UMEÅ UNIVERSITY

EFFORTLESS CHARGING: ENHANCING USABILITY IN ELECTRIC CAR MOBILE APPLICATIONS

Frida Aringskog

Supervisor: Leonid Freidovich
Examiner: Thomas Mejtoft

Abstract

In recent years, there has been an increased interest in the environment, and various efforts has been made in order to reduce human impact upon the planet. One such effort is transitioning the transport industry from using fossil-fuels to more sustainable fuels, such as electricity. This has led to a heightened interest in electric vehicles.

Although electric vehicles have risen in popularity, they still face some challenges. One of these challenges is the lack of charging stations, and the hassle of charging the car. The complicated charging experience has even been expressed as a barrier, making some people hesitant to buy an electric vehicle. This calls for making the charging experience more intuitive and easy. One possible way to achieve this is by providing the drivers of electric vehicles with complementary tools, such as mobile applications, to aid them with charging. However, for these tools to be effective, it is important that they are designed with usability in mind.

The focus of this thesis is enhancing usability in mobile applications for charging stations. In order to achieve this, a mobile application called Greencharge Infra is used as a case. The current design of this application is evaluated using Nielsen's 10 heuristics of usability. Additionally, a user survey is sent out to representative users in order to better understand the user needs in these kinds of applications. Based on the findings from the evaluation and the user survey, and knowledge from established usability principles, a redesigned application is proposed. This proposal is later tested on representative users to ensure that the new design is living up to usability expectations. During the test, five criteria of usability are evaluated, these are efficiency, errors, satisfaction, memorability and learnability.

The usability test result show that the new design of the application was efficient, induced few errors, was pleasant to use, and easy to learn. Therefore, the overall result of this thesis indicates that applying principles of usability in a real world case does work. The research has also led to wider understanding of how crucial usability is in mobile applications for charging stations.

Keywords
Usability, Mobile applications, Electric vehicles, Charging

Sammanfattning

De senaste åren, har intresset för miljön och klimatet ökat. Detta har lätt till att en mängd olika åtgärder har gjorts för att minska människans påverkan på planeten. En sådan åtgärd är att övergå transportindustrin från att använda fossila bränslen till mer hållbara alternativ, som el. Detta har i sin tur ökat intresset för elektriska fordon.

Elektriska fordon må ha ökat i popularitet men de står fortfarande inför en del utmaningar. En av dessa utmaningar är bristen på laddningsstationer och den besvärliga laddningsupplevelsen.Den komplicerade laddningsprocessen har till och med framstått som ett hinder för vissa personer att köpa en elbil. Det här tyder på att laddningen av elbilar behöver bli mer intuitiv och enkel. Ett möjligt sätt att uppnå detta är att erbjuda elbilsförare kompletterande verktyg, såsom mobilapplikationer, som kan hjälpa dem när de ska ladda. För att dessa verktyg ska vara effektiva är det dock viktigt att de är utformade med användarvänlighet i åtanke.

Syftet med denna avhandling är att förbättra användarvänligheten mobilapplikationer för laddstationer. För att lyckas med detta används mobilappen Greencharge Infra som ett fall. Den nuvarande designen av applikationen blir utvärderad utifrån Nielsen's 10 heuristics of usability. För att få en bättre förståelse för användarna, och deras behov av sådana här applikationer, skickas en enkät ut till representativa användare. Baserat på resultatet från utvärderingen och användarenkäten, samt kunskap från etablerade principer för användbarhet, tas ett nytt designförslag fram. Detta designförslag testas sedan på representativa användare för att säkerställa att den nya designen uppfyller deras förväntningar när det gäller användarvänlighet. Under testet utvärderas designförslaget utifrån fem kriterier, dessa är effektivitet, fel, tillfredsställelse, memorering och inlärning.

Resultaten från användartestet visar att den nya designen av applikationen är effektiv, genererar få fel, är tillfredsställande att använda och är lätt att lära sig. Därmed indikerar resultatet av denna avhandling att det fungerar att applicera principer för användbarhet på verkliga fall. Arbetet har även bidragit till en bredare förståelse av hur viktig användbarhet är för mobilapplikationer för laddningsstationer.

