customers who are unable to use online payment to top up their accounts, can pay cash to partner vendors and top up their account (similar to prepaid cell phones).
    - Possibility of automated vending systems to transfer cash to credit (is already used in ticketing stations and have greater awareness)
- **Separate visual identities for types of chargers** at charging stations to allow users to recognise compatibility. Will also be recognisable from distances.
- People may be unaware of power output from different outlets. To solve this, software on the EV (or app) can **show the estimated time to full charge** based on power input to make users aware of charging speed.

Charging Accessories

- The introduction of **adapters** to allow charging across charging stations with different hardware specifications.
- In case the range requirement is very high or the user needs to make spontaneous long trips, **portable battery banks** can be installed inside the boot space or at the back so that the user can extend battery life at the cost of seating space.
- With the help of **adapters,** all EV chargers can be made compatible for the range of EV plugs in the market. This will increase the **number** of compatible chargers for the users.

CREATING A SYSTEM

It was very clear after this that all of these subsystems require intervention, and they were all interdependent on each other. We referenced scenarios to anticipate problems from different stakeholders and finalised on solutions for individual systems.

1. Locations of Chargers

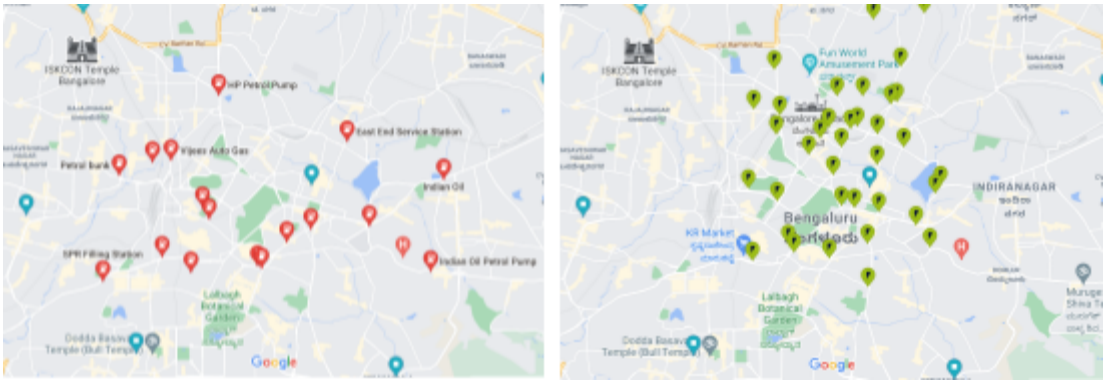
A realisation we had early in the ideation process was charging stations do not require massive set up costs. With access to electricity as the only requirement along with enough space, it makes it much easier to set up, compared to fuel stations who require pipelines or fuel trucks to supply it.

But while fuel stations refuel ICEVs relatively quickly, EV chargers would require vehicles to be parked for some time. This would mean more space requirements.

For the system we planned to propose, we knew it would be necessary to implement charging stations in existing businesses first for two reasons.

- This would help increase visibility of EV chargers and reduce range anxiety.
- Since EVs are still at an early stage of adoption, investors would not be willing to set up massive stations solely for EV charging, especially within the city limits.

With focus on 2 wheeler vehicles, and they being primarily used for smaller commutes within the city, it was important we come up with solutions to where they would be charged in public spaces. With most small and big businesses having parking space for 2 wheelers either on or outside their premises made them ideal locations to set up charging stations spread evenly throughout large cities in India.



Existing fuel stations (L) v/s Predicted EV Charging Stations (R)

From the business point of view, we predict it to become a feature of sorts, where customers would prefer choosing stores, pharmacies, or supermarkets with charging stations over those without. It would bring them benefit along with contributing to the larger EV public charging system.

