

E-HUB

The Charging Station Of The Future.

Researching the System of E-Hub
&
Developing a User Interface for the Charging Infrastructure

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Developing a User Interface for the Charging
Infrastructure

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Preface

I am glad I got to be a part of the E-Hub project thanks to **Maarten Bonnema** and **Sjoerd Moorman**. I would also like to thank them for guiding me throughout the project and providing crucial feedback on my work.

I have been given a great opportunity to work along side other students to start on the conceptual development stage. I was excited for the project as the focus was in the field of green energy and it came with a challenge; changing the structure of the current charging stations and increasing the uptake of electric vehicle by developing the E-Hub. The entire topic attracted me and I was delighted to be able to work on it.

It was an interesting time living in The Hague and going to the Technical University of Delft to work on this project. Interesting people were met during this period and the dynamic of the group was really enjoyable. Thus I would like to thank the **E-Hub team** for the great experience during the project.

I would also like to thank **Julia Garde** for providing expertise on the user interface development.

All in all, the project offered a great learning experience for me. I hope that this paper reflects my skills as an Industrial Designer and that I have contributed something for future projects to use and further develop. I am looking forward to the moment when the E-Hub is implemented into society.

Glossary

E-Hub;	electrical charging station of the future.
Architecture;	system structure consisting of components.
Component;	essential parts to the system (building blocks)
Interface;	the way a component interacts with another component of the system.
User Interface;	the way the user interacts with a component and the system. A user interface must allow the user to effectively operate and control the system from the human end. The system will feed the user with the necessary information needed for the user to make the right and wanted decision. The user interface should help the user in the decision-making process.
Target Group;	users of the E-Hub, mainly owners of electric vehicles.
Market Players;	companies who have a position in the market / competitors.

Abstract in Dutch

De E-Hub is gericht om 'het laadstation van de toekomst' te worden. De opname van elektrische auto neemt langzaam toe, maar de perceptie van de technologie is nog terughoudend bij het grote publiek. Een van de redenen is door het gebrek aan oplaad infrastructuur en de verandering van levensstijl die met het bezit van een elektrisch voertuig meebrengt.

Een groep studenten werken samen aan de conceptuele ontwikkeling van de E-Hub. Dit multidisciplinair team werkt aan verschillende aspecten van de E-Hub en proberen samen het concept van de E-Hub concreter te maken. De bachelor opdracht richt zich op het onderzoek van het systeem van de E-Hub en het ontwikkelen van de user interface voor de laadinfrastructuur.

Het ontwerpproces is begonnen met een analyse fase. Ten eerste zijn de problemen die bij de E-Hub behoren onderzocht. Ten tweede wordt de doelgroep onderzocht en bepaald. Ten derde wordt een marktanalyse uitgevoerd om te indentificeren wie de huidige spelers op de markt zijn en hoe zij de uitdaging behandelen. Een overzicht van de interface van de spelers wordt gecreëerd om hun systeem duidelijk naar voren te brengen. Met de analyse voltooid, wordt een scenario gemaakt zodat de lezer zich met de huidige situatie kan inleven. De visie van de E-Hub wordt ook vast gesteld om het doel niet uit het oog te verliezen tijdens het ontwikkelingsproces. De analyse wordt verder gebruikt om een programma van eisen te stellen.

Het systeem van de E-Hub is nog onbekend en moet nog vastgesteld worden. De verschillende componenten die bij de E-Hub behoren worden onderzocht en individueel naar gekeken om te zien hoe elk component in de maatschappij functioneert. Er wordt een datastroom gemaakt om duidelijk te illustreren wat elke component vereist van de ander. Daarna worden er architecturen gemaakt met verschillende kenmerken door de positie en interactie tussen de componenten te variëren. Als laatste wordt er een vergelijking gemaakt tussen twee architecturen en flowcharts om te bepalen welke het meest geschikt is voor de E-Hub.

Het volgende proces is om te onderzoeken welke componenten een behoefte hebben aan een user interface design. De functies die de gebruiker moet uitvoeren per component en de informatie die de gebruiker wilt weten van de componenten wordt onderzocht. Door de twee te combineren is het mogelijk om te zien welke mogelijke user interface designs ontwikkeld kunnen worden per component.

Het echte doel van de bachelor opdracht is om een user interface van de laadinfrastructuur te ontwerpen. De laadinfrastructuur en de keuzes die eerder werden gemaakt worden onderzocht. Ideeën worden ontwikkeld, waaruit er drie concepten uit komen. Het gekozen concept wordt vervolgens verder uitgewerkt in détail. Een flowchart van de interactie tussen de gebruiker en de laadinfrastructuur wordt gemaakt en een prototype wordt gemaakt op base van de flowchart.

Het resultaat van de bachelor opdracht is een wetenschappelijk onderzoek van de E-Hub systeem, een definitief ontwerp van de laadinfrastructuur en een functionele prototype om het gebruik te illustreren.

Abstract

The E-Hub is aimed at being 'the charging station of the future'. The uptake of electric vehicle is slowly increasing, but the perception of the technology is hesitant by the general public. One of the reasons is due to the lack of charging infrastructures and also the change of lifestyle which comes with owning an electric vehicle.

The conceptual development of the E-Hub is worked on by a group of students. This multidisciplinary team work on different aspects of the E-Hub and together try and make the concept of the E-Hub more concrete. The bachelor assignment focusses on researching the system of the E-Hub and developing the user interface for the charging infrastructure.

The design process started with an analyses phase. Firstly, the challenges belonging to the E-Hub are investigated. Secondly, the target group is looked into and defined. Thirdly, a market research is conducted to analyse and try and understand how the current market players decided to handle the challenge. An overview of the current market player's interface is created to bring clarity into their system. With the analyses complete, a scenario is created to enable the reader to envision the current situation, as well as stating the vision of the E-Hub to not lose sight of the goal during the development. The analyses is further used to create a design brief and define the requirements of the E-Hub.

The system of the E-Hub is yet to be defined. The different components belonging to the E-Hub are researched and looked at individually to discern how each component is functions in society. A data chart is created to further illustrate what each component requires from the other. After which architectures can be made by varying the positioning and interaction between the components to give each a distinctive characteristic. A comparison is made between two architectures and flowcharts to determine which is best suited for the E-Hub.

The following process is to research which components are in need of a user interface design. The functions that the user needs to undertake with each component and the data that the user wants from the components are investigated. By combining the two it is possible to see which user interfaces could be developed for each of the components.

The real goal of the bachelor assignment is to develop the user interface of the charging infrastructure. The charging infrastructure and the choices made earlier are looked into. Ideas are developed and three concepts are chosen. The chosen concept is then further developed in more detail. A flowchart of the interaction between the user and the charging infrastructure is created. A prototype is developed according to the flowchart.

The result of the bachelor assignment is a research of the E-Hub system, a final design of the charging infrastructure and a prototype to illustrate the usage.

1 Introduction



1.1 General Information E-Hub

The E-Hub is a concept that is aimed at breaking the chicken-egg cycle in the electric vehicle and charging infrastructure debate by providing an innovative solution for electric vehicle charging. This will be a hub where people will want to come to charge their car and can spend their time productively by making use of the facilities on site, or change over to an alternative means of transportation to travel further into the city center.

The general goal of this project is to solve the problem of the slow uptake of electric vehicles. The current situation shows that the slow uptake has to do with the lack of charging infrastructure for electric vehicles. However there is little incentive to build charging infrastructure when there is only a limited amount of electric vehicle users. A secondary goal is to reduce CO₂ pollution in the city center by for example reducing the amount of internal combustion engine cars in city. The aim is to provide an all-in-one charging station with multiple facilities at the edge of the city center to solve these challenges. As a result the uptake of electric vehicles is increased and a step is taken towards a more sustainable energy society.

The concept of the E-Hub will be presented in May 2016 at the FabCity Campus in Amsterdam where the Future of Everyday Living in Europe will be exhibited. A mobile version of the E-Hub will be developed to showcase this innovative solution to the rest of the world. Involved parties in the project are the Technical University of Delft, University of Twente, Amsterdam University of Applied Sciences and Dutch-INCERT (cooperation between knowledge institutes for electric mobility).

1.2 Personal Assignment

For this bachelor assignment the focus lies on discerning the interfaces between the different components found at the E-Hub and determining the different possibilities for the user interfaces of these components. The other main focus will be to research and develop the user interface of the charging infrastructure, and creating a fitting basic user interface for it.

Currently the interfaces as well as the user interfaces of the components are unknown. For the users of the E-Hub it is vital that these components are well thought of and developed. One of the inspirations for the E-Hub is the current gas stations, where users are able to fully tank their vehicle within 5 minutes and be on the road. The fact that electric vehicles is a new technology and takes a long time to charge means that it will be difficult for society to adapt to the changes.

The assignment will focus on; mainly looking into appropriate user interfaces for the different components of the E-Hub to increase the acceptability and usage of the E-Hub. Discerning possible architectures of interfaces and designing a user interface of a chosen architecture.

The real goal will be to design a specific user interface for the charging infrastructure and to provide a functional mock-up of the user interface. The aim is to provide comfort and convenience to the users of the E-Hub.

2 Analyses



2.1 Current Situation Scenario

John is a proud owner of an electric vehicle. An electric vehicle takes hours to charge, but John always charges the vehicle overnight. John wakes up in the morning and prepares to go to work. He works at the bank in the centre of the city. Before going to work he decides to make a detour to a cafe to grab a breakfast meal and a coffee. It is a hot day and John decides to turn up the air conditioning all the way up. The detour has caused John to lose time and he could be late to work. John decides to drive faster than he usually would. John arrives in the nick of time for work. However, the work location does not provide a charging infrastructure. The inability to charge the electric vehicle while at work will cause John a hindrance in the future. Work is finished and John still needs to do groceries. He starts the electric vehicle and sees that there is enough energy to do groceries but not enough to get back home. After doing groceries, John starts searching for a charging infrastructure to be able to charge his electric vehicle. He gets a little frantic but luckily finds a charging infrastructure near the highway. It takes some time for John to understand how to work with the charging station. He needs to call the company of the charging station to manually activate it for him. John decides to charge the electric vehicle with enough energy to make it home. This takes over 45 minutes. John finally arrives back at home and inserts the charging plug into the vehicle to allow it to charge throughout the night. John wonders if the situation could have been avoided or if there was another solution to the problem.

2.2 Challenges

Electric vehicle is evidently a niche product and is in the process of developing. There are issues and uncertainty surrounding electric vehicle. The two main concerns of electric vehicle are the range of the electric vehicle and the ability to charge (EVARTS, 2015). As stated before there is a lack of charging infrastructure, which leads to users feeling insecure about the vehicle running out of battery in the middle of nowhere. This accompanies the issue that users feel insecure about the range of the electric vehicle. This is one of the greatest fear and reason as to why users are not yet opting for the technology. However, study shows that the average user drives less than 30 kilometer per day, which is way below the range of an electric vehicle. Furthermore, the technology continues to develop and the battery capacity increases with each development. Another issue for the users is the fact that charging is a long process which could take hours before being fully charged. It is difficult to compete with the current refueling speed of vehicles with internal combustion engine.

The E-Hub is meant to tackle these concerns, remove them from the mind of the user and put the user at ease.

2.3 Target Group

The target group of the E-Hub is currently the early adopters of electric vehicle. The early adopters enjoys adopting innovations early on. They believe in the upcoming technology and want to be one of the first to use it and be part of the movement. However once electric vehicle becomes a dominant technology, the target group will begin to consist of the general public. Examinations of the early adopters show that they have a lot of characteristics in common. Most of the electric vehicle owners are middle aged men, with a high education and income, and live near the city centre. They usually own multiple vehicles, and have an electric vehicle for the benefits of having free parking, reduced annual tax, no vat, and saving money from charging (Hjorthol, 2013).

The target group is familiar with modern technology and will continue to be once the E-Hub is implemented. Most of the users use a computer, a laptop, smart phones, and the internet on a daily basis. They are up to date with the latest technology. The users are able to understand the concept of touch screens and how they function.

The target group of the E-Hub will most likely be the early adopters who work in the city centre. These users are the ones who will be making the most use of the E-Hub. They work an average of 8 hours in the weekday and are able to leave their electric vehicle to charge at the E-Hub while at work. The services such as flexible working spaces or meeting rooms found in the E-Hub will also be useful for these users.

The E-Hub will take into consideration two types of users; those who can leave their vehicle for a long period and those who need a quick charge and be on the road again.

2.4 Current Market Players

The market of electric vehicle continues to grow and it will surely become the dominant technology in the nearby future. The Netherlands is proposing to ban the sales of petrol and diesel vehicle in the year of 2025. The ban will surely push electric vehicle to become the main means of transportation if it were to be realized. There are already a vast amount of players who have been trying to capitalize on the market of electric vehicle.

In the Netherlands one of the main market players is Fastned, which has over 50 charging infrastructures placed next to the highway. Fastned aims to achieve a nationwide grid and has seized 200 out of the 250 possible locations on the highway. The charging infrastructures uses 100% green energy received from the solar panels used as a roof and wind energy produced by nearby windmills. A charging station can be seen in figure 1. Users are advised to first subscribe to Fastned before being able to make use of their infrastructure. This is possible by either using the Fastned app or by sending a text message to register. Once the user has been registered into the system, they can enter the ID of the charging station and select a plug and the system will be available for use. The charging may be stopped within the app or by sending another text message, and the user will be billed depending on the chosen payment option. A variety of payment options are available such as credit card, tank pass, bank account, or charge card.



[Figure 1] FastNed charging station

Another market player in the Netherlands is the road company ANWB. They have also placed charging infrastructures throughout the Netherlands and offer users the possibility to have a charging pole placed near their home for a fee. Before making use of the service from ANWB, users must first apply for a charge pass. The user will be allowed to make use of all the available charge poles scattered in the Netherlands, once the charge pass has been received. There are two types of charge pass, a free and a monthly pay charge pass. Contrary to its name, for the free charge pass, the user must pay € 0,28 to make use of the charging pole and must pay additional fee, such as the cost per kWh, the cost to start and the cost of time. The monthly charge pass costs a fixed price of € 5,20 per month to make use of the charging poles, and also here additional fees apply. The charge pole consists of a plug outlet with LEDs, a card scanner, and instructions (see figure 2).



[Figure 2] ANWB charging poles

The LED provides the user with useful information such as if the pole is available and ready for charging or if there is a malfunction with the pole. The user must first plug their own charging cable into the pole and vehicle, and scan their card to begin charging. Once scanned the charging cable will be locked into the pole to prevent removal and theft. If the charging cable is removed from the vehicle the charging will be halted until the cable is plugged into the vehicle and the charge pass is swiped again. This prevents others to make use of the charging cable and charge on your behalf.

In New Zealand the prominent charging company called Chorgenet is leading the development of electric charging stations. They have built a nation-wide network of Fast DC Chargers, named the Veefil Rapid Charger. Their aim is to provide users with fast charging at each charging infrastructure, allowing users to typically charge their car between 10 to 25 minutes. The charge pole developed is able to charge two cars at once, and has an easy to use interface. The user must register on the website and become a member of Chorgenet. Once registered the user will receive an RFID Fob which will be used to scan and begin charging. Another way to activate the charging pole is to send a text via the phone. It is however recommended to register as this is more convenient for the user. At the charging station the user will first plug the charge plug into their vehicle. After which they will scan their RFID Fob and choose from two charging options; 80% or 100%. It is standard on 80% to prolong the battery life of the electric vehicle. The user can press start to begin charging. Chorgenet's rates are 25c/min + 25c/kWh when using their charging stations. At the end of each month a statement is send, and the credit card is charged.



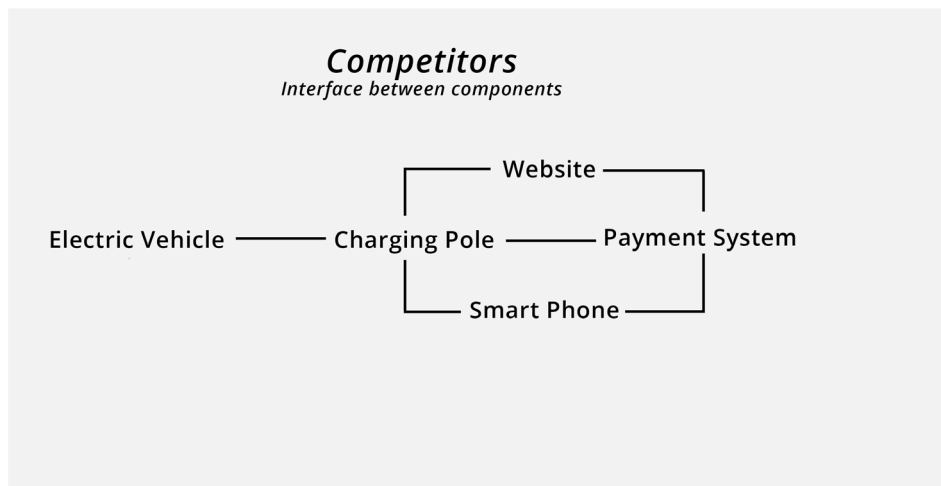
[Figure 3] Chorgenet Veefil Rapid Charger

Norway is the leading country in electric mobility. The country has given huge incentives to own an electric vehicle by exempting owners from road tolls, providing free public parking and free public charging, reduced ferry rates, and are able to drive on most bus lanes. One of the market leaders in the charging business is Fortum's Charge&Drive. They currently operate more than 150 rapid chargers and will be deploying even more. The charging infrastructure includes different types of charge plugs such as CHAdeMo, CCS, and AC43. The users are steered to subscribe and become a member. They will also receive a RFIB Fob to gain access to the charging station. Payment occurs through credit cards or via text message. The option of text message would allow users to start and stop charging by texting a certain code, and the costs will be added to the customer's mobile phone bill. However, it became clear that too many users were calling customer support due to confusion. Charge&Drive has tackled this issue by adding a payment option in their app.

Arctic Roads is another company found in Norway. Their goal is to build and operate infrastructures for fast charging of electric vehicle. The charging stations that are being implemented are one of the most powerful fast chargers, which can deliver 120kW+ per outlet. These powerful chargers enable significantly more efficient charging of electric vehicles for the new market vehicles which come with larger battery packs and higher charging power. Arctic Roads has established over 12 charging locations and are aiming to provide nearly 400 of these locations in the long run. Arctic Roads mainly operates with a membership subscription payment, but the charging stations could also be activated through text.

2.5 Current Market Player's Interface

By looking into the current market players, it is visible that the architecture consists of the components; an electric vehicle, a charging infrastructure, a payment system, a website, and an app. These components are necessary for the market players to have a working charging infrastructure. An illustration of the current market player's interface can be seen in figure 4. The relation between the components will be explained in detail in the following section.