Nyckelord
Användarvänlighet, Mobilapplikationer, Elbilar, Laddning

Contents

1   Introduction

In 2022, the transport sector accounted for approximately 22% of the European Union's CO_2 emissions, according to EU data [1]. However, there has been a decrease in greenhouse gas emissions from new passenger cars, mainly due to the growing number of electric vehicles (EVs) replacing old petrol-fuelled vehicles [2]. Therefore, increasing the number of electric vehicles on the roads can be seen as an effective way to reduce the climate impact of road transport.

One of the challenges of EVs is the limitations of the battery. Although the technology is constantly developing, there are still constraints when it comes to the distance that can be travelled before the battery needs charging [3]. Additionally, charging the battery can be a time-consuming process. To fully charge a battery pack, it can require up to 4 to 8 hours of charging time. Even so-called "fast-charging," which charges the battery up to 80% of its capacity, takes about 30 minutes to complete.

Increasing the number of available charging stations is crucial for the increased adoption of EVs on the roads [3][4]. But, an expanded infrastructure of charging stations is not enough. It is also important that the driver of the electric vehicle can locate and utilize the stations when they are in need of charging. A solution is to provide the drivers with mobile applications to aid them with the charging experience.

These electric car charging applications provide an overview of nearby charging stations, allowing drivers to plan their trips and avoid running out of battery power on the road. The applications might also enable users to book and pay for charging services, as well as monitor and manage their charging history. Although many of these applications exist, and are in service today, a remarkably high number of these applications have low ratings and poor reviews on mobile app marketplaces.

This master thesis will consist of applying principles of usability and user experience (UX) to create a new and improved design for one of these electric car mobile applications.

1.1   External Partners

This project is conducted in collaboration with the Swedish consultant agency Rejlers and their client Greencharge Infra.

1.1.1   Rejlers

Rejlers is a consultant agency founded in 1942, Sweden, by Power Technician Gunnar Rejlers [5]. The company has since then grown from being a small family company to a large organization with offices in Sweden, Finland, Norway, and the United Arab Emirates. Rejlers focuses on digitalization and helping companies to modernize their operations. Through its services and expertise, Rejlers aims to support clients in their digital transformation and drive innovation in various industries.

1.1.2   Greencharge Infra

Greencharge Infra is a company that provides electro mobility services and aims to make the transition from fossil fuel-powered vehicles to electric vehicles easier. They achieve this by delivering software for electric vehicle charging stations and by making it easier for cities and companies to install and maintain these stations [6]. They also provide a mobile application for locating, and monitoring electric car charging.

2 Objective

The Greencharge infra mobile application, like many of its competitors, has received low ratings on app marketplaces. Reviews indicate that customers are experiencing functional issues and that their needs are not being met. Furthermore, the application's design presents limitations in terms of navigation, consistency, and usability. To retain existing customers and attract new ones, an improved application is necessary.

The objective of this thesis is to enhance the user experience of the Greencharge infra mobile application by applying known design theories such as gestalt theory. The aim is to improve usability and to deliver an intuitive and user-friendly interface.

2.1 Design requirements

To determine whether the new design is satisfactory, to both the user of the application and the client in charge of the application, the following requirements have been identified:

- The application should be modern and minimalistic.
- The application should be intuitive and easy to use while being mobile.
- The application should provide the user with feedback about the system's current status.
- The application should provide the user with sufficient feedback to help them identify and recover from errors.
- The process of signing in and signing up should be quick and easy.
- The visual language of the design should be flexible and easily adaptable to different companies or graphical profiles.

2.2 Delimitation

Due to the scope of this thesis, the project will only aim to deliver a hi-fi prototype created in the prototype tool Figma. There will be no real implementation of the application.

3 Theory

In this section, some important concepts of mobile app-design will be highlighted. The section will also include a description of electric vehicles (EVs), and the process of charging an electric vehicle. Although the focus of this thesis is not electric vehicles, but the mobile applications associated with charging an EV, understanding electric cars can be necessary to contextualize the usage of these apps. The section will conclude with an overview of theoretical foundations for the research methods used in this thesis.