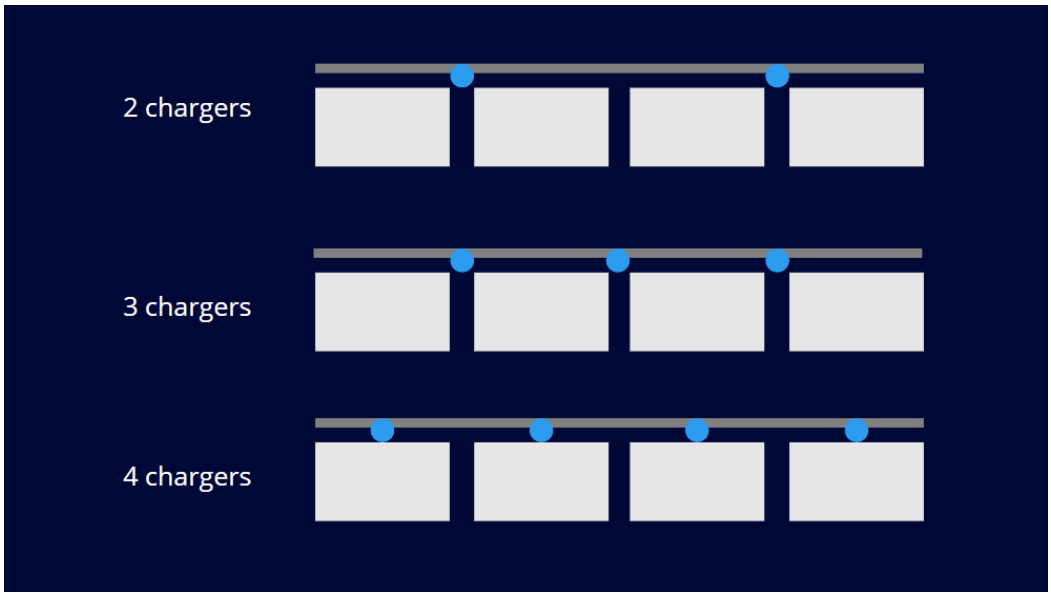
2. Parking Space Organisation

We found this to be a vital area after studying existing parking structures, especially for 2 wheelers. They are very disorganised and at most places very random and do not cater to convenience of entering and exiting the area.

Disorganised two wheeler parking spaces

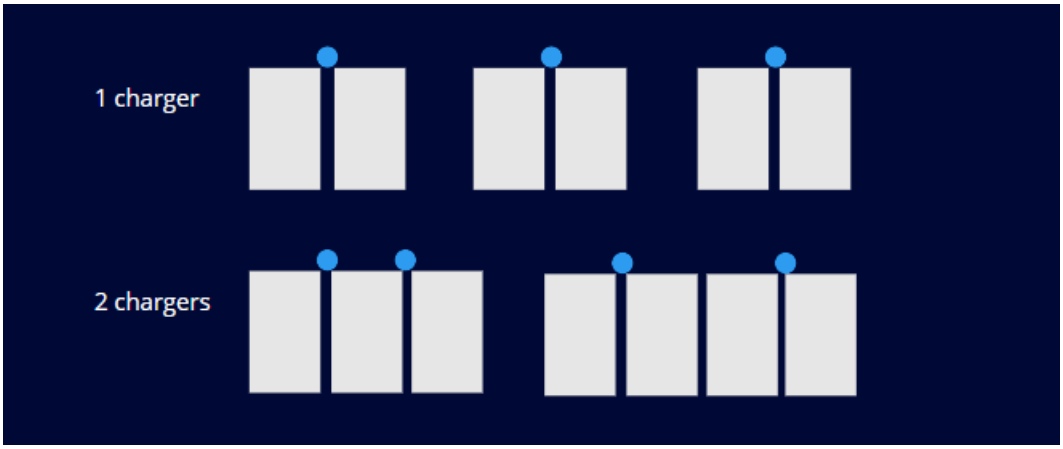
With EV chargers in place, it would be more important to understand how to organise parking since chargers would need to be installed. We came up with a few guidelines to follow while setting up an EV charging space.

- In case of road side parallel parking, EV chargers would need to be placed on the side of the 2 wheeler. Based on the area available and context, one would need to ensure the placement of chargers does not obstruct pedestrian pathways and/or vehicular traffic.