[Figure 4] Overview of Competitor's interface

The current market players have opted for a swiping-system. As stated in the previous section, users must first become a member through the website or app to make use of the charging infrastructure. A card or a RFID Fob will be send to the user, which is personal to the user. When the user swipes the card or RFID Fob, the system will register the user and give access to the charging system. The system will add the costs of charging to the account and the user will be charged at the end of the month. Certain companies have created an app to enable the user to have an overview of the current situation as well as activate the charging pole. Creating a personal user account is urged, as it allows the owners of the infrastructure to identify the user, verify the access, save preferences and data, hold them responsible, and create a community around the infrastructure.

2.6 Reasoning for Current Market Player's Interface

In this section the focus will be on how the market player's components are connected to one another. The interface may vary depending on if the user is a member of the system or not.

Electric Vehicle – Charging Pole

The electric vehicle needs a charging pole to be able to charge the vehicle. This is achieved with a charge plug either from the owner or included with the charging pole. Once the charge plug is inserted into the vehicle, data such as the state of charge is sent from the electric vehicle to the charging pole. With this data the charging pole is able to determine how much energy and time is necessary to charge to the desired state. This depends on the type of charge plug used, the type of charging, and the desired end charge.

Charging Pole – Payment System

The charge pole is connected to the payment system as the user may only make use of the charging infrastructure if payment is possible. Currently you may only pay through a bank account or a credit card attached to your member account. This eliminates the need of having a separate terminal at each charging infrastructure. In most cases access is granted by swiping the personal card or RFID Fob. The payment system sends the charging pole verification for access to the user if they have enough funds and begins charging the electric vehicle. Data such as the cost of using the charging infrastructure is sent to the payment system afterwards when charging has been completed.

Website – Charging Pole & Payment System

A website is initially created and used to promote, inform, and help the users with the charging infrastructure. On the website the users are able to learn about the company, create an account, and look for the location of the charging poles. Furthermore the users are also able to activate the charging pole through the website if the card is forgotten or lost. The website requests data from the charging pole such as the locations, availability, and the current user.

The user is able to add a payment method through the website when creating an account. On the website the user can always manage their account and change preferences if wanted.

Smart Phone – Charging Pole & Payment System

The smart phone is used to offer the user an overview of the current situation and available options in a single platform. The application is a streamlined version of the website. Data is retrieved from the charging pole to show how the current state of charge is and allows the users to change the options if necessary, for example stopping the charge or switching the type of charging. The location of nearby charging poles is also illustrated on the app. The payment system sends information such as the current cost of charging to the smart phone. And lastly the user is also able to activate the charging pole through the smart phone.

2.7 E-Hub Vision

The implementation of the E-Hub will bring a change in the socio-technical regime as the way of living will be altered. The E-Hub is placed near the outskirts of the city where users are able to make efficient use of their time. The E-Hub will offer people the option of a flexible working space, an alternative means of transportation to the city and different facilities to spend their time. The E-Hub has an effective interface between the different components and the user has no issues with the interaction between the components. Convenience is maximized for the user. With this in mind a future vision of the E-Hub is created.

The user of the electric vehicle is on the way to work in the morning. The satellite navigation is set to one of the many E-Hubs near the city. The user parks the electric vehicle near a charging pole and inserts the charging plug into the vehicle. The user informs the system on the estimated time of return. Once the user is certain that the vehicle is charging, they head towards the rack of E-bikes. The alternative transportation is taken to travel further into the city and towards the work location. At the work location the user is able to check the website and app to see the current state of charge of the vehicle. A notification is sent to the owner once the charging is complete. The E-bike is ridden back towards the E-Hub and neatly placed back into the rack. At the E-Hub the user decides to have a cup of coffee and relax a bit before heading home. The plug is then manually removed from the vehicle and the owner heads back home with a fully charged vehicle.

2.8 Design Brief - General

- E-Hub must provide additional value to the users.
- E-Hub must provide alternative solutions; charging types, charging plugs, transportation, payment systems.
- E-Hub must provide an efficient system for the users.
- E-Hub must ensure sufficient parking for electric vehicles.
- Users must be able to comprehend the system of the E-Hub.
- Users must be able to comprehend the user interface of the E-Hub.

2.9 Analyses Conclusion

We can conclude from the analysis phase that the technology is making its way to becoming a dominant technology in the world. This will create a change in the socio-technical regime as we know it. The way of living will be altered as electric vehicles need time to charge and efficient use of time is proposed. The issues that currently exist will be solved with the development of better technology and the implementation of strategically placed charging infrastructures. Technology will continue to develop and the world will familiarize itself with the latest technologies. Touch screens will be the standard or perhaps even a thing of the past.

The market players have offered us useful insight into how the system currently works and what is important for the user. Fast charging and convenience is an important point which each market player aims for. Currently all market players urge the users to turn into a member of their system by providing more convenience and benefits to the members. Other useful information is the way users (non members & members) interact with the charging station. Members are able to activate the charging pole in different ways; scanning a RFID chip or activating through a website or app. While non members are able to text or call to activate the charging pole. At each step the user must receive feedback from the component to aid them in the following step. The user will be able to distinguish if the system is currently active and if the system is charging their electric vehicle.

3 E-Hub

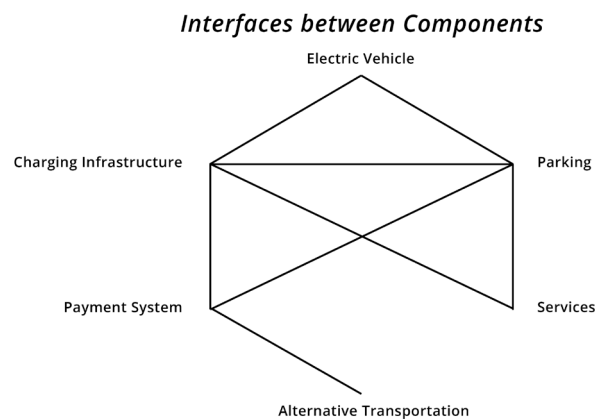


3.1 System

The E-Hub is a new concept aimed at bringing different components together and offering the user additional value compared to the current charging infrastructures. The structure of the system and the components found within the E-Hub are however still unclear. The following chapters are focused on figuring out which components are vital for the E-Hub and how the structure of the system will become when combining the components. We can begin to understand how to E-Hub functions once the architecture is developed. This will also enable us to see where a user interface is and is not necessary in the E-Hub.

3.2 Basic Component Architectures

The E-Hub architecture can be discerned by looking at the different components and seeing which ones are vital for the development of a functioning charging station. We can describe the E-Hub into different situations, and possibly find a way to combine them to create a fitting architecture. A comparison will be made between a personal situation and company situation to see what components are crucial or need to be added in the case of company situation. A personal situation is defined as the components necessary to achieve the function for personal use. While a company situation is defined as the components necessary to achieve the function in a public domain.



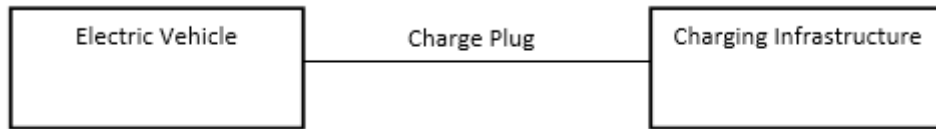
[Figure 5] Expected connection between components

In figure 5 the main components belonging to the architecture of the E-Hub are shown. The lines represent a connection between the components. A connection is defined here as the component needing the other component for the E-Hub to function properly, through an interface between the components. A connection could be tangible in the sense of a plug or intangible such as data. The six chosen components are considered essential to the E-Hub resulting from the analysis and the goal of the E-Hub. The image is an expectation of the connections between the components and will be analyzed further in the following section. The overview of interfaces will be altered throughout the paper to better match the desired system.

Charging Infrastructure

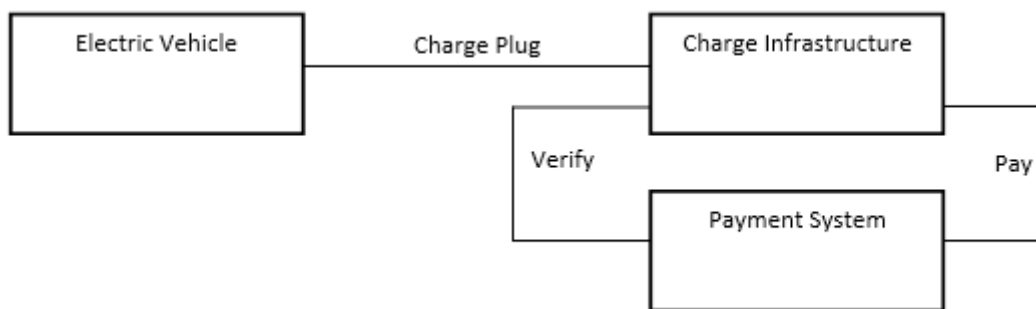
First we will look at the situation of the charging infrastructure. The main function here is to charge the electric vehicle.

For the personal situation the components are an electric vehicle and a charging infrastructure, with the interface between the two being a charge plug.



This type of situation can be found at home. The user inserts the charge plug from the charging infrastructure into the electric vehicle and the charging will begin.

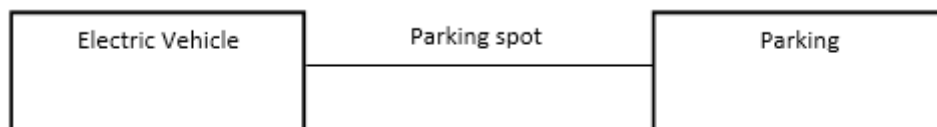
The company situation is similar to the personal however a payment is required to make use of the service offered by the company. In this case the service is charging the electric vehicle.



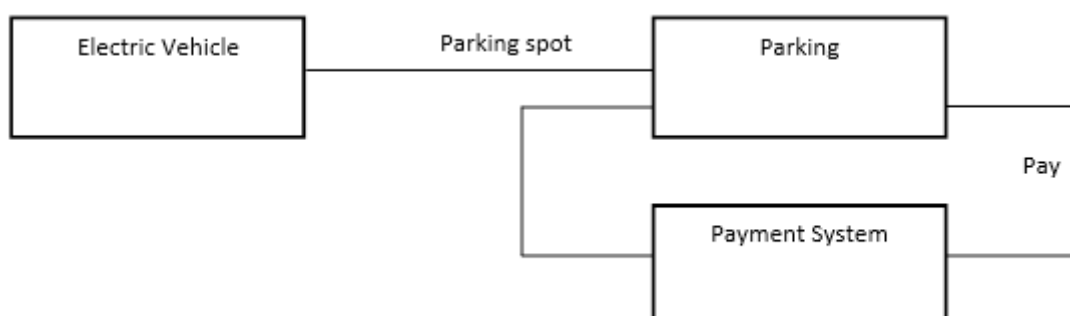
This situation can be found in a public domain. The user inserts the charge plug from the charging infrastructure into the electric vehicle. The user must then insert or have an amount of credit before the charging begins. The payment system verifies the credit and sends the charging infrastructure a confirmation to begin charging.

Parking

The next situation is that of parking. The E-Hub requires a parking location to enable the users to either charge or leave their vehicle. The situation of parking differs on if it is free to park an electric vehicle or if the user needs to pay to make use of the parking spots. The personal situation of parking has the two components of electric vehicle and parking. This situation is mainly the case with free parking.



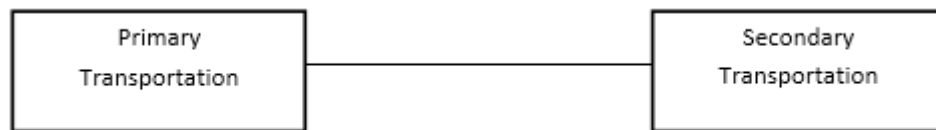
A payment system component is added to the situation if payment is required for parking. The payment is usually done afterwards, and the amount to be paid depends on how long the car has been stationed at the parking lot.



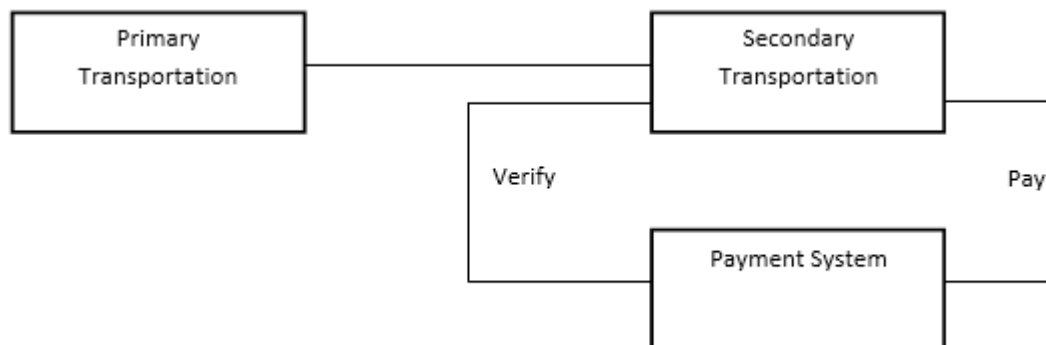
Alternative Transportation

The third situation is that of the alternative transportation. The E-Hub offers users the possibility of changing to another mode of transportation while the electric vehicle is charging. This is part of the unique selling point of the E-Hub. The alternative transportation is also essential to the E-Hub due to the likely positioning of the E-Hub, near the outskirts of the city centre. It gives the users an additional value and a reason to charge their vehicle at the E-Hub and aids them in further traveling to the city centre.

Once again a personal situation for alternative transportation is created. In this case the user switches from a personally owned primary transportation to another personally owned secondary transportation. This could be for example a bicycle to car, or vice versa.



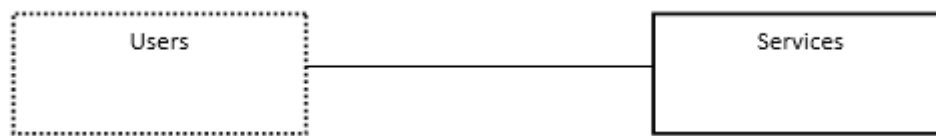
For the company situation of alternative transportation, payment is required from the user to be able to make use of the service provided.



Payment is either done before taking the secondary transportation such as buying a ticket for the metro, bus, or train; or a fixed amount is taken from the user and a deducted amount is given back when the user is finished with the service.

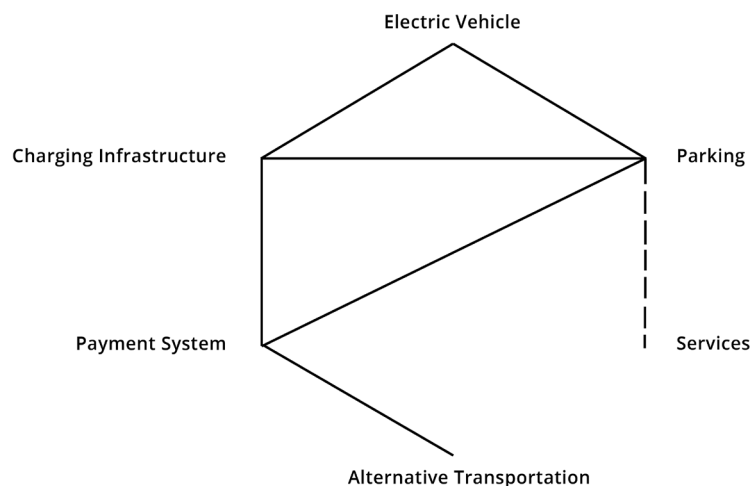
Services

The last component to consider is that of services which the E-Hub provides. The services and facilities found at the E-Hub are for example, flexible working spaces, a cafe, a gym, a library, and more. A separate payment system is not found here as it is not yet certain if the E-Hub will be providing all of these services on its own or if other companies will rent out the space at the E-Hub and provide the service themselves, it is most likely that the latter option will be the case. And if so, they would have their own payment system. However, integration of the payment system may be possible depending on the type of services provided. In the case of flexible working spaces it is the E-Hub which provides the service and space. Everyone can enter the E-Hub and make use of the services. It can be considered a separate yet vital component to the E-Hub, as it enables the users to make more efficient use of their time.



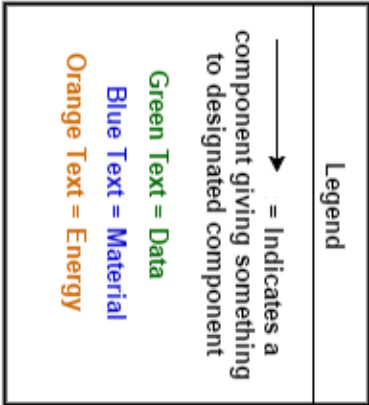
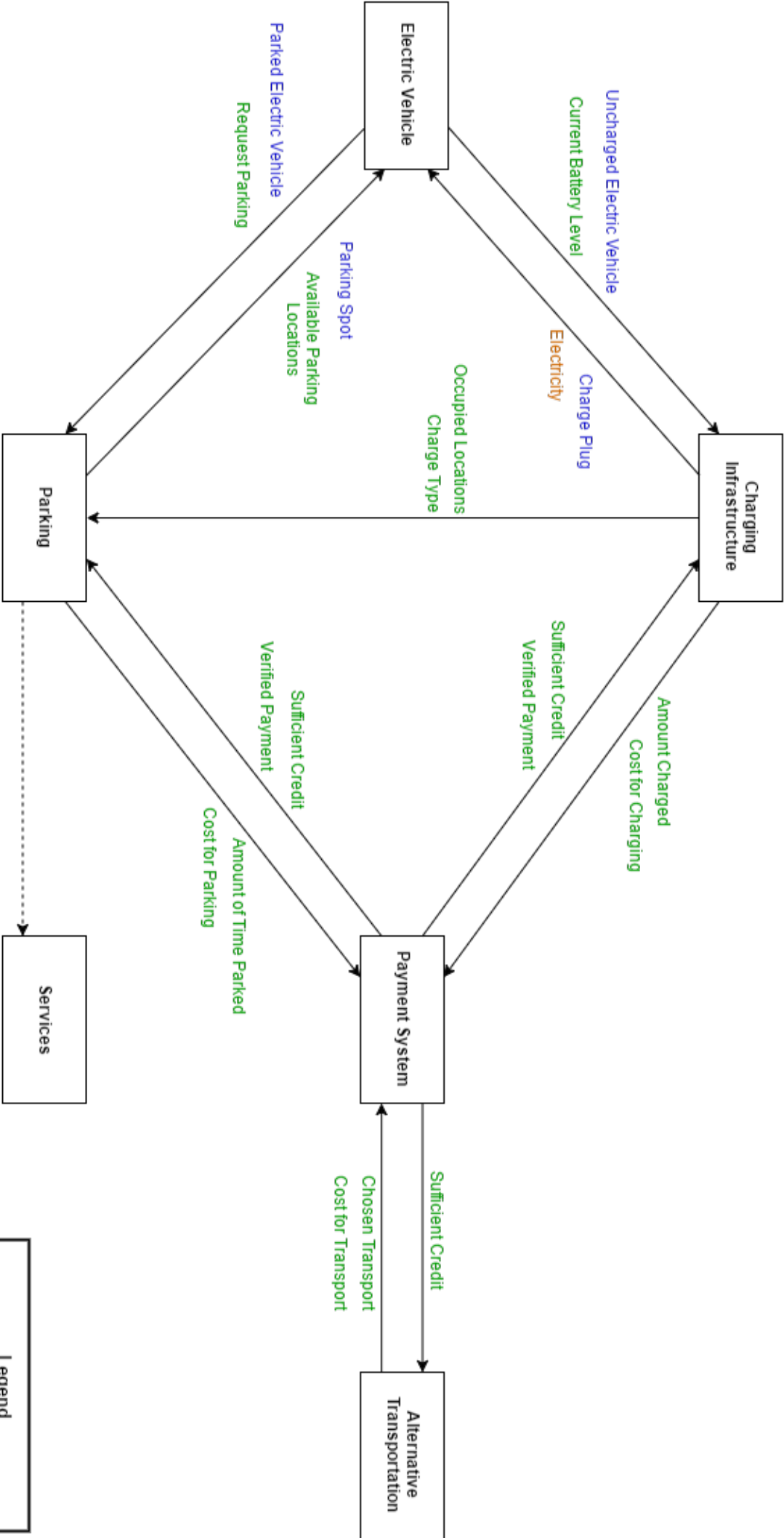
Changes are made to the overview of interfaces between the components. Noticeable changes are the connections of services. The charging infrastructure does not have a connection with the provided services. Parking however still remains with minor connection to services as it offers the users of the E-Hub a parking location while using the available services.