3.1 Mobile Application Design

Smartphones, and thereby mobile applications, have become a central part of everyday life for many. When designing applications for the smartphone domain, rather than designing for computers, it is important to realize some key differences between smartphones and traditional desktop computers [7]. One of these differences is the smaller screen size of the smartphone. Another difference is the type of interaction that users have with smartphones, which relies solely on touchscreen input instead of a separate mouse and keyboard. Additionally, the context in which mobile devices are used varies greatly from that of desktop computers. Smartphones are often used on-the-go and in diverse environments, which can present unique design challenges. Mobile devices, in contrast to desktop computers, are generally handheld. This also affect the way the user interact with the device.

3.1.1 Usability

In Human-computer interaction (HCI), or interaction design, the term usability is often mentioned as an important aspect in digital products or services. However, usability is quite often interchanged with other similar sounding terms like "ease of use", "user-friendly", and "useful" which have led to the term of usability being hard to fully define [8].

In the case of this thesis, usability will be defined according to renowned author and usability-champion Jakob Nielsen of *Nielsen Norman Group*. Nielsen [9] simply defines usability as how easy a product or service is to use. According to Nielsen, there are five main concepts of usability. These are:

- **Learnability:** How easy it is for a new user to learn how to use a product or service.
- **Efficiency:** How quickly a user can complete a set of tasks, i.e. how efficient the user is when they use a product or service.
- **Memorability:** How memorable a product or service is. Will a user remember how to use something, even after a prolonged time of disuse.
- **Errors:** The number of errors a user conducts while trying to complete a task.
- **Satisfaction:** How pleasant it is to use a product or service.

To design with usability in mind is important, as a lack of usability can cause users to refrain from using a product or service [8].

3.1.2 User Experience

User experience is related to usability but can be considered a wider concept. Instead of solely focusing on how easy it is to use a product or service, user experience includes other factors such as the user's feelings, perceptions, and overall experience of using a product or service.

Hassenzahl and Tractinsky [10] describe UX as a combination of outer and inner factors. It is not only the functionality or usability of a product; it also involves the user's expectations, needs, and attitude, as well as the context in which the product or service is being used (see Figure 1). Taking this into account, designing for good UX can be a tricky practice, but it opens up new and interesting opportunities. Hassenzahl and Tractinsky argue that UX design goes beyond traditional HCI by not only improving usability and efficiency, but also by designing for fun and pleasure.
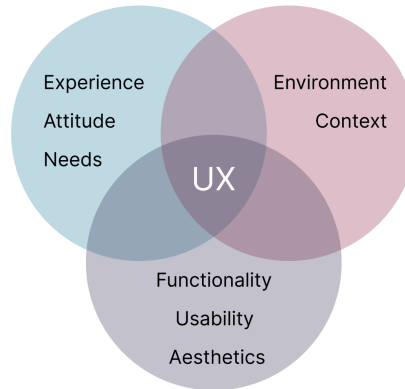

Figure 1: An illustration of the concept of User Experience.

In the book, *Mobile User Experience: Patterns to Make Sense of It All* [11], Mendoza suggests that the mobile user experience is dependent on these domain specific factors:

- **Carriers:** The cell phone carriers and the fluctuations in signal strength depending on the user's location.

- **Device:** What type of device the user is currently using.

- **Screen size:** The screen size of the device, as well as the type of screen.

- **Operating system:** Which operating system the device is using.

3.1.3 Navigation

Navigation pertains to how the user find its way around an application. Important features of navigation are the design of menus and shortcuts, and the order of the different pages of the application. An intuitive and logical order, often referred to as flow, of the application, can make the application easier to use and thereby enhance usability.

Designing navigation for mobile applications requires special consideration for the limited screen size. To address the issue of the smaller screen, a creative solution is to utilize a bigger space than that offered by the screen [12]. This "thinking outside the box"-mindset let designers include more features in their design than what can fit into the confines of the screen. While this can be effective, it's important to make sure the user is aware that there is more content outside the visible screen area.