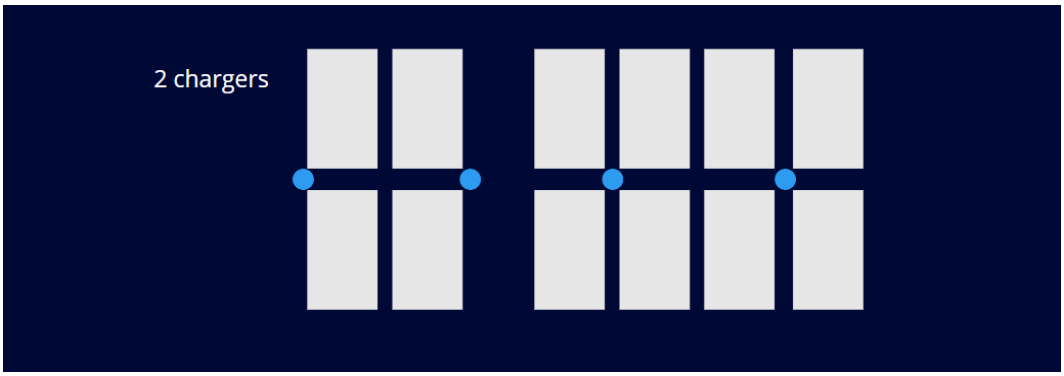
Parallel Parking Layout

- In cases of single row perpendicular parking, EV chargers would be placed between two parking spots, on any one side. However, while installing, one would need to make sure it does not obstruct users from getting on and off their 2 wheeler.



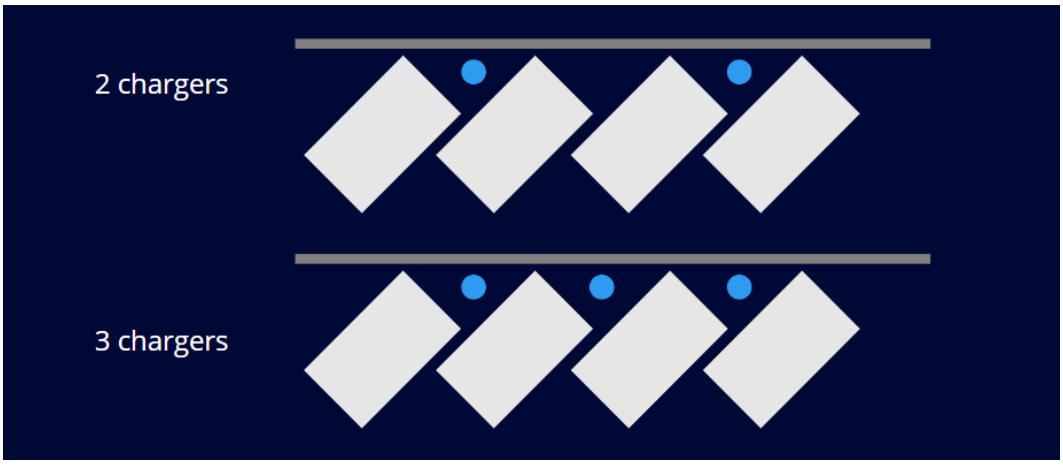
Single Row Perpendicular Parking

- In cases of double row perpendicular parking, EV chargers would be placed at the note at the centre of four parking spots. This would allow all 4 spots to have access to the charger in case other spots are taken up by ICEV vehicles.



Double Row Perpendicular Parking

- In case of angular parking, EV chargers would be placed at the small triangular spaces in front of the parking spots.