Interfaces between Components



[Figure 6] Actual connection between components

3.3 Data Stream E-Hub

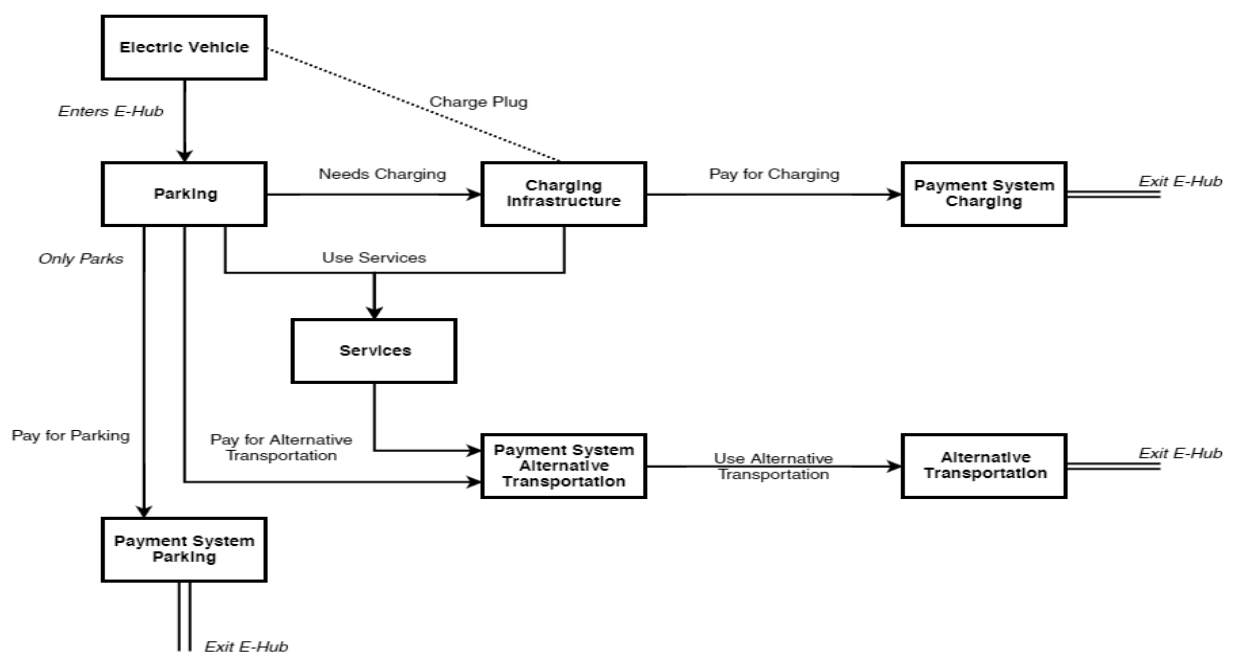


3.4 Architectures

Now that the E-Hub has been disassembled into smaller architectures we can begin to assemble them to form an overview of the entire E-Hub architecture. A variety of combined architectures will be created each with its own characteristics. The architectures will allow us to evaluate which and how each component is connected while demonstrating how a user goes through the E-Hub system.

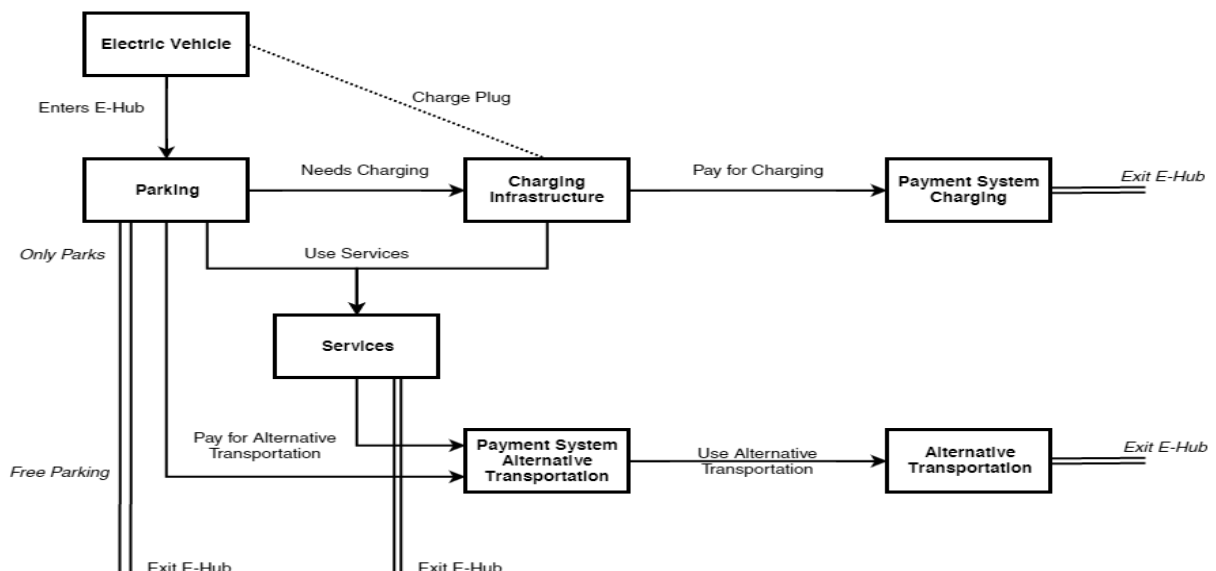
The first combined architecture is characterized by its decentralized system. The architecture is divided into three sections. Separate payment system components can be found for parking, charging infrastructure, and alternative transportation. In this situation payment is due after charging is completed, after the user is finished with parking, and before being able to make use of the alternative transportation.

Architecture E-Hub [1]



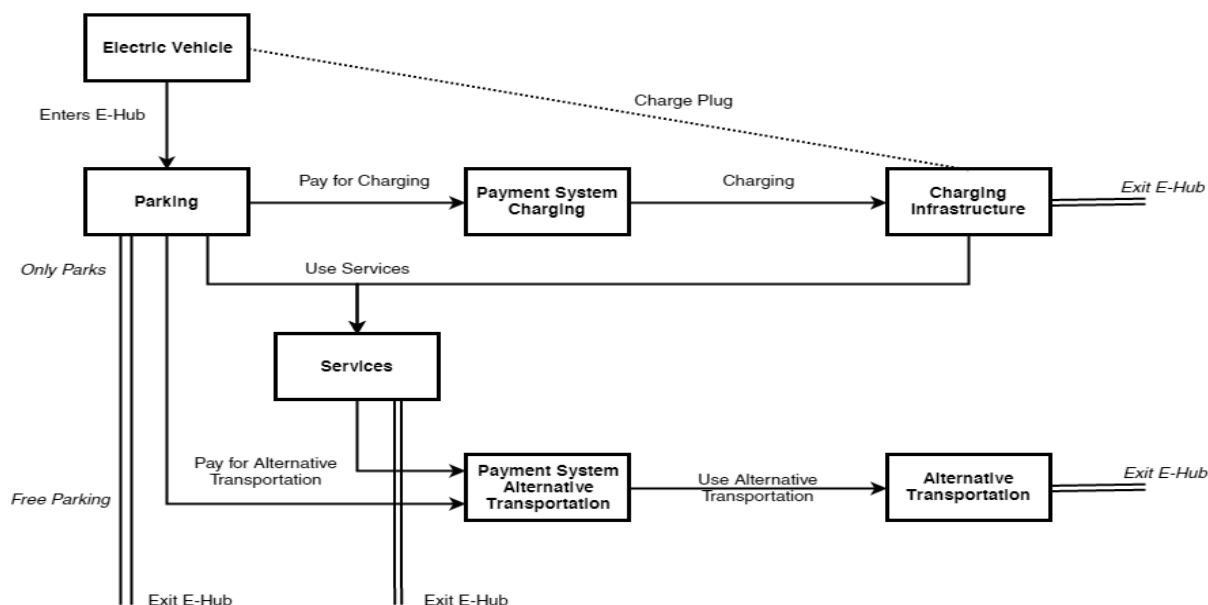
The second combined architecture is also characterized by its decentralized system, however the user no longer needs to pay for parking. Users are able to freely park and leave the E-Hub but must still pay once charging is completed and before taking the alternative transportation.

Architecture E-Hub [2]



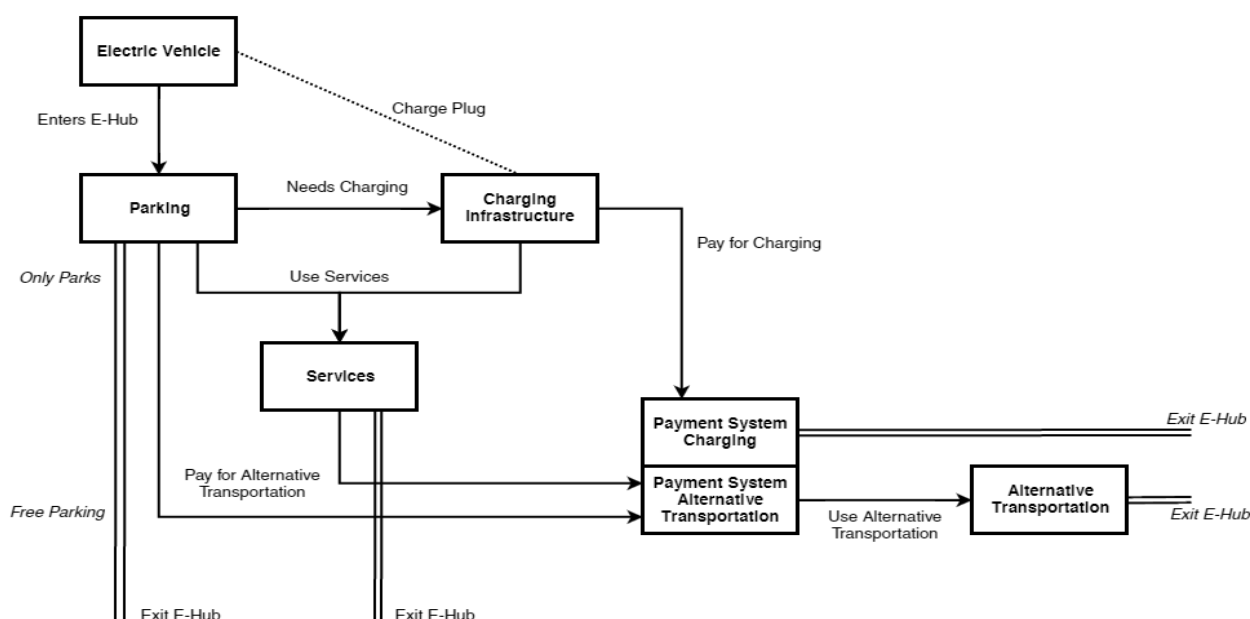
The following combined architecture is similar to the second, with the exception of the payment system taking place before allowing the user to make use of the charging infrastructure. Users must first pay an amount of credit to begin charging.

Architecture E-Hub [3]



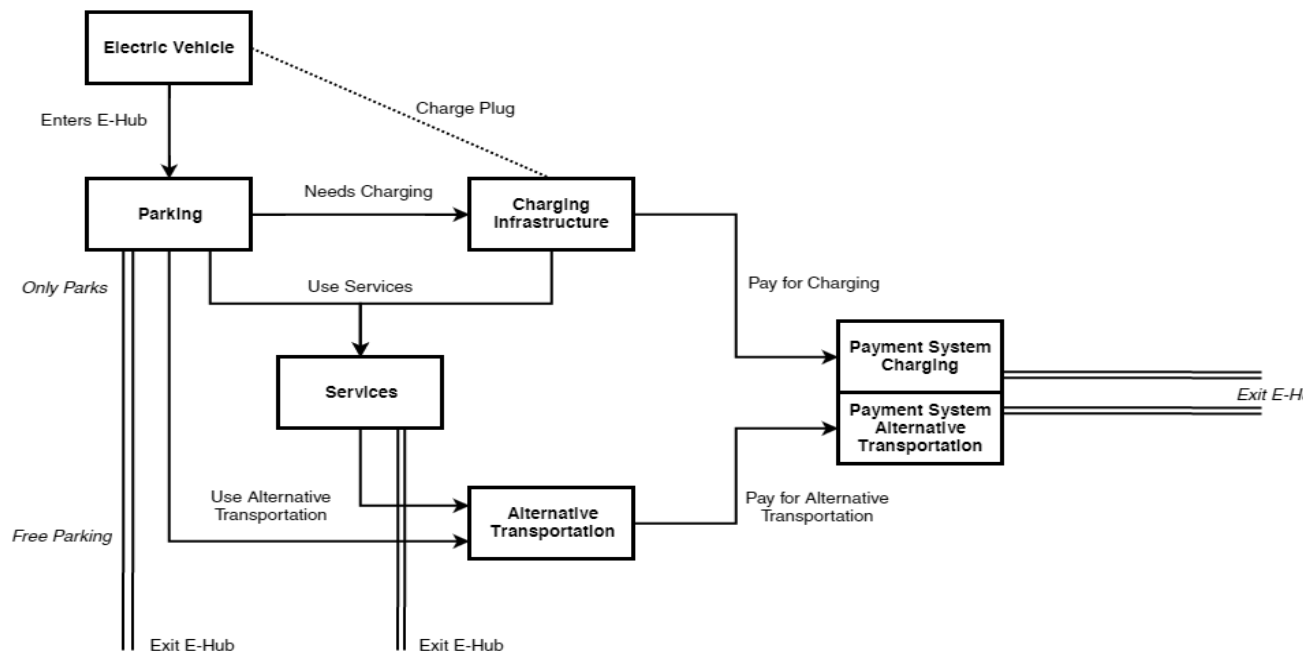
The fourth combined architecture is characterized by its semi-centralized system. The payment system of the charging infrastructure is merged with the payment system of the alternative transportation. In this situation the user needs to go to a single payment system to pay for the amount charged, as well as paying to be able to make use of the alternative transportation.

Architecture E-Hub [4]



And lastly, the fifth combined architecture is characterized by its centralized system. The payment systems are merged into one, and payment is only required after the user has finished using the E-Hub. The user can freely use everything that the E-Hub offers while the system keeps track of all the components used by the user. The user can charge their electric vehicle and use an alternative transportation, and the costs are added to form a single sum. The user must pay the amount of cost before being able to exit the E-Hub.

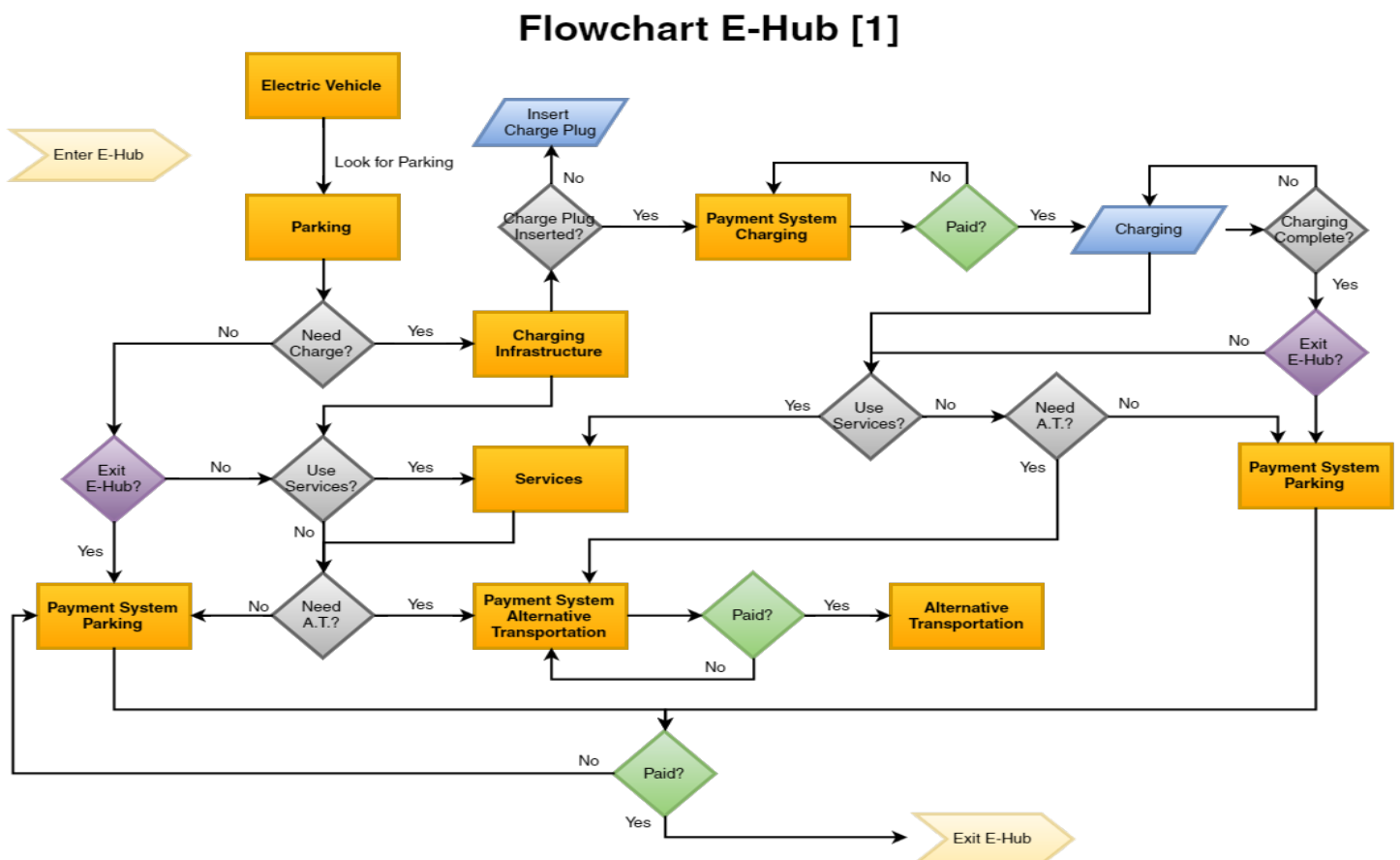
Architecture E-Hub [5]