There are many ways to create navigations in mobile applications [12]. Some common ones are off-canvas navigation, top or bottom tab bars, or springboards (see Figure 2). Off-canvas navigation is when menus are hidden behind a menu button. Top or bottom bars are rows of page shortcuts displayed at either the bottom or the top of the user interface. A springboard is when apps or page shortcuts are displayed in a grid pattern.

Smartphone operating systems, like iOS and Android, traditionally use these kinds of grid patterns for their app displays.
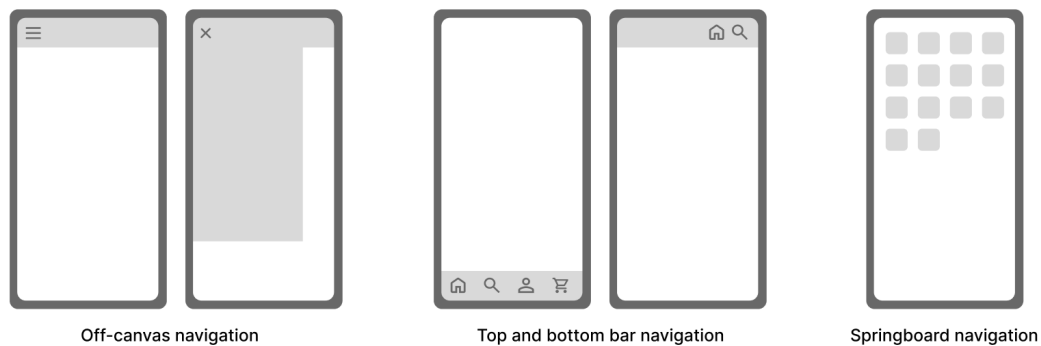

Figure 2: Illustration of off-canvas, top and bottom bar, and springboard navigation.

3.1.4 Consistency

Consistency is a crucial aspect of mobile app design and User interface (UI) design in general. By providing a consistent user interface, designers can create more useful and intuitive designs. There are two aspects of consistency to consider: external and internal [13]. External consistency involves using known and accepted design patterns in new designs. Instead of having to learn and remember application-specific symbols or functionalities, the user can rely on their previous knowledge and experiences while interacting with the application. Internal consistency is more focused on whether the design is inline with the company or brand. And, whether there is consistency within the application itself. Letting user interface elements that prompt the same kind of action look the same can also help the user learn and navigate the system.

3.1.5 Feedback

Initiating an action, and not knowing whether it was successful or not, can be a frustrating experience for the user of a product or service. It is therefore essential to provide the user with feedback about what is happening within the system [14]. Feedback can for instance be used to communicate if the system is loading, progress of some sort, or if an error has occurred (see Figure 3). Feedback is time-sensitive, it needs to be provided immediately after the user has initiated an action. A delay before the feedback is displayed can take the feedback out of context, and confuse rather than aid the user. It may also be enough for the user to lose interest, and abandon the prospect.

Figure 3: Different examples of visual feedback. Figure *A* represent a loading symbol, *B* a progress bar, and *C* an indication that an error has occurred.

Feedback does not have to be visual, it can be audial, something that can be heard, or tactile, something that can be felt. When it comes to delivering good feedback, it is crucial to consider how understandable

the feedback is [14]. A flashing light, beeping sound, or random vibration might not be sufficient to convey the message to the user. It is also important to not overdo it, since too much feedback can be perceived as overwhelming or annoying.

3.1.6 Aesthetics

Aesthetic, is a word of many meanings depending on the context in which it is being used. In UI and UX-design, aesthetics refer to how something looks, i.e. a set of visual characteristics that describe a product or service.

While the appearance of an application is typically considered late in the design process, it is still an important aspect of design, with some aesthetic decisions being directly related to usability. E.g. avoiding cluttering and providing enough contrast.

The visual presentation of a product or service also plays a crucial role in its reception. According to Norman [15], users tend to be more lenient towards beautiful user interfaces. In the article, *Emotion & Design: Attractive Things Work Better*, Norman [15] argues that this is due to beautiful things awakening human creativity, which tends to make people more skilled at problem-solving.