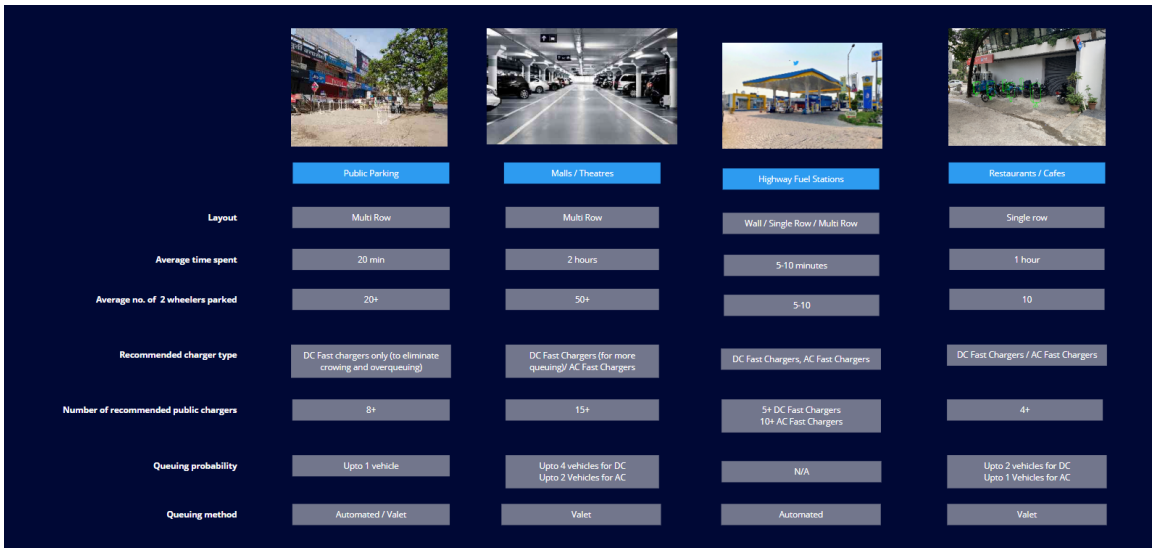
Angular Parking

In all of these organisations, the number of chargers installed would depend on the traffic the charging station is expecting. For example, chargers in the city centre would require a ratio between charger to parking space of 1:1 while chargers in malls or stadiums would ideally have a one charger able to reach up to 4 parking spots in case other spots are occupied.

We divided the types of areas into two categories. Low demand scenarios would include small businesses that would mostly install EV chargers as a feature rather than an important commodity.

Low Demand Scenarios

The second category was high demand scenarios. This would include existing fuel stations where vehicles already stop to refuel and larger parking spaces like mall parking lots or public parking structures.

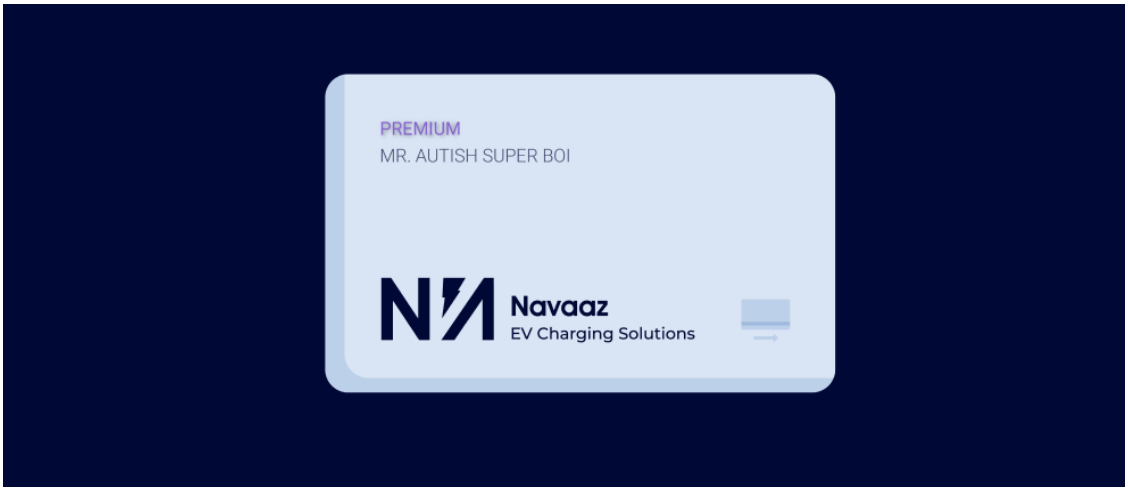


High Demand Scenarios

3. Payment and Queuing System

With the timeline to recharge an EV already being comparatively higher to refueling and ICEV, we recognised payment systems as important to reduce any extra delay. While many existing chargers claim to be ‘smart’, customers are unable to use the feature because of proprietary or underdeveloped systems.

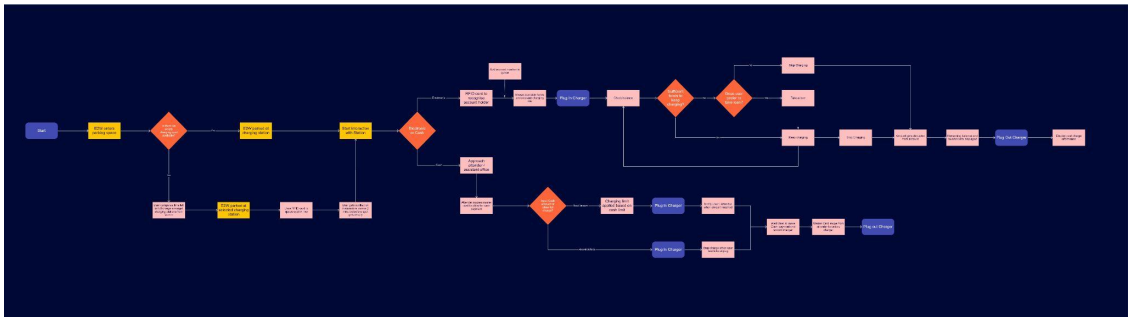
We came up with a system that would help users pay online with added features like queuing their vehicle at charging stations in case of heavy traffic. The system would work based on NFC technology present on everyone's mobile phones today or RFID cards that they could scan on the charger to register their account. An attender with a master card would initiate this in case of an unregistered customer or a cash based transaction.