3.5 Flowcharts

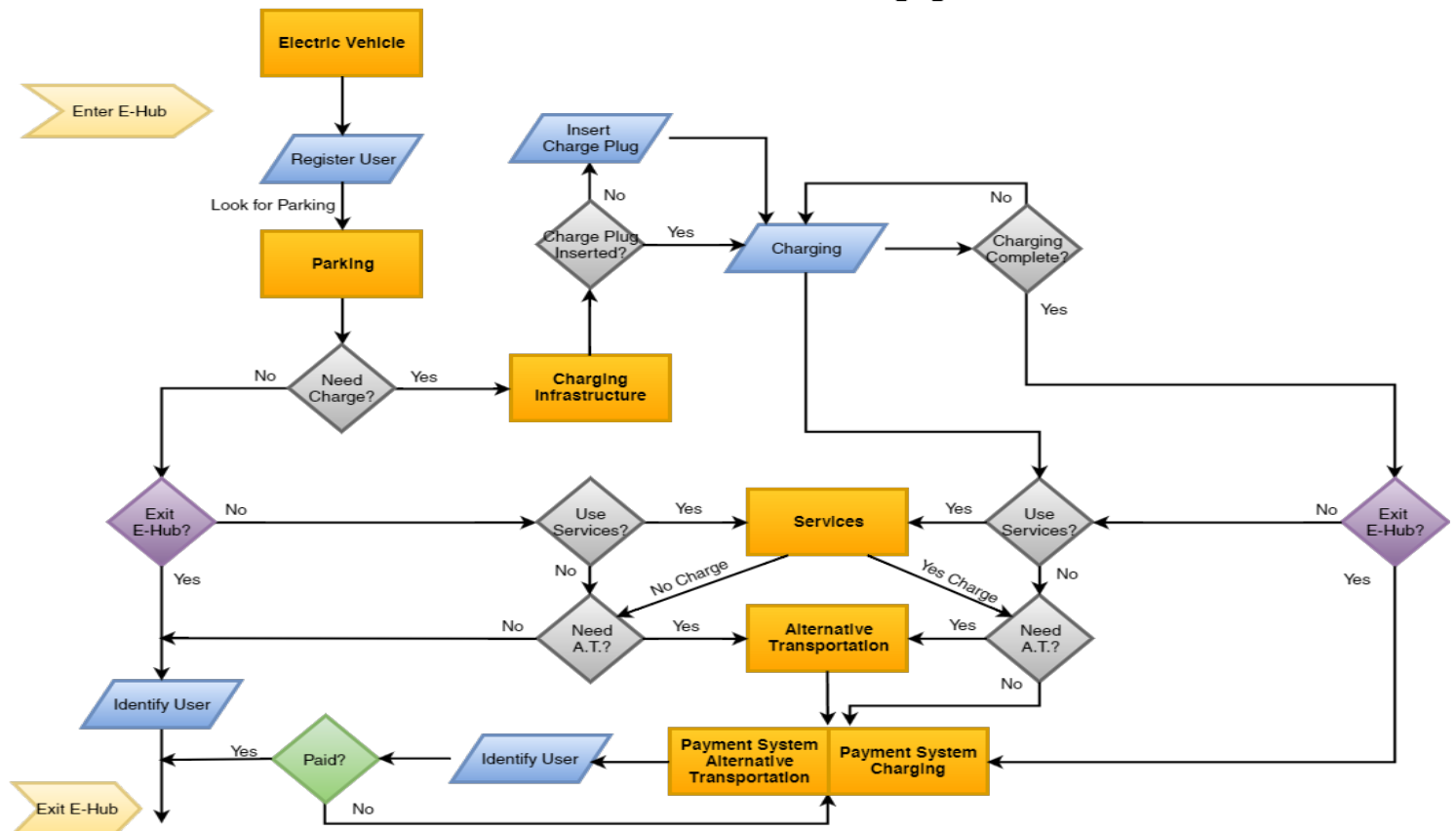
Now that different architectures have been developed, we can look more precisely into the steps that a user needs to take to go through the system. Two flowcharts are created based on the first and last architecture. The two architectures are chosen because of their extreme nature of either being decentralized or centralized system. A comparison will be made afterwards to discern which architecture fits the best with the E-Hub and for its users.

The flowchart of the first architecture can be found in the illustration below. The user must go through different actions before being able to continue according to this flowchart. Payment is required before charging, as well as before taking the alternative transportation. Furthermore the user needs to pay for parking at the E-Hub before leaving. The system checks to see if the user has paid before the next action is taken. The flowchart emphasizes the decentralized system found in architecture one.



The following flowchart belongs to the fifth architecture with its distinctive centralized system. The user is free to use the E-Hub and is only charged once the user is exiting the E-Hub. A single payment system is necessary for the E-Hub to function. The flowchart emphasizes the centralized system of the architecture. Every component is in some way connected to each other and the system keeps track of what the user does within the system.

Flowchart E-Hub [5]



3.6 Comparing the Architectures and Flowcharts

Both architectures are viable for the E-Hub, each with their own characteristic, positives and negatives. In the first architecture the user needs to go through more action to reach the desired destination. At each component the user needs to go to a separate payment system to pay the costs. There is also more moments found in which the system checks if the user has paid. The user is able to see the exact costs for using each of the components. The first architecture requires more time for the user to complete.

In the second architecture less time is required for the user due to the payment systems being combined. This system may be more convenient for the user as there is only one moment where the user needs to go and pay at a payment system. However the system is more complex as the different components need to be more interconnected, and the system needs to monitor the different actions of the users. This architecture always requires to user to have sufficient credit to pay at the end otherwise they will not be able to leave the premises. While at the first architecture the user can already see and decide if they have enough funds to use multiple components.

As a conclusion the latter architecture is recommended as it suits the requirement of convenience for the user and is a much more streamlined system. As seen in the flowchart it is much easier for the user to use the system. This architecture does require trust from the user. Multiple identify user element may be placed before each main component to demand the user to 'check in' to the system and aid the system in keeping track of the users action. The rest of the project will be based on this architecture.

	Architecture 1	Architecture 5
Type	Decentralized	Centralized
# of Components	8	6
# of Payment Systems	3	1
# of steps using whole E-HuB	7	5
Convenience	+	++
Time Saved	-	+

3.7 Comparing Non-Member & Member System

We can conclude from the analysis phase that the technology is making its way to becoming a dominant technology in the world. This will create a change in the socio-technical regime as we know it. The way of living will be altered as electric vehicles need time to charge and efficient use of time is proposed. The issues that currently exist will be solved with the development of better technology and the implementation of strategically placed charging infrastructures. Technology will continue to develop and the world will familiarize itself with the latest technologies. Touch screens will be the standard or perhaps even a thing of the past.

The market players have offered us useful insight into how the system currently works and what is important for the user. Fast charging and convenience is an important point which each market player aims for. Currently all market players urge the users to turn into a member of their system by providing more convenience and benefits to the members. Other useful information is the way users (non members & members) interact with the charging station. Members are able to activate the charging pole in different ways; scanning a RFID chip or activating through a website or app. While non members are able to text or call to activate the charging pole. At each step the user must receive feedback from the component to aid them in the following step. The user will be able to distinguish if the system is currently active and if the system is charging.

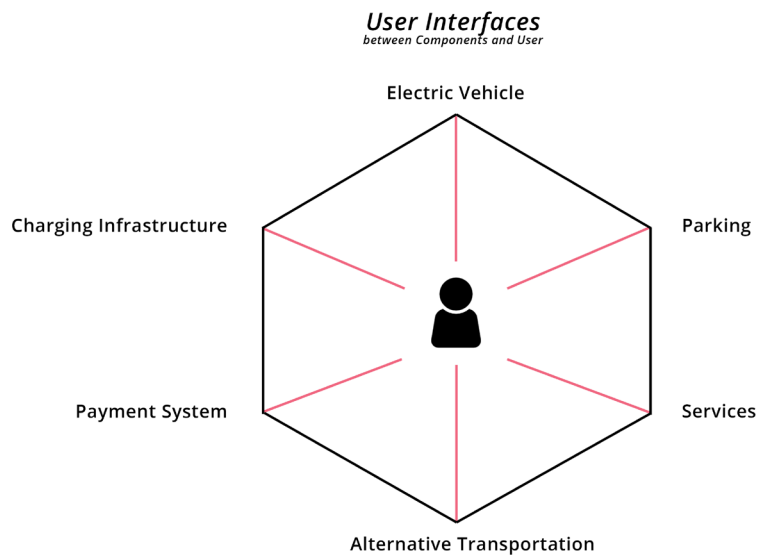
4 User Interface



4.1 E-Hub User Interfaces

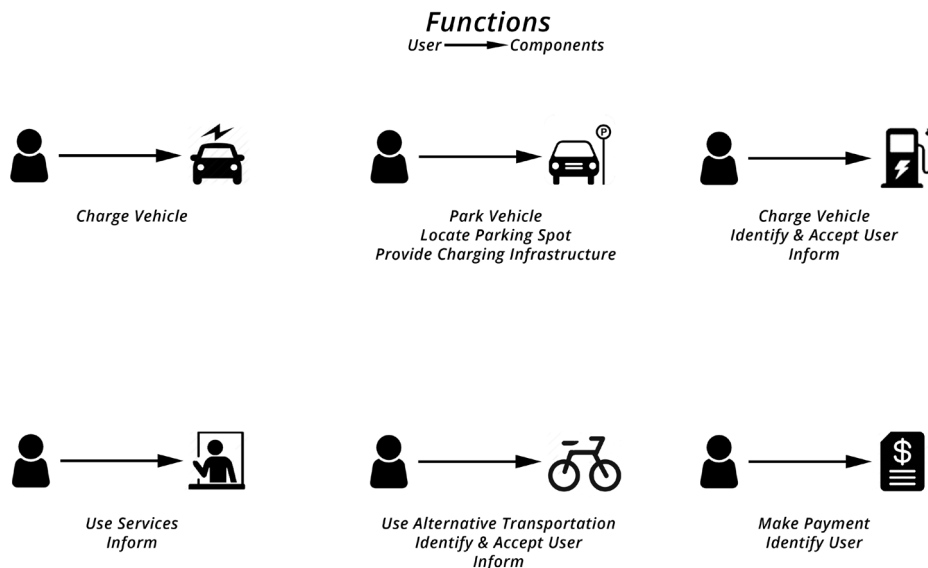
This section will focus on the user interfaces and the components of the E-Hub which need one. A user interface is necessary for the user to interact with the different components as well as the system as a whole. The user interface must aid and guide the user through the system. All users must be able to understand and be able to work with the system. The user interface must give feedback to the user when an action is taken to inform the user and help them to make the next decision.

Figure 7 shows the different components and the user at the center. The red lines represent a user interface between the components and the user. The image is an expectation of the where a user interface can be found. Throughout the chapter we focus on the components and see if the expectations are correct.



[Figure 7] Expected user interfaces between components and user

The user has certain functions which the E-Hub needs to fulfill. The functions are similar to that of the E-Hub architecture, including additional functions to complete the component. With the information we can discern where a user interface is needed within the E-Hub system.



[Figure 8] Function between user and component

When looking at the chosen architecture, a user interface can be found at each of the components. The possible user interfaces of the components will be looked at individually.

Electric vehicle

The electric vehicle has a built in user interface. The car manufacturers have designed a user interface with all the necessary functions with regards to the E-Hub such as; displaying total battery level, displaying driving range, and opening the charge port. The E-Hub requires the the function of opening the charge port and sending data to the charging infrastructure.

It is not recommended to create another user interface for the electric vehicle, as it is extremely difficult to do so for all the different vehicles and their different software.

Parking

The parking component consists of the subcomponents registering user (and identifying user). Before the user is able to park, the system needs to have the user registered into the system. This is the starting point for the system to begin keeping track of the activities of the user. The user interface of the parking also includes signs or signals to guide the users to the right parking location.

Charging Infrastructure

A user interface can be found at the charging infrastructure as it enables the user to understand and use the charging infrastructure. The user has to follow certain steps to begin the process of charging the electric vehicle. The user interface must guide the users through the steps and the different available options. These options are for example; choosing a charging station/port 1 or 2, the charge plug, the desired charge (80% or 100%), and the charging options (short term or long term). The user interface of the charging infrastructure should give the user feedback on the choices made and the current state of charging.

Alternative Transportation

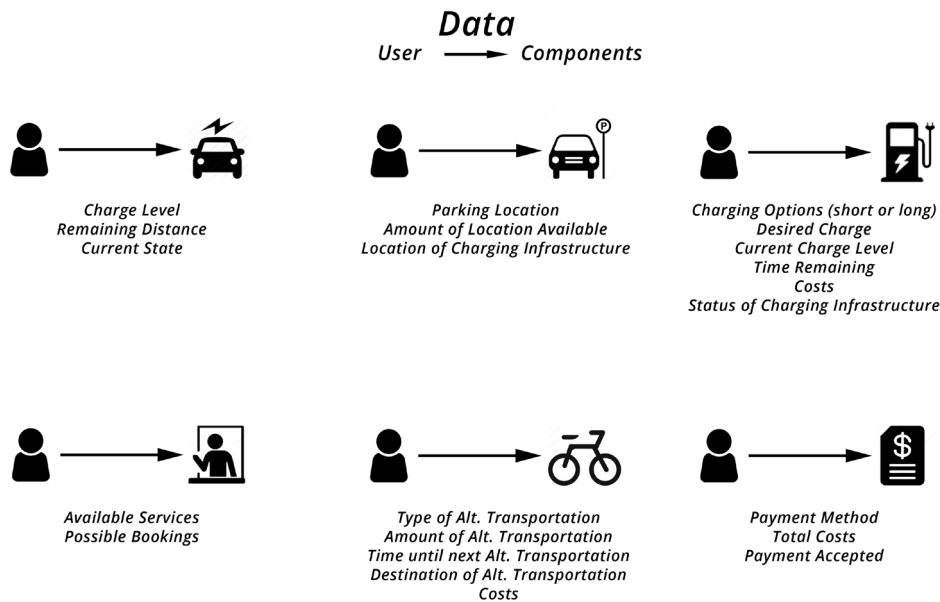
A user interface is required at the Alternative Transportation component to enable the user to make use of the system. The user will be using other means of transportation available at the E-Hub, which needs to give access to the user. The user interface should inform the user of the available alternatives, the time till departure, and the costs of using the transportation.

Payment System

A payment is required from the user if the charging infrastructure and alternative transportation were used. The method of payment depends on the type of interface, which will be coupled to a certain user interface. The user should be able to use the payment system and pay the total costs without a hassle. It could guide the user step by step through the system.

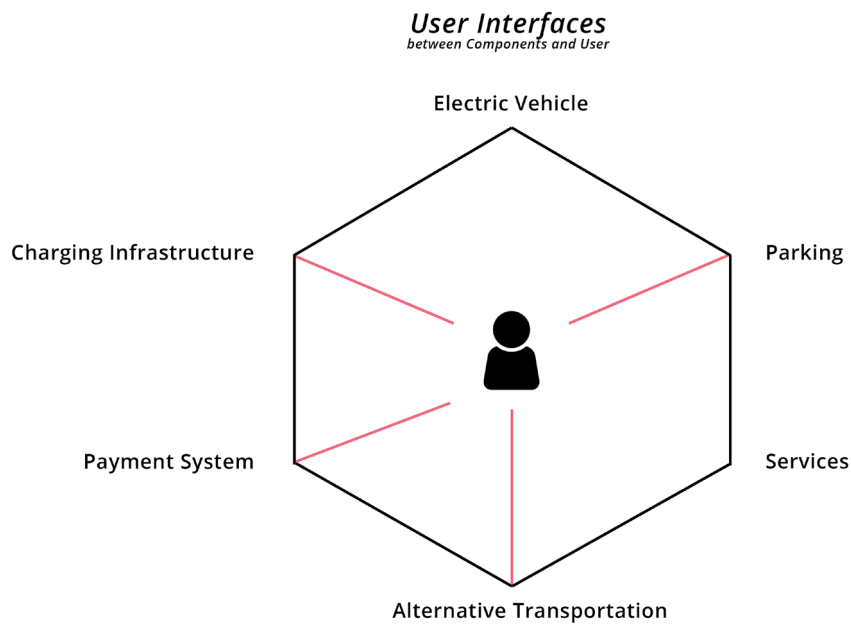
Services

The users need to be informed of the available services at the E-Hub. A user interface can assist in informing the user of the possibilities, in addition to booking facilities.



[Figure 9] Desired data from components to the user

The illustration above shows the information and options that users would want from each of the components. The system would be complete if the desired functions and data were provided to the user.