3.1.7 Gestalt Principles

Gestalt theory is a psychology theory that emerged in the 1920s with the aim to explain or conceptualize how human beings perceive things [16]. Based on this theory, a couple of gestalt principles have been stated. Some of the more common ones are listed below:

- **The law of proximity:** Things that are located near each other are often perceived as belonging together.

- **The law of similarity:** Things that look similar are often grouped together.

- **The law of common-region:** Things that are displayed within the same boundary, tend to be grouped together.

- **The law of focal point:** A thing that is visually distinguished from its surroundings acts as a focal point, and thereby catches the beholders' attention.

The gestalt principles can effectively be applied to user interface design in order to create more user-friendly UIs. One example of how the gestalt principles can be applied to UI-design is the design of an input form (see Figure 4). By letting the label lie close to the text field, the law of proximity is at hand, ensuring that the beholder immediately knows which label correlates with which text field [17].

Figure 4: Two examples of an input form. In example *A*, the law of proximity has been considered, in example *B*, this law is disregarded.

3.2 Electric Vehicles

Electric cars have existed since the 19th century, but the development of electric vehicles has been a slow process [18]. Though some electric cars have risen in popularity over the decades, they have often been surpassed by the more affordable combustion engine. However, in the past two decades, due to the advancement of technology, the reduction of costs, the high fuel prices, as well as the growing interest for the environment, electric vehicles have now become a current and future part of the transport industry [19].

There are many variations of EVs, but three common types are the battery electric vehicle (BEV), the hybrid electric vehicle (HEV), and the plug-in hybrid electric vehicle (PHEV) [3][19]. The battery electric vehicle is fully electric, meaning that it does not use any fossil fuels to power the car. Instead, this kind of car is reliant on a battery to operate. A hybrid electric vehicle is a vehicle that is combining battery power with fossil fuels to function. The hybrid car does not need charging, instead the battery is charged automatically while the vehicle is driving. A hybrid plug-in vehicle, as the name suggests, require charging of the battery. In these hybrid cars, the driver can opt to use the battery to power the car or to use fossil fuel.

3.2.1 Charging an Electric Vehicle

Charging the battery via a charging station, rather than charging at home, provides some extra security measures, like communication between the vehicle and the station and a blockade that prevents charging if the needed security conditions are not met [3].

There are different standards for charging connectors, that is, the cord and adapters connecting the EV to the charging station. Some common standards are type 1, type 2 (Mennekes), and type 4 CHAdeMO (see Figure 5).

Figure 5: Illustration of some common charging connectors, based on [3].

3.2.2 Electric Vehicle Mobile Applications

In the car industry, mobile applications have been used as a complement to cars for several years. Some areas where mobile applications are used to aid the driver is navigation, route planning, carpooling or traffic safety [20]. There are also some applications that are directly provided by the car manufacturer. These apps give car owners an overview of the car status and allow remote functions like locking and unlocking the car, or preconditioning the temperature of the car.

The increase in electric vehicles open up for new opportunities concerning mobile applications. These applications can help EV drivers find nearby charging stations, monitor the charging status, and view their charging history, among other things.

There exist a plethora of these kinds of electric car mobile applications. Some of them are distributed directly by a car manufacturer, like the Tesla or Volvo cars applications, while other apps are standalone. The apps are often connected to a specific brand, of either car or charging station supplier, meaning that an EV driver generally need more than one application in order to see or use all available charging stations in the vicinity.

3.3 Research Methods

In order to create designs with usability in mind, it is important to understand not only the product or service, but also the potential users of the product or service. To gather insights in the field of electric car charging mobile applications, some known research methods have been applied. These methods include heuristic evaluation, user surveys, prototyping, and user testing.

3.3.1 Heuristic Evaluation of a User Interface

There are multiple ways to investigate usability in a user interface. One way to do this is by conducting a heuristic evaluation. A heuristic evaluation is done by looking at user interface and determining which parts are good and which parts are bad [21]. Commonly, the evaluation is done based on a set of guidelines, or rules with regard to usability.