An illustration of an RFID card for each registered user

Once plugged in, the user can go about their work in the vicinity while keeping track of the status through an app on their mobile. Users would need to be registered for this feature. Once the recharge is complete, money would be deducted from the account holder's wallet and incase of the cash transaction, a second swipe would be required from the attender to confirm received payment.

To study this system and lay it down visually, we came up with a user flow diagram. This helped us understand how interconnected the system was and work on detailing out smaller solutions that may be required.



User Flow Diagram for the Payment System

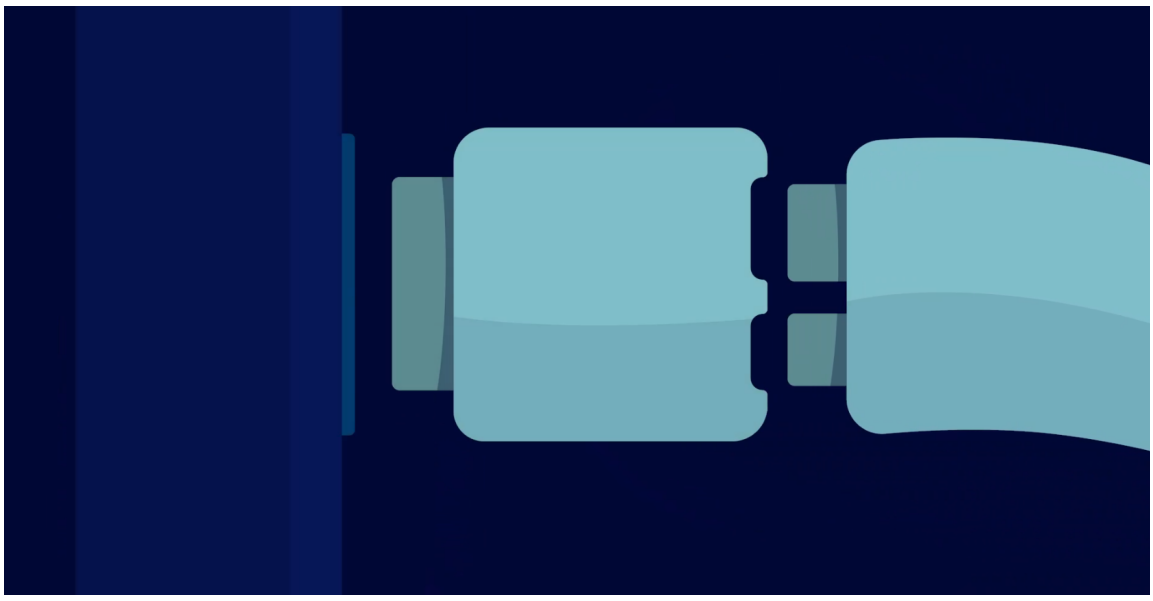
In the case that a customer reaches a location and finds all chargers occupied, they can queue their vehicle at any charger, or with a valet if there is one, by scanning their account on the charger. They would then be notified when the charger gets vacant, or if the valet plugs it in, and can keep track of it through a mobile application.

4. Compatibility and Security of chargers

All of these systems rested on the assumption that the charger would actually work and connect perfectly into the customers' vehicle. We did identify an issue of multiple unique charging connectors in the electric 2 wheeler world. There is some standardisation in the electric 4 wheeler industry but still, the problem exists there as well.

What the current solution is requires customers to carry their own cable for their vehicle, and plug it into a 3 point outlet at the charging station. While this makes it a lot easier for manufacturers to deal with the problem, it causes massive inconvenience for customers, security risks and chances of wear and tear.

We imagine a solution where adaptors are placed at the charger in case the standard (whatever that may come to be in the future) does not fit. A cable would be connected to the charger so users wouldn't need to carry their own.



An illustration of an adapter

There are also smaller security features that may be obvious but we thought we should at least mention. We expect verification to be required every time the charger is unplugged from either port, secure locking of the connector when not in use as well as unibody

designs of chargers to counter possibilities of tampering ,something we felt was important to gain trust in the Indian context.