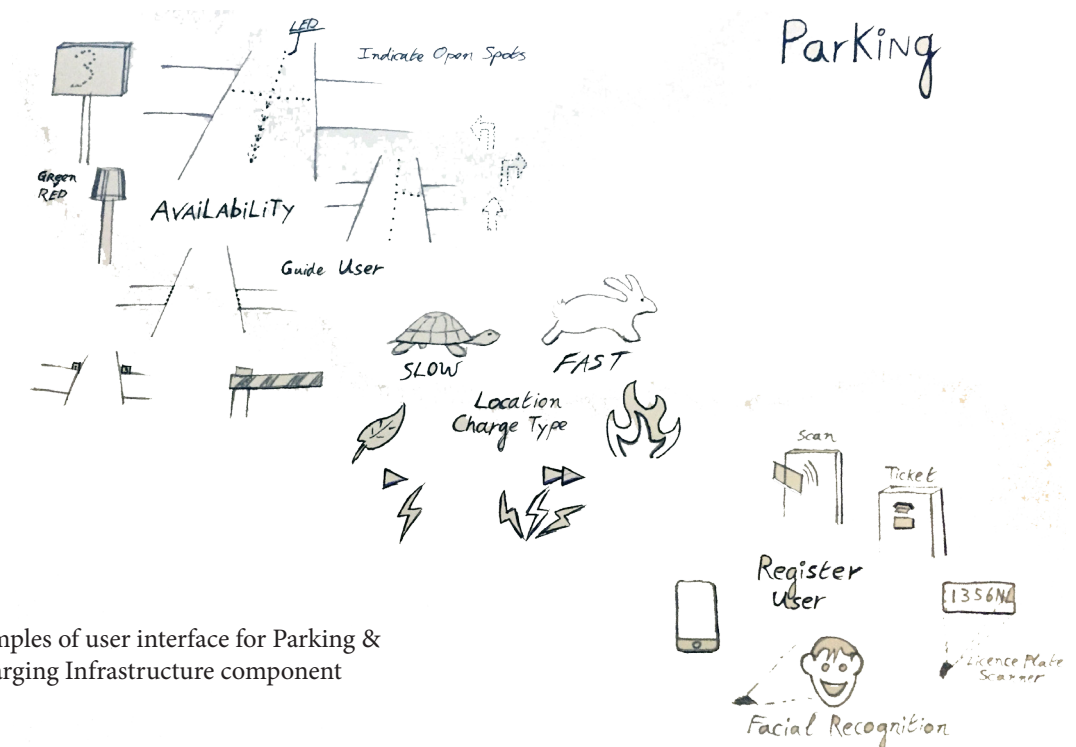
[Figure 10] Actual user interfaces between components and user

In figure 10 the actual user interfaces needed to be developed for the E-Hub can be seen. A user interface no longer needs to be created for the Electric Vehicle and Services due to the reasons previously mentioned. Services has no user interface as it is uncertain which services will be provided and may be the task of the other company providing the services.

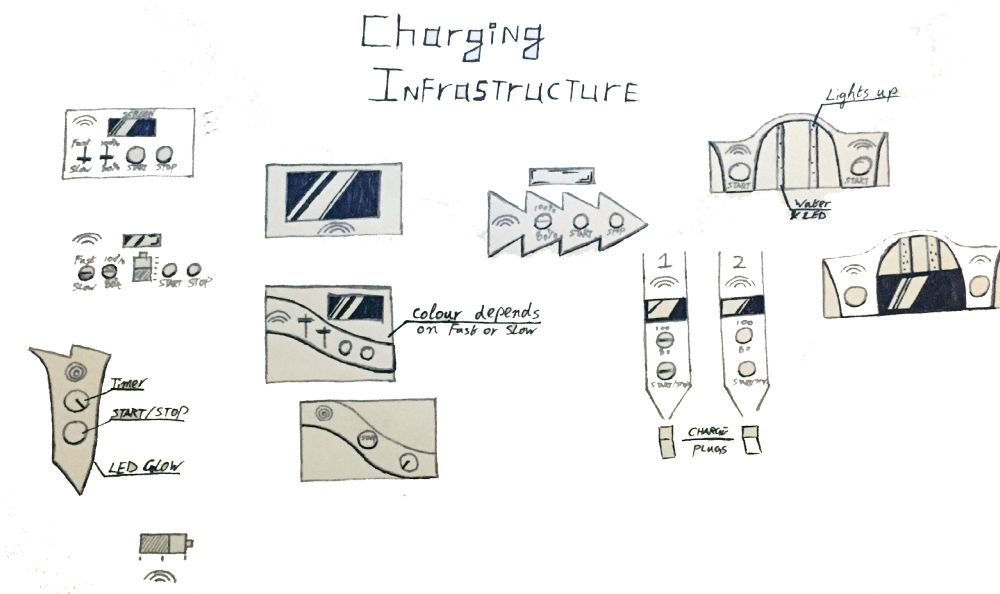
4.2 Different User Interfaces per Component

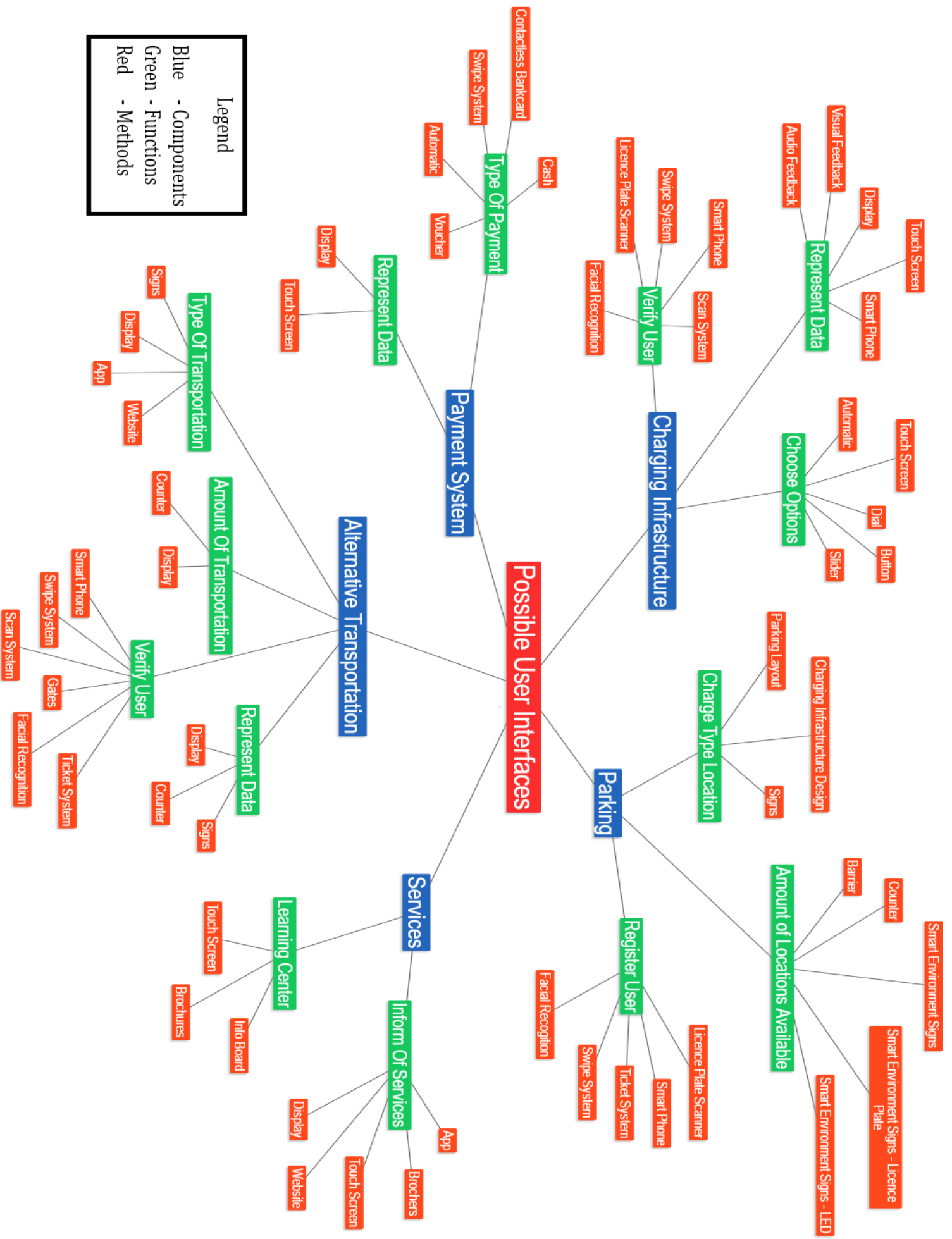
On the following page a mind map is created to provide an overview of different methods to fulfill the functions of the components. The main components are shown with their corresponding functions and extended with multiple methods. The mindmap allows us to have an overview of the different methods and choosing a single or multiple method which is most appropriate.

This can be used as a basis when developing a user interface for a certain component. Some methods are applicable to multiple components and could be combined.



[Figure 11] Examples of user interface for Parking & Charging Infrastructure component





4.3 E-Hub User Interface Conclusion

Before exploring the different possibilities for user interfaces, it is necessary to look at each main component individually. A user interface does not need to be developed for all the main components as some may already have one. The crucial items to look into for the components are the functions and the data.

Which functions are expected of the components from the user? The components need to provide the necessary functions to the user. The functions enable the user to achieve the desired result.

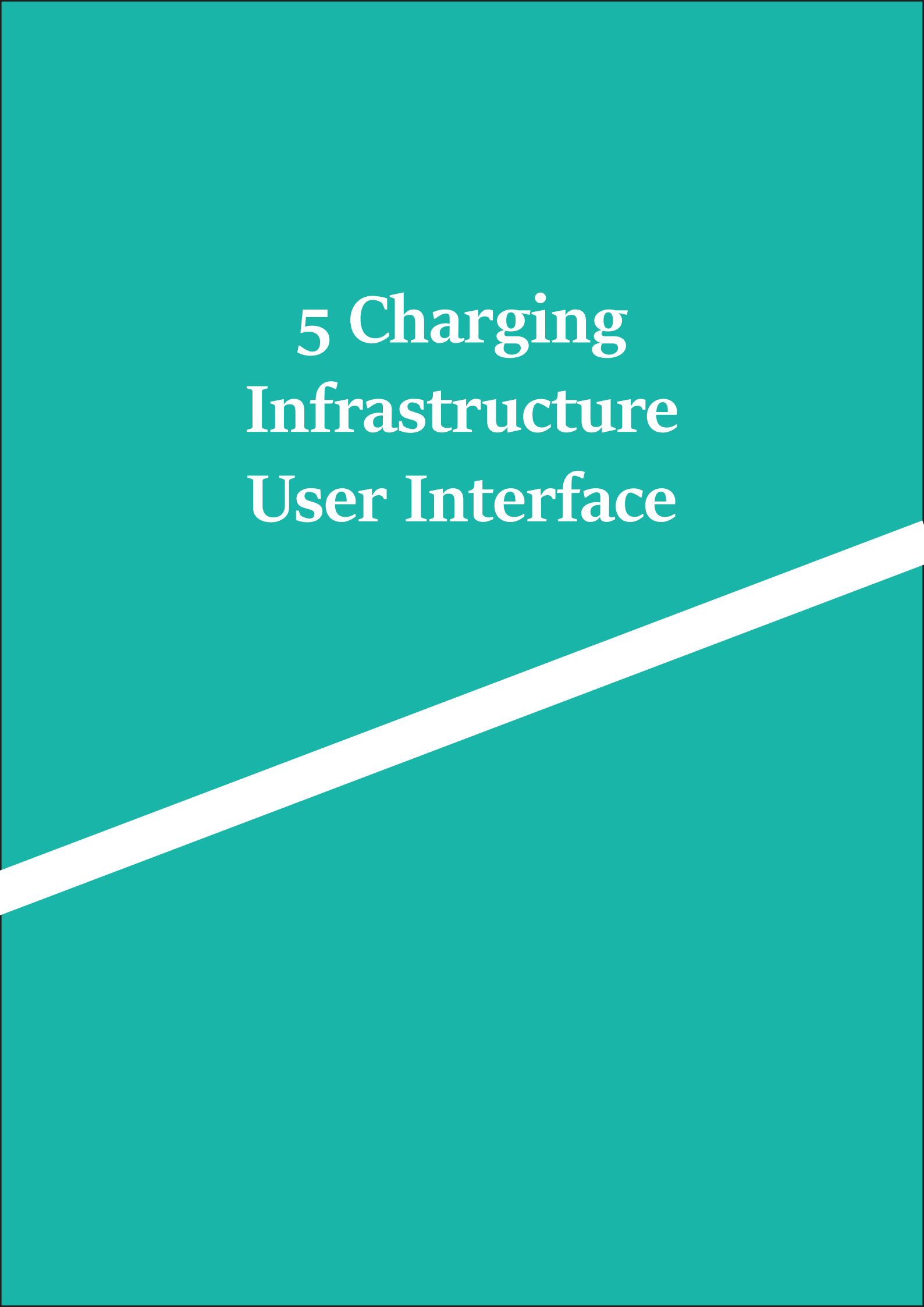
Which data are expected of the components from the user? The data that is provided by the components will aid the user in having awareness of the situation. The more the user is aware of the situation, the easier it is for them to make a choice and to guide them through the E-Hub.

Once the functions and data are defined, the possibilities for user interfaces are explored. The possibilities are focused on achieving the function in a clear manner.

The options are to be further investigated by the follow-up project to exhaust the different possibilities and determine which is most proper for the component.

The following chapter will continue on the real goal of the bachelor assignment which is the development of the user interface for the charging infrastructure.

5 Charging Infrastructure User Interface

The background is a solid teal color. A thick white diagonal line runs from the bottom-left corner towards the top-right corner, passing behind the text.

5.1 Charging Infrastructure

The charging infrastructure is one of the main components of the entire system. The charging infrastructure is in charge of enabling the users to charge their electric vehicle. This section will go in depth on the charging infrastructure and the design of the user interface.

Starting with what the user would want from a charging infrastructure. The user would want to charge at the charging infrastructure by taking the charge plug from it and inserting it into the electric vehicle. The actions taken should be similar to that of a gas station to ease the implementation of the E-Hub. Furthermore the user would want information from the charging infrastructure such as; the time remaining until the electric vehicle is completely charged, an indication of the current status of the charging infrastructure, and the cost of charging.

Certain decisions were made during the development of the E-Hub which will affect the design of the charging infrastructure. One of decisions was to divide the parking into two, a short term and a long term parking. The implications of this decision is a more structured parking lot, better energy distribution and separate attention to each of the types. Time is an important factor for the short term parking. Therefore the short term parking would be located closer to the building to increase the efficiency of time.

The long term parking are vehicles that are parked and charging for more than 2 hours. Time is no longer an important factor for the long term parking, therefore the parking spots are located further away from the building. Due to the extended period of time that the electric vehicle is parked a roof is provided above the long term parking. The roof will have solar panels to aid in the charging of the electric vehicles.

Another important decision was to base the E-Hub system on the centralized architecture. This architecture would ensure a streamlined system as it allows the user to use all the components of the E-Hub. The costs of using the components will continue to be added and the payment is due once the user is finished with the E-Hub. This architecture favors a card-system with membership.

The users need only to swipe their card before using a component and the system will keep track of the usage. Once the user returns to their vehicle, they must swipe their card to stop the charging and the summed cost will be displayed.

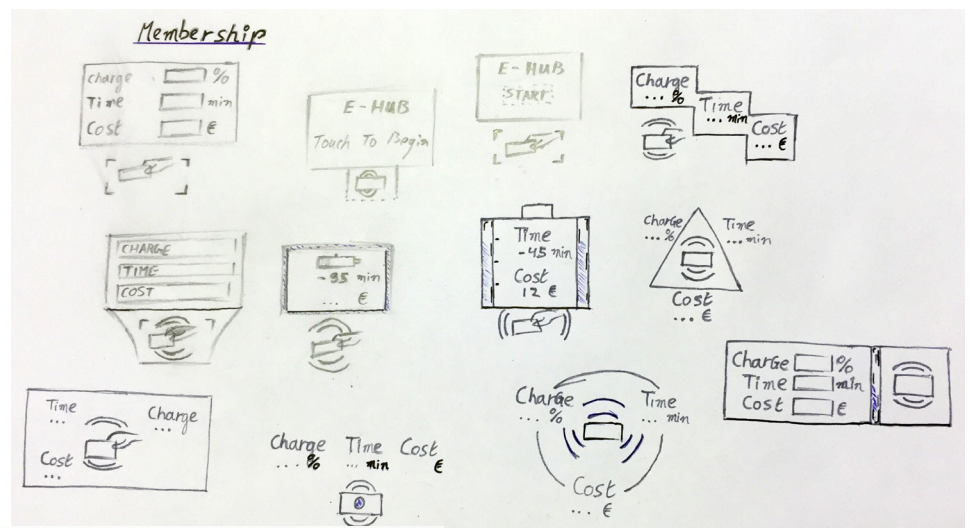
The implications of the decisions for the user interface of the charging infrastructure is the removal of the choice in charging types, and the implementation of a card swiping technology.

5.2 Idea Phase

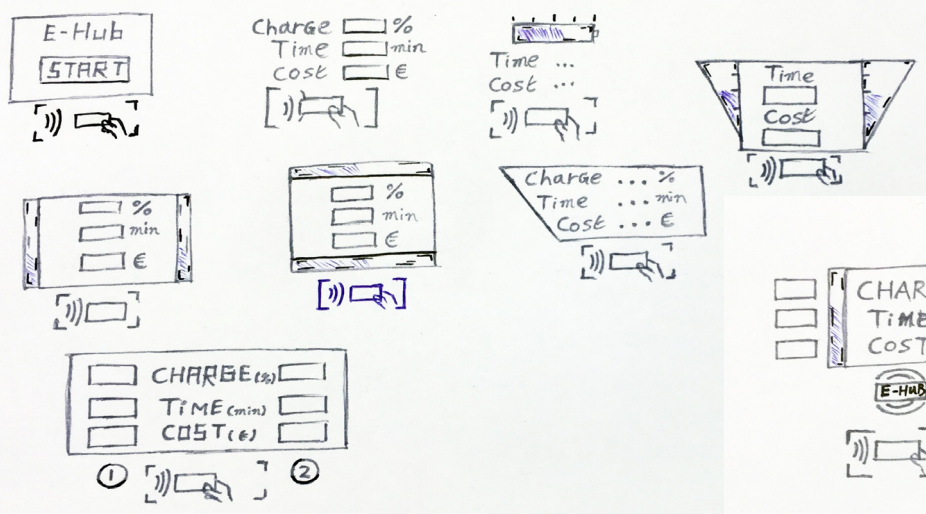
Design Brief - User Interface Charging Infrastructure

- Must display current status of the charging infrastructure
- Enable charging of electric vehicle
- Must display current battery level of the electric vehicle
- Must display estimated time left until completely charged
- Must display total costs of E-Hub usage of the user
- Instructions must be visible

Ideas are sketched using the requirements set which can be seen in the illustrations below. The user interfaces are sketched with distinguishable characteristics. The difference lies in how the user operates the user interfaces. For example values can be presented through a 7-segment-display or a touch screen. Scanners are used to either scan membership cards, debit cards, or both. LEDs are found to highlight values such as current charge level, or current status of the charging infrastructure. These ideas are incorporated into the sketches to discern which concepts would best fit the E-Hub.

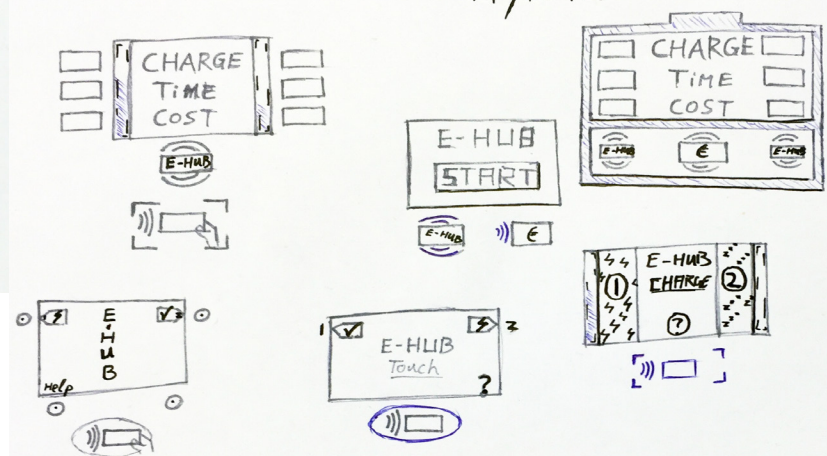


Non-Membership



[Figure 12] Various idea sketches

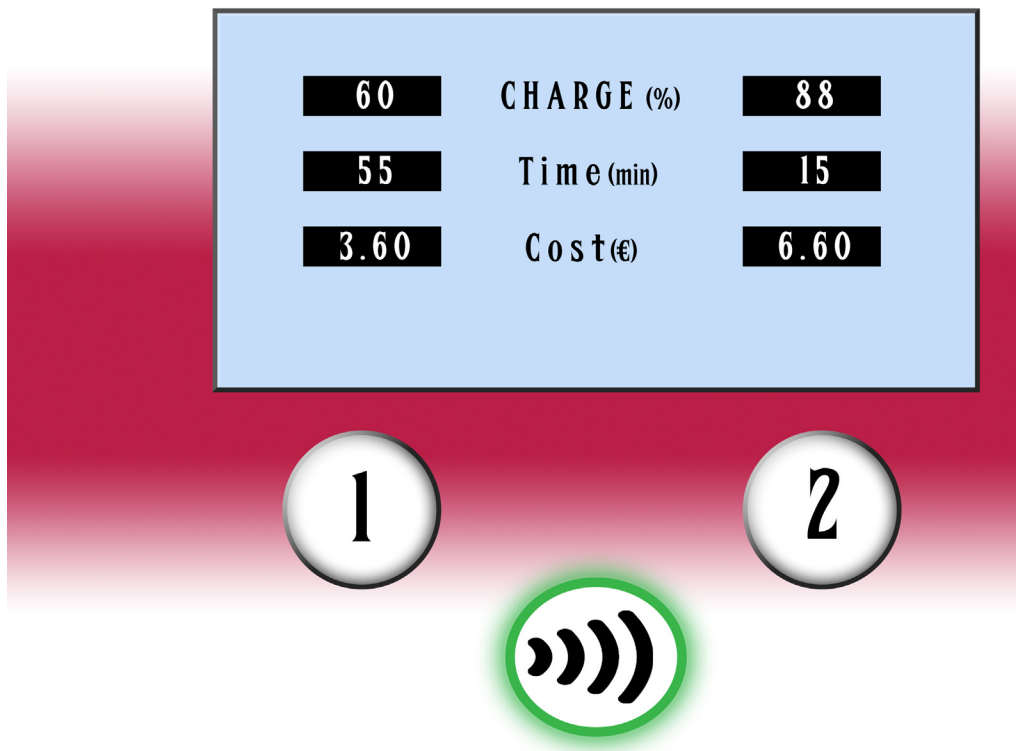
Hybrid



5.3 Concept Phase

This phase will focus on the chosen concepts and their working and reasoning behind them. Concepts are chosen by evaluating the ideas and deciding which ideas are possible solutions for the user interface of the charging infrastructure.

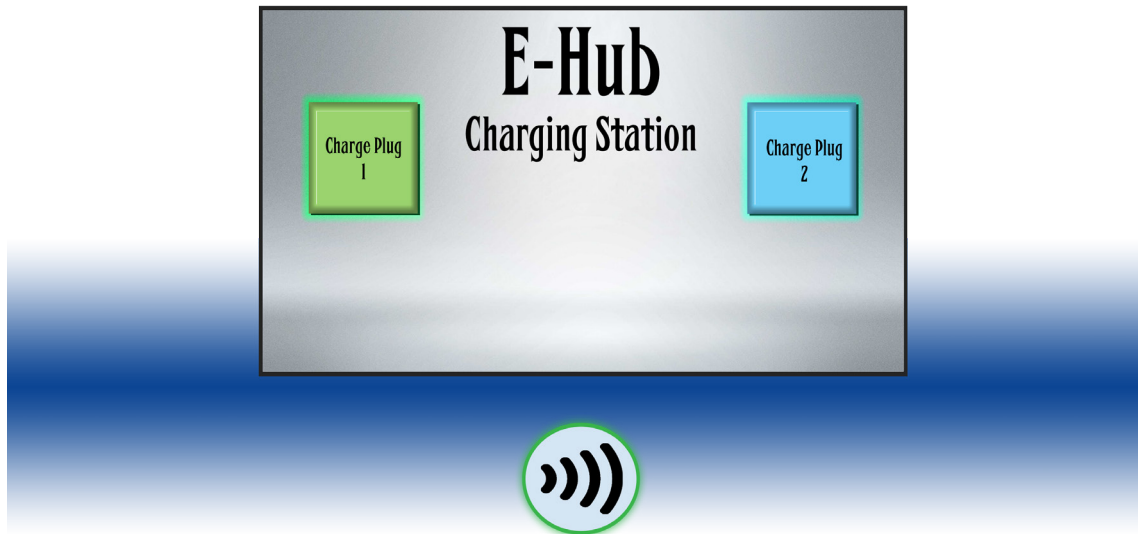
Concept 1



Concept 1 consists of six 7-segment-display, two buttons, a contactless payment scanner, LED highlights, and a sticker.

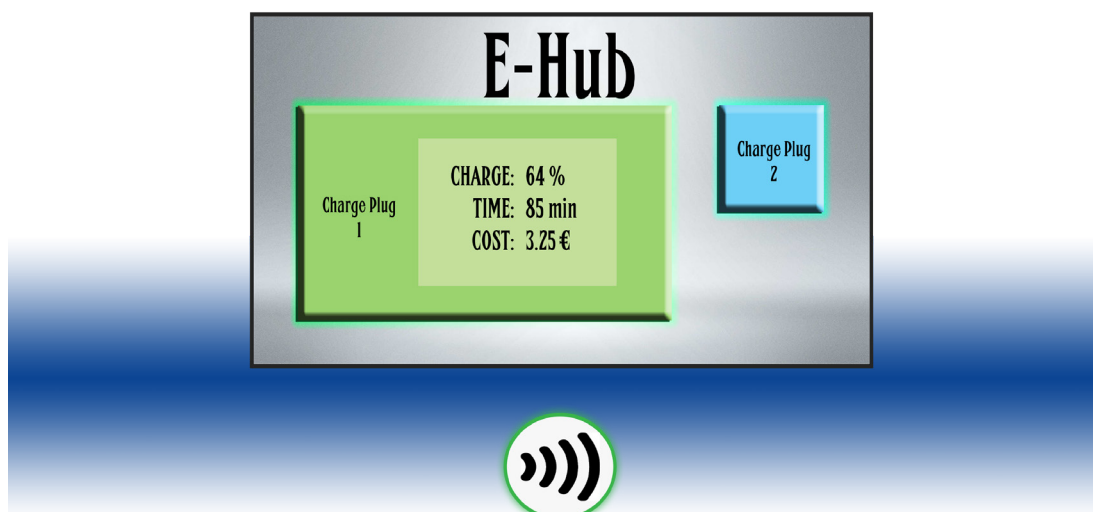
This concept is influenced by the current fuel dispensers found at gasoline stations. The values stated on the sticker are represented on the 7-segment-display. The values will automatically change depending on how long the user has been charging. The values in which the user is interested in is the current amount of charge in the electric vehicle, the time it will take to fully charge, and the costs of charging. The user operates the charging infrastructure by first inserting the charge plug into the electric vehicle. Charging will begin once the user scans the debit card and presses on the button corresponding to the charge plug they are using. The max cost of charging will be deducted upon scanning to prevent fraud. When the user is finished charging, the plug is removed from the electric vehicle and the remaining credit will be returned. An additional sticker with instructions can be found near the user interface to clarify any confusion the user may have.

Concept 2

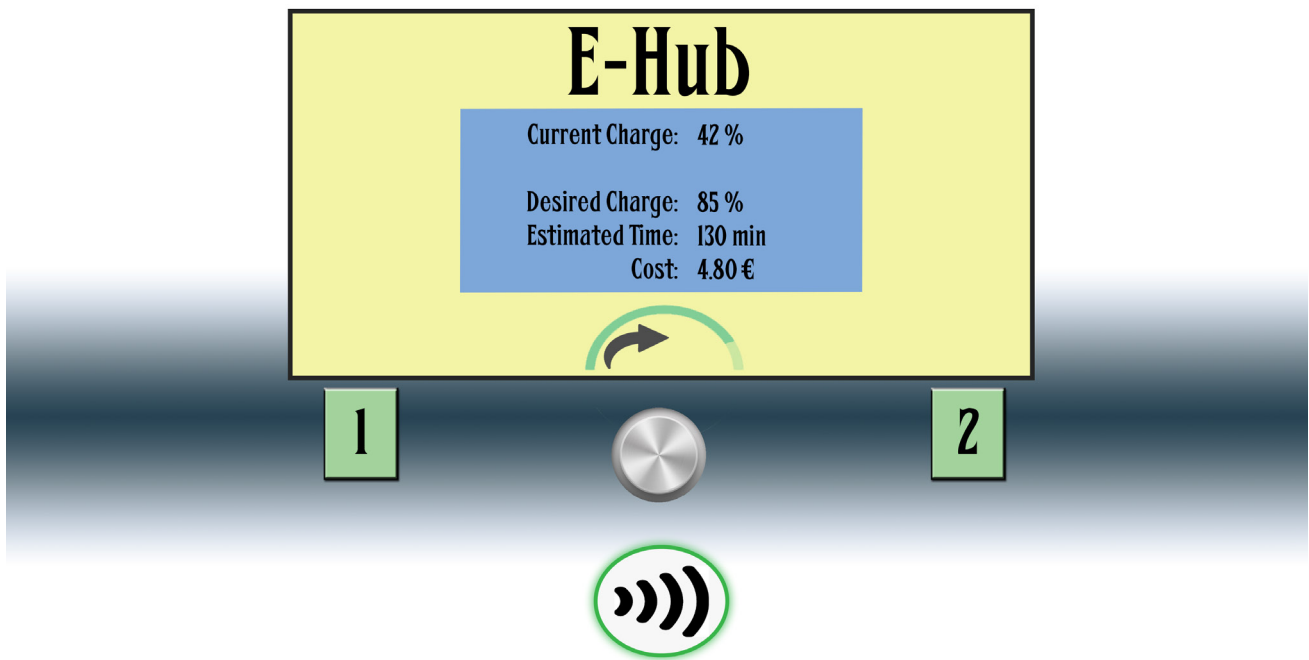


Concept 2 consists of a touch screen, a membership card scanner and LED highlights.

The interaction with the user interface is mainly through the touch screen. Users will touch the corresponding button of the charge plug and follow the instructions stated on screen. The system will request the user to identify themselves by scanning their membership card. Once the charge plug is inserted into the electric vehicle, the charging will begin. The crucial values presented to the user is the current amount of charge in the electric vehicle, the estimated time until the electric vehicle is completely charged, and the costs of charging. Users are able to view the values by touching the corresponding button which will expand upon touch. The user has to scan their membership card again to end the charging and the total costs of using the E-Hub will be presented on screen.



Concept 3



Concept 3 consists of a display, a membership card scanner, two buttons, and a control knob. The concept offers the user the possibility to decide the amount of charge they want. The user must insert the charge plug into the electric vehicle and press one of the corresponding button. The display will show the current charge of the electric vehicle. The desired charge, estimated time, and cost are displayed below, which are coupled with one another. The user can adjust the desired charge by turning the control knob. The desired charge cannot go below the current charge. The half circle meter is used to further visually represent the value of the desired charge. Once the user is satisfied with their choice, they must scan their membership card to begin charging. The charging will stop once the desired charge has been reached or if the user scans their membership card again.

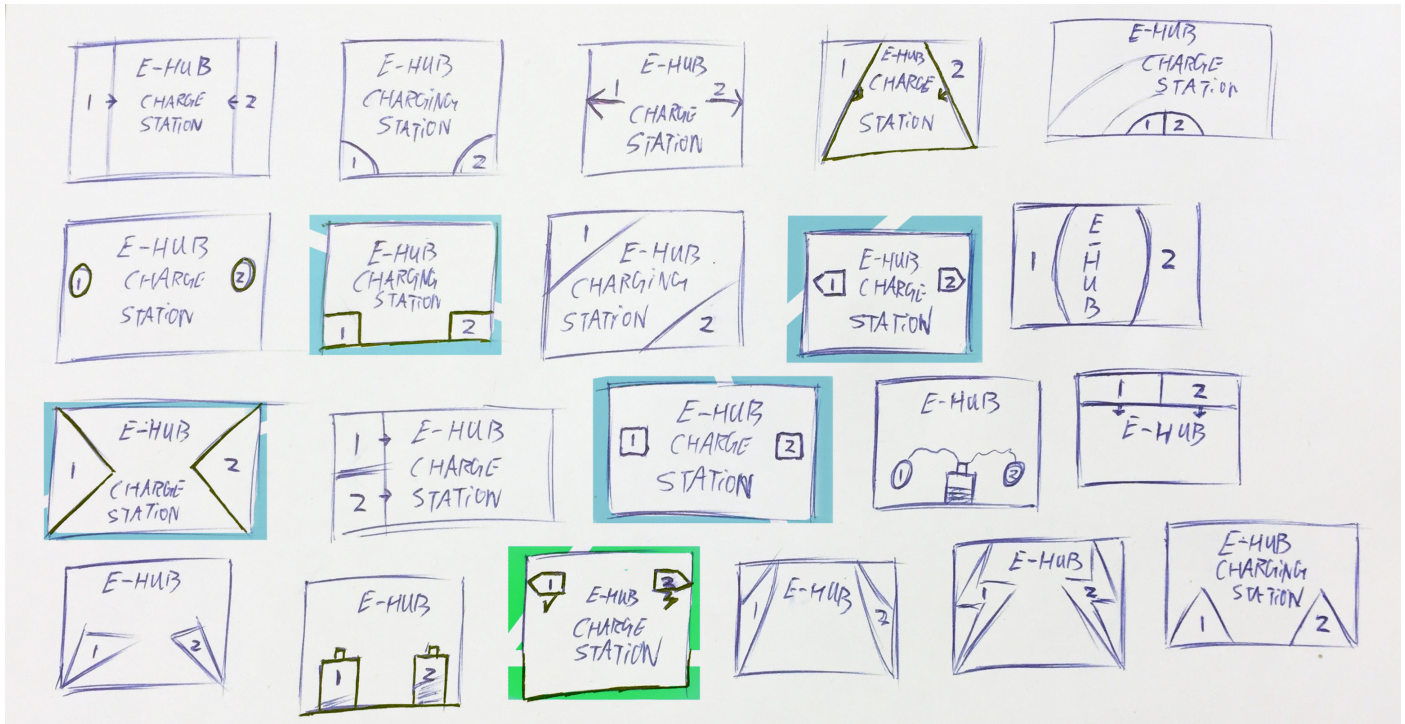
Chosen Concept

It is chosen to further develop the second concept due to the following reasons;

- The first reason is that the touch screen is more attractive than the 7-seg-display in the sense that through a touch screen we are more able to guide the user through the user interface to avoid confusion for the user. The interactivity of a touch screen is also a plus point as it gives the user a feeling of control and the actions of the users are reflected more clearly. Touch screen also allows for more creativity (moving background, animations, advertisements) when compared to the 7-seg-display.
- Concept two also has the least steps to allow the user to begin charging. The user must simply touch the corresponding button and scan their membership card. To be able to decide the desired charge is a nice feature, but it is unnecessary. Removing the option to decide the desired charge will make it much easier for the user and errors are neglected.
- Membership system is a recommendation for the E-Hub as it complements the chosen architecture. With a membership system we can ensure a smoother usage of the E-Hub system while the system keeps track of the usage of the user. With membership the user would only need to swipe their card when they are finished charging and using the E-Hub and the total cost will be automatically deducted from their account. Client loyalty will be an important aspect for the E-Hub if it were to become a success, and membership will allow us to have that. We can create a community around the E-Hub and in return have users handle our products with more care. Promotions could be used to stimulate user to become members of the E-Hub.
- Another reason is the data management that comes with users being a member and having an account. They will be able to keep track of their usage, and as mentioned above the ability to automatically pay for using the E-Hub. As a result it eliminates the possibility of users cheating the E-Hub system due to the system identifying the user upon scanning. The E-Hub will be able to hold the user responsible.

5.4 Detail Phase

Further focus will go into the design of the user interface of the touch screen. The design is crucial for users to understand the system at first sight. Obeying certain rules such as; form follows functions and less is more, will aid the design in being intuitive. The user interface should guide and aid the user in the decision making. Simplicity is key to not overcomplicate the system and to avoid clutter. Various sketches are made to identify possible layouts and how the response will be when an action is taken.