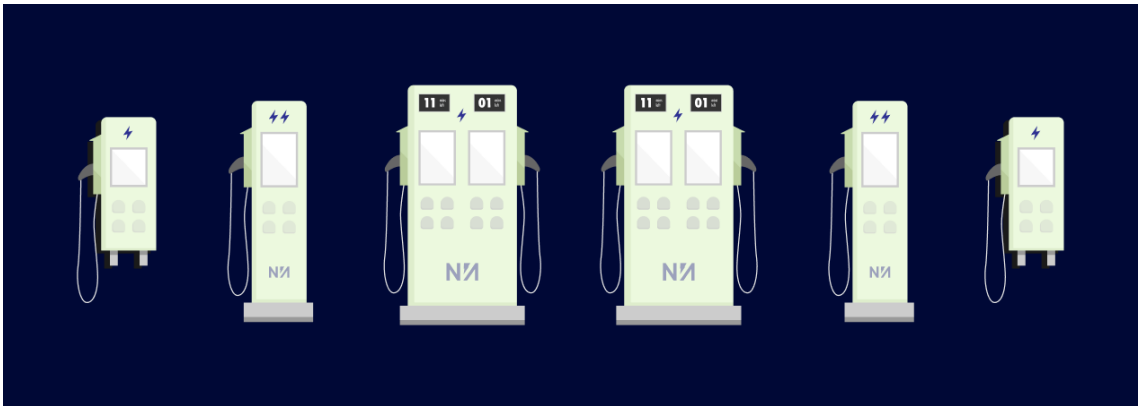
THE FINAL PITCH

Navaaz EV Charging Solutions Branding

We decided that the best plan of action for us would be to create a service that will help individuals and organisations set up EV charging stations catered and optimised specifically to their needs. The broad vision of the company would be to help the Indian two wheeler market to transition to an electric one. It would be a business to business (B2B) model where we would design chargers, the charging space and work on implementing the activities that follow.

1. Design and Manufacturing

   We would design a range of charging stations that would cater to clients in different contexts. From high traffic malls, to small businesses, our chargers would be accessible, convenient and profitable. We came up with a few barebone designs for different chargers in different contexts as well.

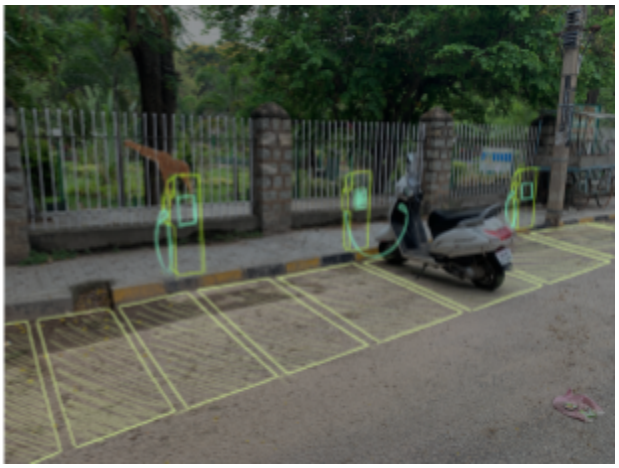


An illustration of types of chargers

2. Consultation and Installation

When a client, who may be a small business owner or a large corporation, approaches us, we would study and understand their needs first. By understanding the expected traffic, the expected time of stay and the group of customers that would visit, we would recommend solutions.

We would help organise the parking space, advise them on the number of chargers that would be optimal to maximise profits and aid the client in selecting the right chargers. We added a few illustrations to existing parking structures to show how such chargers would be installed based on our guidelines.



Quick sketches for visualising charging spaces

3. Providing a Complete User Experience

After the charging station is completely set up, the software for the payments and queuing system will be maintained by us. Since our vision included numerous small businesses to invest in chargers, we would monitor, maintain and update the software for payments and tracking and wherever required, queuing as well.

SOME OF OUR SOLUTIONS

We needed to show how our solutions would pan out in reality. Would it work for different scenarios? We chose to detail out a few of them to show our involvement as a business. We have also visualised the layout for each of them to help understand it better.

Highway

Illustration of a highway EV charging station

Fuel stations are already very common on such roads, and for a very valid reason too. We attempted to visualise what a charging station would look like in such a scenario. There would certainly be one or more businesses attached to the charging space to allow customers to spend their time refreshing or re-energising themselves while their vehicle gets topped up.

There would be multiple chargers for 2 wheelers and 4 wheelers to cater to high traffic times. The recommended type of charging would be DC fast chargers to not keep customers **waiting** for their vehicle to charge.