[Figure 13] User Interface layout sketches

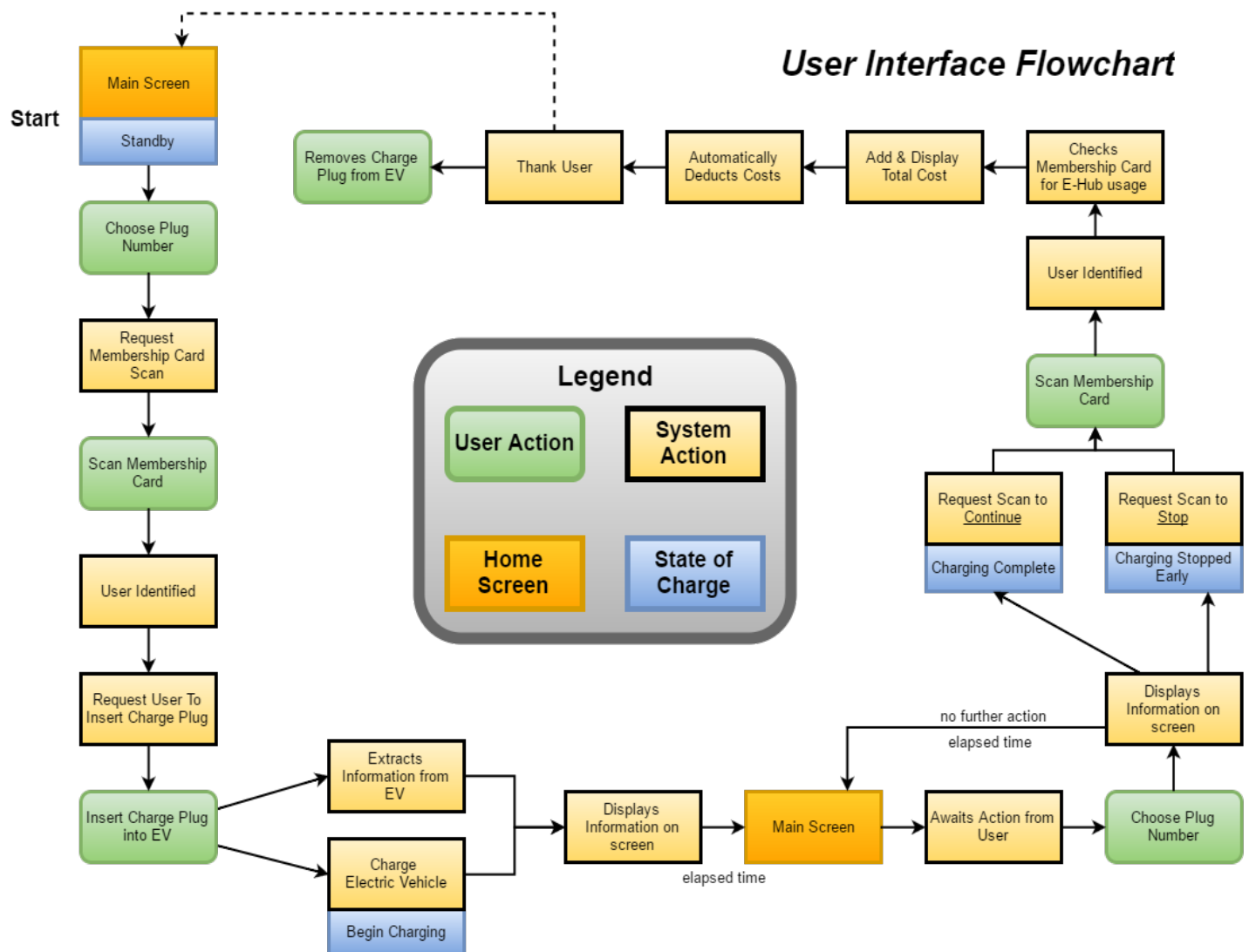
Additional items are considered and added to the design such as; a clock, symbols representing the current state of the charging infrastructure, and a sticker with instructions and directions for support. We believe this will bring more clarity when using the user interface as well as ensure the user of assistance if necessary.

The highlighted sketches are designs which are considered for the layout of the user interface. They are the most clear by having the buttons separated and showing the corresponding charge plug, as well as visibly showing the user which button to touch.

The green highlighted sketch is chosen for the final design. The design is chosen based on which would be most comprehensible by the users. It incorporates the separation of the buttons and adds a direction to further reinforce the connection with the charge plug. The symbols are used to inform the user of the current status of the charging without having to touch the button first.

5.5 Interaction with System

The section will focus on how the user interacts with the charging infrastructure to achieve the function of charging the electric vehicle. The user needs to take certain action to charge their vehicle, while the system reacts to the user's action. A flowchart of the user interface is created and shown below. The chart illustrates the actions of the user, the actions of the system, and the state of charge.



[Figure 14] Flowchart of the User Interface

5.6 User Interface Prototype

With the actions of both the user and system defined, a prototype of the user interface is created using the program Intuiface.

The actions are in line with the User Interface Flowchart. The main functions of the charging infrastructure and the steps needed to achieve them can be found below. The images of the steps are shown in the following section.

To Charge Vehicle

- 1.1 The user presses on the button corresponding to the plug that they are going to use.
- 1.2 The system instructs the user to swipe their membership card.
- 1.3 The user scans their membership card.
- 1.4 The system will verify and register the user.
- 1.5 The system instructs the user to insert the charge plug into their vehicle.
- 1.6 The user takes the charge plug from the charging infrastructure and inserts the charge plug into the electric vehicle.
- 1.7 The system will extract information from the electric vehicle
The charging will begin.
- 1.8 The values will be displayed on the touch screen.
The user will receive an estimated time until charging is complete.

To Stop Charging

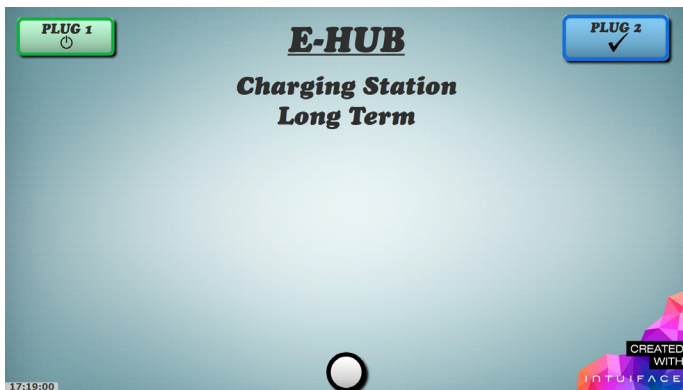
- 2.1 The user presses on the same button earlier.
- 2.2 The values are displayed on the touch screen.
'To stop charging, swipe membership card' will be displayed.
- 2.3 The user scans their membership card.
- 2.4 The system will verify the user
The system will check if the user has used other E-Hub components.
- 2.5 If so, the costs will be added.
- 2.6 The system will display the total cost to the user
and the cost will be automatically deducted from the user's bank account.
- 2.7 The system will thank the user for using the E-Hub.
- 2.8 The user will remove the charge plug from the electric vehicle and place it back into the charging infrastructure.
- 2.9 The system will display the home screen and show it is available for use.

Charging Completed

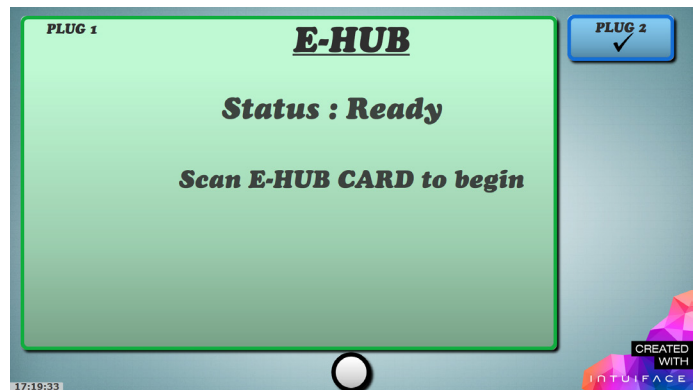
- 3.1 The user presses on the same button earlier.
- 3.2 The values are displayed on the touch screen.
100% charge and the cost is shown.
'To continue, swipe membership card' will be displayed.
- 3.3 The user scans their membership card.
- 3.4 The system will verify the user
The system will check if the user has used other E-Hub components.
- 3.5 If so, the costs will be added.
- 3.6 The system will display the total cost to the user
and the cost will be automatically deducted from the user's bank account.
- 3.7 The system will thank the user for using the E-Hub.
- 3.8 The user will remove the charge plug from the electric vehicle and place it back into the charging infrastructure.
- 3.9 The system will display the home screen and show it is available for use.

User Interface Intuiface

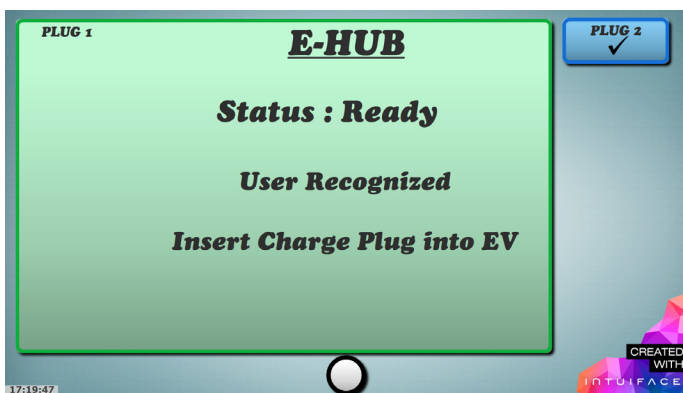
A button is placed on the bottom of the user interface design to simulate scanning a card.



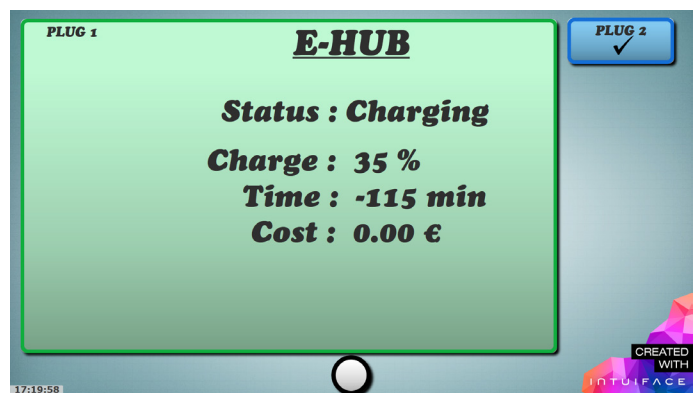
1.1



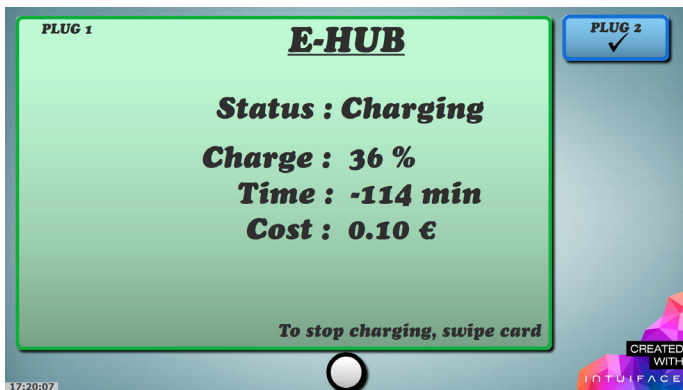
1.2



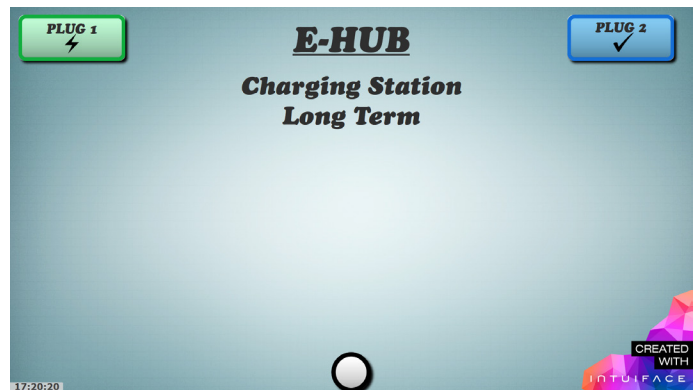
1.4 - 1.5



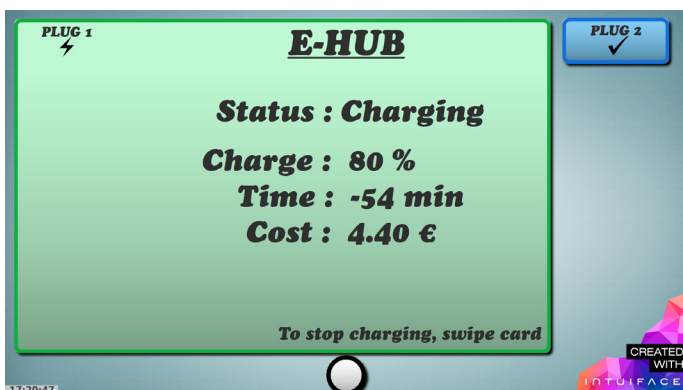
1.7 - 1.8



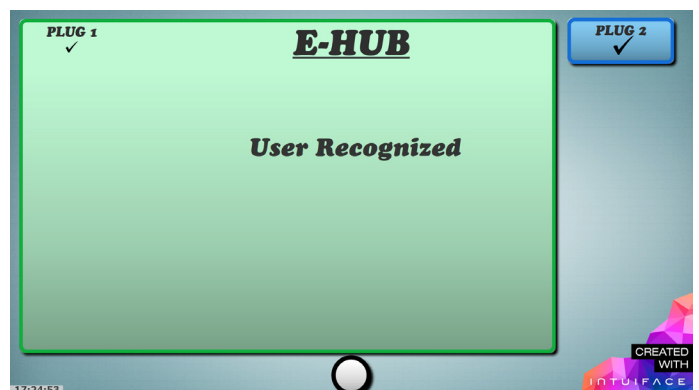
1.7 - 1.8



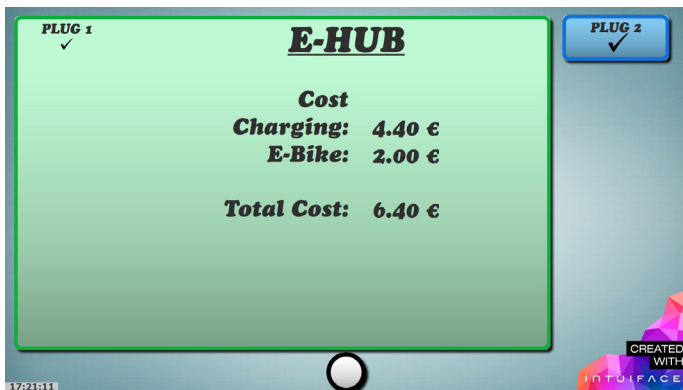
2.1



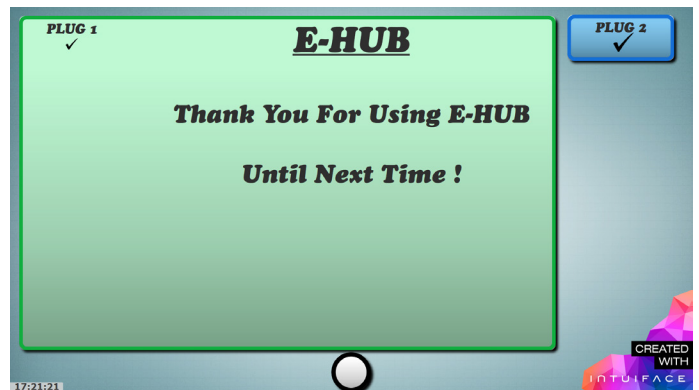
2.2



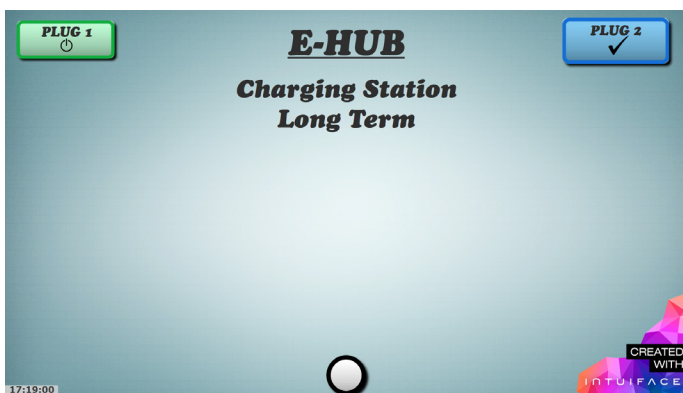
2.4



2.5 - 2.6



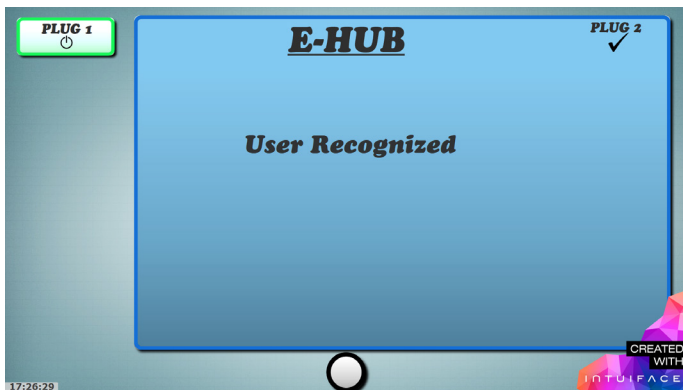
2.7



2.9 - 3.1



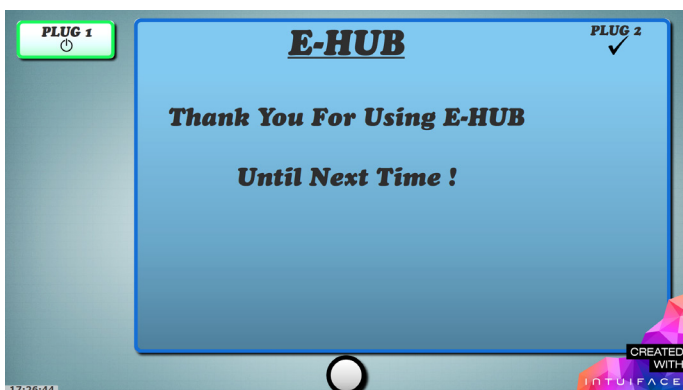
3.2



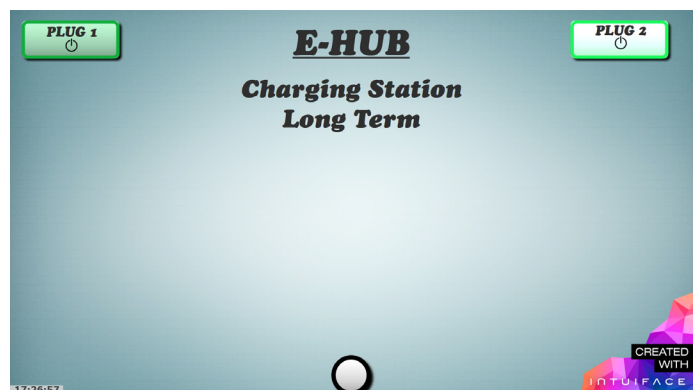
3.4



3.6



3.7



3.9

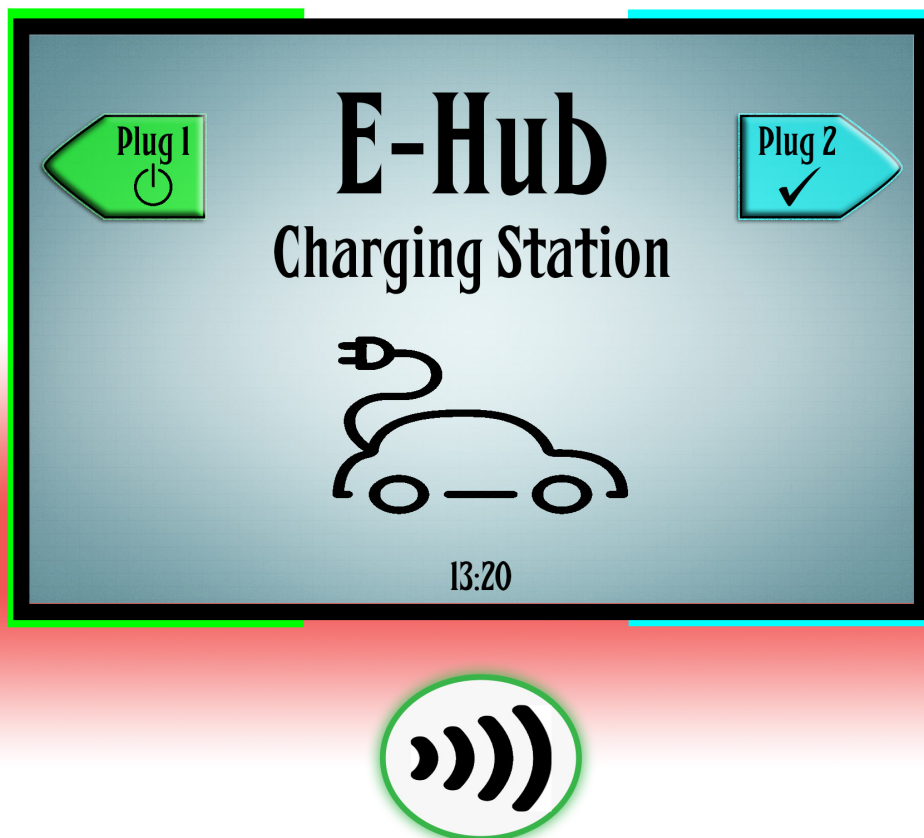
5.7 Final Design

The optimised design of the user interface can be found in the image below. The design is aimed at being convenient and consistent in combination with the membership system.