Office Structures

Illustration of EV Charging at Offices (Left), Supermarkets (Middle) and Restaurants (Right)

The set up of chargers would be very different around a small office. A minimum number of chargers would be installed based on the number of workers, and if there are more requests, they can be added in. The type of charging would certainly be much slower. This would keep the costs down as well as provide a full charge by the time they finish their work at the office.

Supermarkets

Supermarkets, or any other small businesses, would be placed within the city so the need for charging may not be as dire since customers would probably live close by. However, we do imagine few chargers to still be available with AC fast charging at a minimum if DC charging is not affordable.

Restaurants

Customers who visit such businesses would have a minimum stay time of 1.5 hours. This would make DC charging unnecessary. While regular AC charging would give them enough juice to get back home, we would recommend clients to install AC fast charging if affordable.

Mall Parking

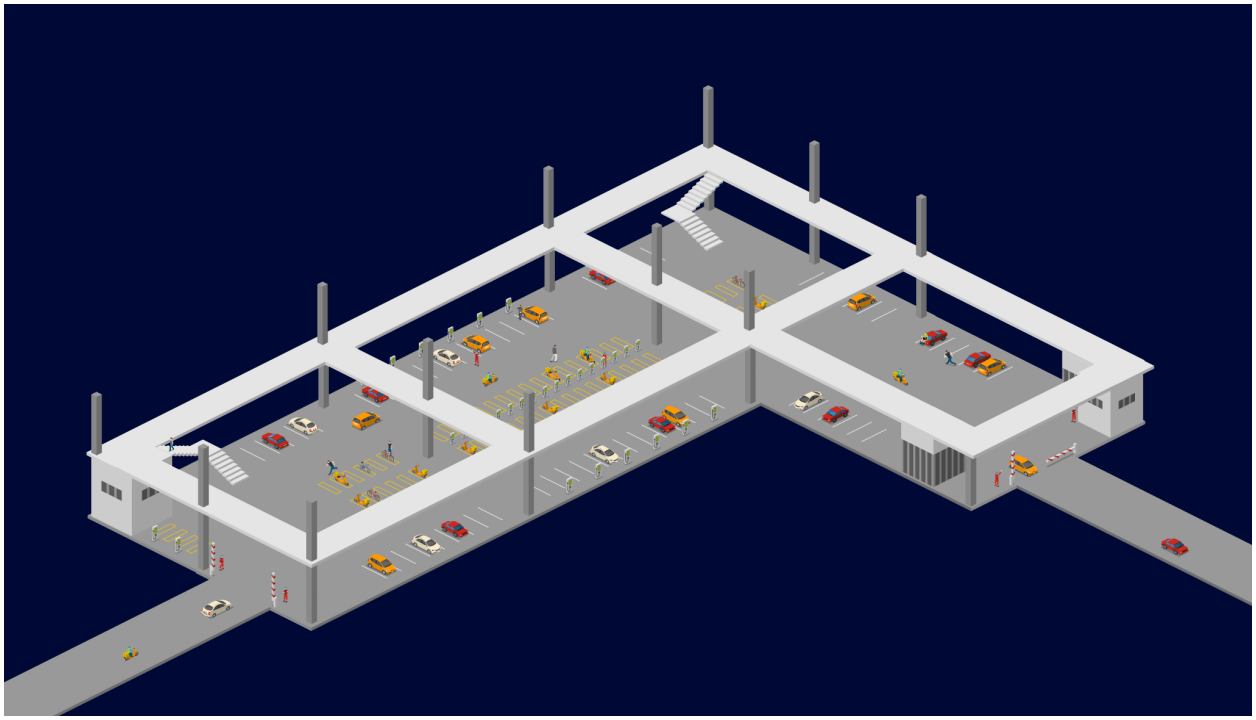


Illustration of an underground EV charging station at malls/theatres

Mall parking, or any large public parking like stadiums, would need a large parking capacity. However, the speed is not a priority for these users. Such areas would still be within city limits so users would only need enough juice to get back home and that can easily be provided with regular AC charging, since they would spend a minimum of 2 hours at such destinations.

To cater to an overflow of traffic, chargers installed at this destination would display the time left to a full charge. This would allow valets, or users themselves, to queue their vehicle and plug it in as soon as a space is available.

CONCLUSION

The in depth study of the automobile industry along with the future of electric vehicles was an eye opener of the scope of this area. We were initially very uncertain as to how we could make change in a system as massive as this, but as the weeks progressed, we found ourselves on a path with an impactful outcome.

The work we have done, in planning and organisation, in understanding the mindset of the Indian people, and diving deep into technological nuances of EV charging has greatly benefited each one of us. And we are very grateful to our mentors, Prof. Ravi Poovaiah, Prof. Ajanta Sen, and Prof. Pramod Khambate, for guiding us through this incredible journey.

REFERENCES

Deploying Electric vehicles: Gujarat's Low-Carbon Development Pathway
https://www.jstor.org/stable/pdf/resrep26070.8.pdf?ab_segments=0%2Fbasic_search_gsv2%2Fcontrol&refreqid=fastly-default%3Adfc924cf11cb49f6ddc25c432c1a5a15

Challenges for India for Achieving Target of Electric Buses and Cars by 2030
http://ripublication.com/ijeet19/ijeetv9n1_03.pdf

India's Automotive Future looks Electric
https://www.basf.com/in/en/who-we-are/sustainability/future-perfect/stories/India-s-automotive-future-looks-electric.html

Indian Automobile Market Overview
https://www.ibef.org/download/Automobiles-November-2020.pdf

The math behind India's Electric Vehicle Charging Infrastructure
https://inc42.com/features/the-math-behind-indias-electric-vehicle-charging-infrastructure/#:~:text=Considering%20an%20average%20of%2015,battery%20size%20of%2030%20kWh.

National Electric Mobility Mission Plan 2020
https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf

Implementation of National Electric Mobility Mission Plan
https://pib.gov.in/newsite/PrintRelease.aspx?relid=191337

Government Plans to set up Infrastructure for 69000 EV charging stations across India
https://inc42.com/buzz/govt-plans-to-set-up-69000-ev-charging-stations-across-india/

Zero Emission Vehicles (ZEVs): Towards a Policy Framework
https://niti.gov.in/writereaddata/files/document_publication/EV_report.pdf

India's Electric Mobility Transformation
http://niti.gov.in/writereaddata/files/document_publication/NITI-RMI-Report.pdf

Why China is beating the US in Electric Vehicles
https://www.youtube.com/watch?v=q5GGCVIEYts

The 2020 Bicycle Industry & Market Profile with 2019 figures- Confederation of the European Bicycle Industry

https://mailchi.mp/3fc2dd1690af/the-2020-conebi-bicycle-industry-market-profile-is-now-available?e=d9b849ffde

Booming of European e-bike market - European Cyclists' Federation (ECF's)
https://ecf.com/news-and-events/news/european-e-bike-market-booming-latest-industry-figures-show-%E2%80%93-and-there

Customer perception towards electric two-wheeler innovation
https://cibg.org.au/article_7676_81e3d9312e8c7d126a5a66973aed8aba.pdf

Electric Vehicle Adoption: Environmental enthusiast bias in discrete choice models
https://www.sciencedirect.com/science/article/abs/pii/S1361920915302297

You are what you drive: Environmentalist and social innovator symbolism drives electric vehicle adoption intentions
https://www.sciencedirect.com/science/article/abs/pii/S0965856415303153

Government of India: Standardization of Protocol for Charging Infrastructure
https://dhi.nic.in/writereaddata/UploadFile/Standardization%20of%20protocol.pdf

Bharat EV Specifications for AC and DC charging
https://www.pluginindia.com/blogs/bharat-ev-specifications-for-ac-and-dc-charging-everything-you-need-to-know

Masstech solo charging station
https://www.pluginindia.com/masstechsolo.html

Ather 450 e-Scooter: The complete charging guide
https://www.emobilitysimplified.com/2020/07/Ather-escooter-450-complete-charging-guide.html

Types and Specifications of EV Charging Cables Used in Electric Cars
https://www.researchdive.com/blog/choosing-the-right-ev-charging-cable-for-your-electric-car

How Much Will Electric Vehicle Charging Cost You In India?
https://indianauto.com/tips/how-much-will-electric-vehicle-charging-cost-you-in-india-nid4904

Technical & Design Guidelines For EV Charging Infrastructure — #CleanTechnica Report
https://cleantechnica.com/2019/02/16/technical-design-guidelines-for-ev-charging-infrastructure-cleantechnica-report/

Siting and Design Guidelines for electric vehicle supply equipment
https://portal.ct.gov/-/media/DEEP/air/mobile/EVConnecticut/EVSitingandDesignGuidelinespdf.pdf