A membership card scanner can be found below the touch screen. It includes a LED ring which will light up when the system requests the user to scan their card.

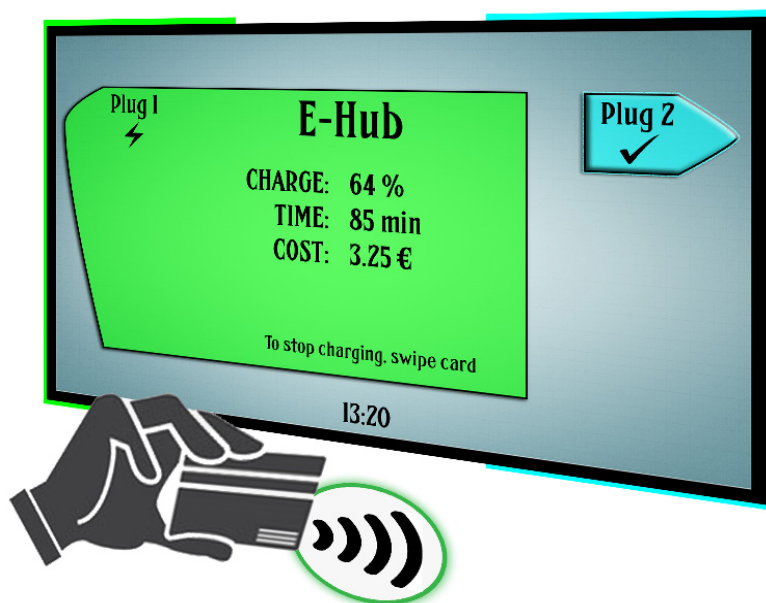
Two buttons are placed on the separate ends of the touch screen, pointing in the direction of the corresponding plug. The LED lights and symbols are used to reinforce the perception of the current status of the charging infrastructure.

Once the button is pressed, it will stretch out to provide a background for the instructions and values. It is chosen to stretch the button into the background to reinforce the idea that the user is interacting with the correct plug. The brand name and clock are found at the center of the touch screen and can be seen at all times.



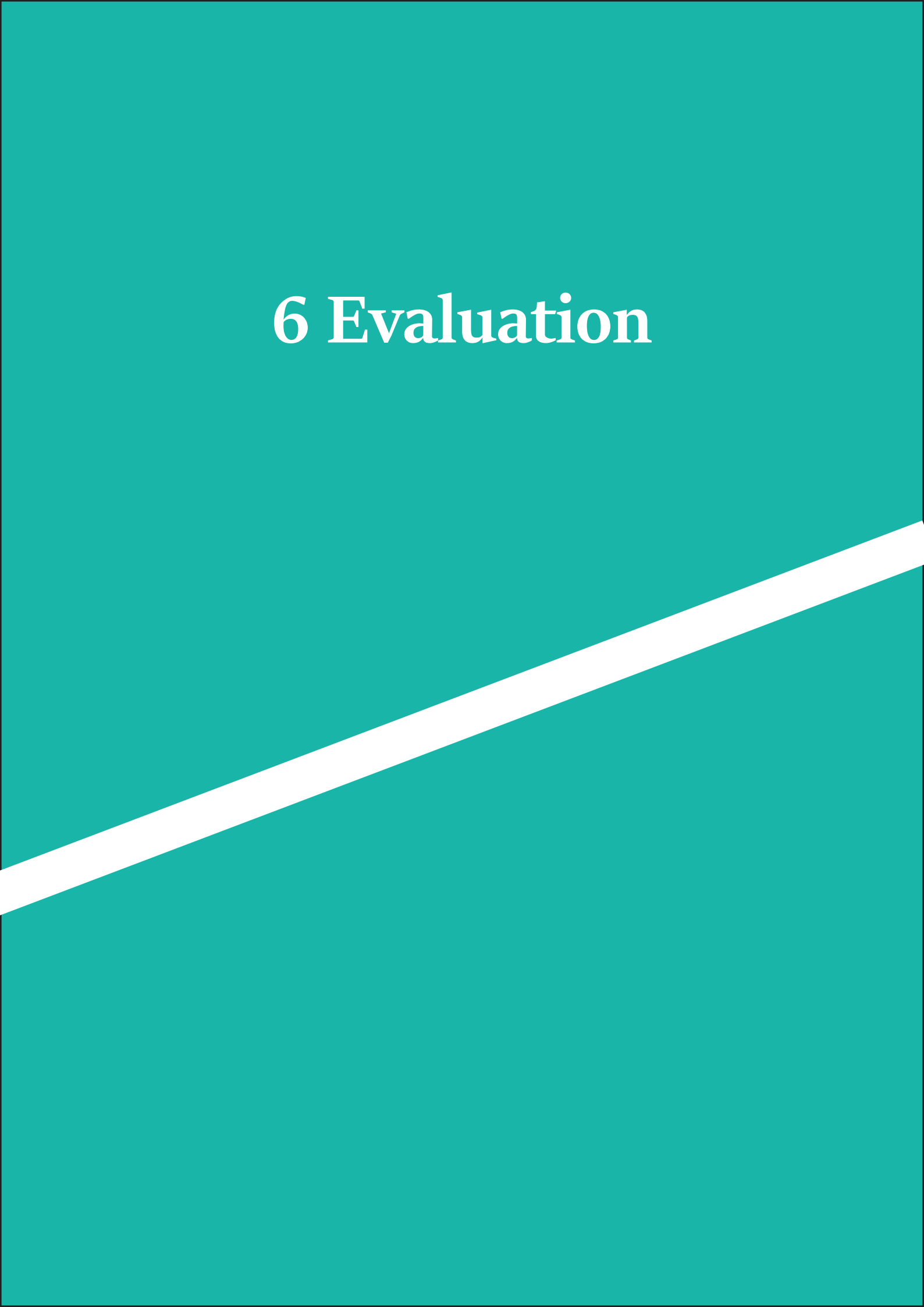


[Figure 15] Home Screen & Touching User Interface



[Figure 16] Displaying Value & Scanning Card

6 Evaluation

The background is a solid teal color. A thick white diagonal line runs from the bottom-left corner towards the top-right corner, dividing the page into two triangular sections.

6.1 Conclusion

The concept of the E-Hub has been made more concrete due to this assignment. The components belonging to the E-Hub and the system which determines how those components interact with one another has been defined. Implementing the developed system will allow for a smooth adaptation by the users. The system does direct the users to all become a member of the E-Hub first, which does give it a sense of exclusivity, however the benefits outweigh the cons. The E-Hub will be able to take advantage of it. A strong brand identity can give the users a perception of trust and community. Excellent service and reliable products will reinforce the perception of trust. While deals can be given out to members as an incentive to become one or stay as a returning consumer.

Once the system is defined, the focus shifted on the development of the user interface.

The charging infrastructure is analysed and a fitting user interface has been developed to accommodate the system. The user interface is aimed at increasing the convenience, by ensuring that the usage is as streamlined as possible, while eliminating possible user errors. Clarity is enhanced in the design with the use of the different elements; LED, symbols, and direction.

The conceptual development phase is concluded and the following project group will certainly be able to use this paper to continue the development of the E-Hub, which will one day become a reality.

6.2 Follow-up Design Opportunities

This project has given way to numerous interesting follow-up design opportunities; further analysis and research will have to be undertaken to further develop the E-Hub. These opportunities are mentioned below.

User Interface In Electric Vehicle

In this paper it is stated that it is difficult to develop a user interface for an electric vehicle as each manufacturer has a unique software and issues. If these issues could be solved, the convenience for the user may be increased due to the usage of the E-Hub system within the comfort of the electric vehicle.

Website

The development of a website is recommended to allow the E-Hub to inform the users and potential users. The website would aid the users in grasping the concept of the E-Hub, as well as allowing the E-Hub to communicate with its users. The E-Hub can take advantage of the website and promote its systems and services. Members would be able to manage their account and have an overview of their usage.

Application

An app would be useful to the E-Hub to enable the users a simplified overview of the situation. With an app the users would be able to see on their smart phone for example; how much charging time is remaining, receive notifications when charging is almost completed, see how many E-bikes are available at the E-Hub, provided services at current E-Hub location, and manage the user account to an extent. The app could possibly also be used to verify the users at the different components belonging to the E-Hub.

Further Development Of The Architecture

Additional research on the architectures is advised as the entire E-Hub system will be based on the architecture. The architecture of the E-Hub will decide if the system is efficient or not, and thus if users will use the E-Hub. The architecture is crucial for society to accept the E-Hub and alter their way of living. The type of architecture may vary depending on location or phase of the E-Hub. Perhaps a decentralized system is more preferable at the launch of the E-Hub, while a centralized system could be more preferable when users have been accustomed to the E-Hub.

To Automate System

In an ideal situation the entire system would be automated. Users would enter the E-Hub and be able to use all the components without needing to manually verify themselves to the system. The system would keep track of the user's activity and deduct the costs automatically. An automated system may improve the convenience of the user, though it may have issues with privacy and trust.

Further Development of User Interfaces in Other Components

In the paper examples were given for possible user interfaces per component. The other user interfaces should all be coherent with one another to increase the acceptance of the E-Hub. The possibilities could be researched more in depth to better decide the most fitting user interface for the components.

7 Appendix



7.1 Participants

During the fourth quarter, five students are working on the E-Hub research project. Two of the five students are working fulltime on the project, the other three contribute by means of a subject on the TU Delft. The E-Hub team consists of the following members with their particular function within the E-Hub project.

Management Team

Gertjan de Werk – Project manager
Dutch-INCERT

Sjoerd Moorman – Project leader
MSc Sustainable Energy Technology – TU Delft

Maurice Thijsen – Assistant manager
BSc System Engineering, Policy Analysis and Management – TU Delft

Natalia Aleksandrova – Energy Club project commissioner
MSc Sustainable Energy Technology – TU Delft

Research projects

Justen Ang – Design of charging infrastructure user-interface
BSc Industrial Design Engineering – UTwente

Robin Vos – Design of charging infrastructure
BSc Industrial Design Engineering – UTwente

Pamela Nunez Araya – Socio-technical analysis of transition of existing infrastructure and business model development
MSc Management of Technology, Emerging Technology-Based Innovation & Entrepreneurship – TU Delft

Palak Gupta – Energy-efficient building design and integration of renewable energy sources
MSc Sustainable Energy Technology – TU Delft

Shaista Kalpoe – Analysis and design of integration process into the electrical grid from technical and institutional perspective
MSc System Engineering, Policy Analysis and Management, Energy & Industry – TU Delft

This very wide range of expertise creates a team with different knowledge and skills which will greatly contribute to the early conceptual development stage of the E-Hub.

7.2 Fabcity



Showcase E-Hub Concept

Idea Box for Fabcity



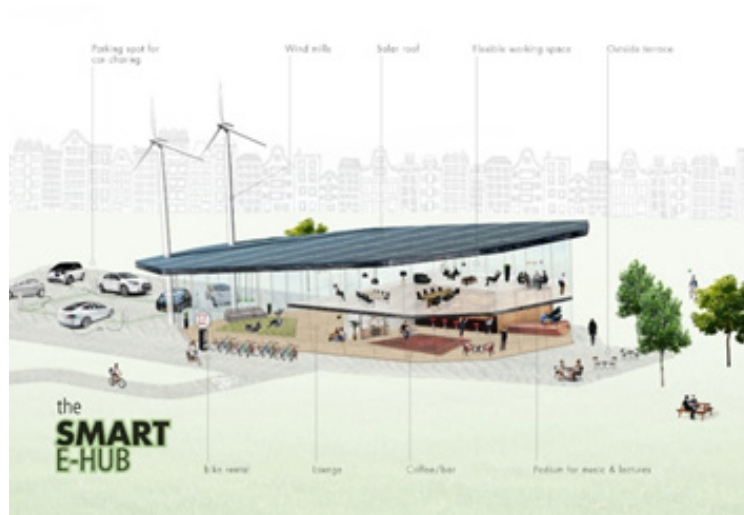
E-Hub Team



7.3 Assignment Description

Innovation in electric mobility: the E-Hub

Would you like to be involved in the development of the **charging station of the future?**



The E-Hub is a concept that is aimed at breaking the chicken-egg cycle in the electric vehicle and charging infrastructure debate by providing an innovative solution for electric vehicle charging. This will be a hub where people will want to come to charge their car and can spend their time productively by making use of the facilities on site, or change over to an electric bike for further transport into the city centre.

This concept will be presented in April at the FabCity Campus in Amsterdam where the Future of Everyday Living in Europe will be explored. And a mobile version of the E-Hub will be developed to showcase this innovative solution to the rest of the world.

Involved parties are the Technical University of Delft, University Twente, Amsterdam University of Applied Sciences and Dutch-INCERT (cooperation between knowledge institutes for electric mobility). There are opportunities in the design of the building, user interfaces, smart charging infrastructure, the integration of renewable energy sources, logistical planning, and much more. You can be involved in this project as a bachelor or master thesis to think with us about the future of electric mobility!

Please feel free to get in touch for any questions:

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sjoerd.moorman@d-incert.nl

Justen Ang

s1063219

j.r.e.l.ang@student.utwente.nl

Plan van Aanpak – Bachelors Assignment

Designing a user interface for the E-Hub.

Actor Analysis

The client is D-INCERT (short for Dutch Innovation Centre for Electric Road Transport). D-INCERT is a network organization which connects scientific research, technological innovation and education with the transition to electric road transport in The Netherlands. The organization was founded in 2008 by the Universities of Technology (TU Eindhoven, TU Twente, and TU Delft), and the Universities of Applied Sciences from Rotterdam, and Arnhem/Nijmegen (HRO and HAN). The organization collaborates with companies as well as the universities aimed at working together on technological innovations for electric mobility and road transport. Strategic partners such as ProRail, KEMA, Eneco, NGInfra, ANWB, and Essent have joined D-INCERT to come up with new innovations.

The aim of D-INCERT is to work together with others to share knowledge, develop joint innovations, and research ways to implement them into society. Developing towards a sustainable future for the world.

Project Framework

Currently there is a large global energy demand which the world now recognizes and urgently is on the way to adopting a more sustainable course towards energy usage. Transportation consists of 27% of the total energy use, as well as contributing to a high fraction of the CO₂ emission. One of the sustainable courses is replacing fuel cars with electric vehicles, in hope of conserving precious resources and combating global warming. Electric vehicles are not popular due to the lack and effectiveness of charging infrastructures.

D-INCERT is an organization that promotes sustainable courses as well as aids in the development of these courses. One of the main focuses of this project is to develop an innovative solution to implement into society and increase the popularity and usage of electric vehicles. D-INCERT wants to develop the E-Hub; electric charging stations near the edge of the city centre. The E-Hub will be available for users to charge their vehicle, while making effective use of their time. The users will be able to spend their time well at the E-Hub or switch transportation to further proceed through the city.

Furthermore the project consists of creating a Product-Service System around the E-Hub. Six different components can be found here namely; Infrastructure, Charging Options, Parking, Application, Attractive Offers, and Payment Models. These components need to be developed to have a well balanced product as a result.

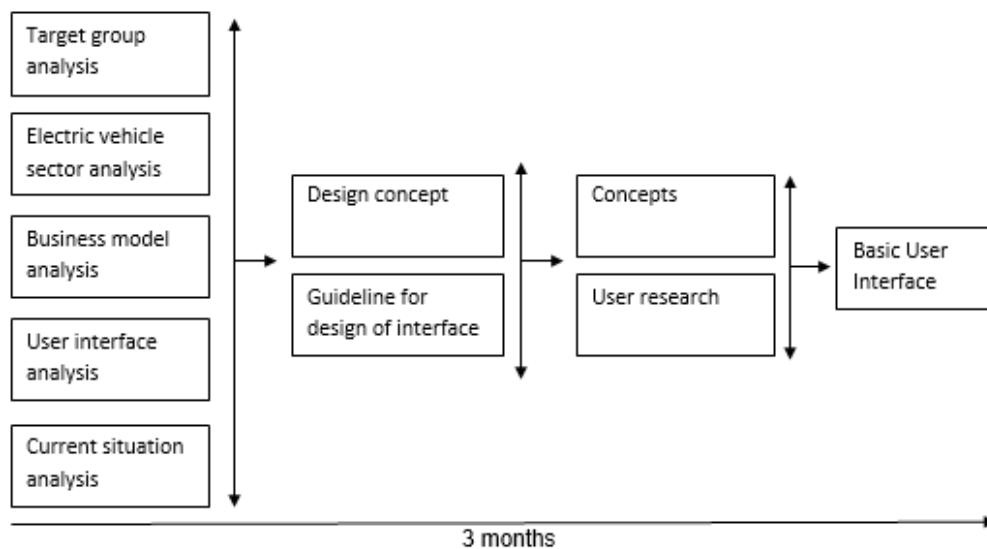
Objective

D-INCERT wishes to develop the E-Hub which will promote and increase the overall acceptance of electric vehicles. The E-Hub is planned to be implemented in the city of Amsterdam.

The goal of this assignment is to research and develop the Application - Product-Service System component, namely the User Interface and the Interface between the different components, which will aid in the usability of the product and correctly informing the users to have an overview of the available choices.

This will be achieved by executing the following steps. The first step will be to hold an analysis on the target group¹, electric vehicle sector, different business models, current situation, and existent user interfaces. The results of the analysis will be used to discern what the best technological approach² will be and to create a fitting user interface for the chosen approach. In the case of multiple approaches, also researching how to best connect these and create a coherent interface. After which a basic user interface³ with functions will be created to demonstrate the end product. Lastly a concrete advice will be given to D-INCERT on how to further improve on the design (if necessary). All of this will take place within a time frame of three months (officially starting in Mei).

Research Model



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