In 1994 Nielsen [22] created 10 heuristics for evaluating usability in a product or service. Although it has been almost 30 years since the heuristics were formulated, they still remain relevant and useful [23]. The heuristics are:

1. **Visibility of system status:** Can the user easily determine the status of the system? Is it visible when the system is processing something? Is it visible where in the system the user is currently at?

2. **Match between system and the real world:** Is the system based on the real world? Is the system using the same language as the intended user of the system?

3. **User control and freedom:** Does the user have freedom while navigating the system? Can the user exit and go back if they accidentally initiate an unwanted process?

4. **Consistency and standards:** Is the system using symbols, metaphors, and language that is known and already implemented and tested in other applications? Is the system consistent within the product, service, or brand? E.g. are the appearance of same-action-buttons the same throughout the system?

5. **Error prevention:** Are errors reduced whenever it is possible? E.g. does the system prompt a confirmation from the user before the start of a high-cost process?

6. **Recognition rather than recall:** Are options and functionality visible and easy to access without having to memorize how to reach them?

7. **Flexibility and efficiency of use:** Can the user personalize the system? Is it possible to skip steps, and make shortcuts if the user is experienced with the system?

8. **Aesthetic and minimalist design:** Is the user interface devoid of cluttering and irrelevant information? Is the most essential information prioritized and easily recognized?

9. **Help users recognize, diagnose, and recover from errors:** If errors occur, is help provided to ensure that the user can recover from the errors?

10. **Help and documentation:** Although it is preferable if the system does not require any extra documentation, does a help-option exist to ensure that the user is provided with help if they need it?

3.3.2 User Survey

Distributing surveys is a common research method in many fields such as politics, health, and interaction design. One of the main advantages of surveys is the possibility of reaching a large set of people in a relatively short time – unbound by distance [24]. A survey consists of a set of questions dedicated to collect data on a specific subject or field. The questions in a survey can be multiple-choice, yes/no, rating scales, or open-ended.

One challenge with surveys is that they are unsupervised, which means that participants complete the survey without any supervision from the sender. This increases the risk that respondents may not fully understand the questions or may provide inaccurate or incomplete responses. To address this, it is crucial that the questions in a survey are well-constructed, well-structured, and thought through before the survey is distributed.

In interaction design, a survey is often referred to as a user survey. A user survey is commonly dedicated to identify user needs or to test users' responses to a new product or service.

3.3.3 Usability Testing

To realize whether the design of a product or service is working or not, it can be efficient to test the design on actual users. This process is called usability testing. Usability testing may mean many things, it can refer to experts evaluating a design, or when a software is determining whether an interface lives up to usability standards or not. Most commonly it is, as Lazar et al. [25] put it, when representative users, perform a set of representative tasks.

Before initiating testing, it is crucial to consider the participant group. Representative users indicate that the participants of the test need to be in the target group that the product or service is aiming for. According to Nielsen [26], a good number of participants in usability testing is five participants, since five participants are said to be able to identify around 80% of the usability issues within a user interface. However, other sources argue that there is no magic number of participants, and that it varies from case to case depending on the scope of the project that is being evaluated and the amount of anticipated issues within the project [25].

The goal of a usability test is to identify flaws in the design of the interface [25]. It is important to note that it is the interface, and not the users, that are being tested. The goal of usability testing is neither to create general guidelines, but rather to find issues to resolve in a specific interface.

Usability testing should be introduced early on in the process, and continue throughout the entire design process [25]. However, depending on the project's resources, this might not always be possible. If the resources of the project allow it, introducing testing early in the process can help identify and eliminate design issues before they become more prominent, expensive and hard to solve problems.

4 Method

This study consists of a preliminary study, and a creation of a design proposal for the Greencharge Infra mobile application. The creation of the design proposal follow the methodology design build test, which is an iterative process of designing, testing, and, based on test result, redesigning.

4.1 Preliminary study

To gather initial knowledge of the field, a preliminary study was conducted. The aim of the preliminary study was to identify the limitations of the current application, and to investigate user needs in these kinds of applications. This was done by conducting an evaluation of the current design and by distributing a user survey.

4.1.1 Evaluation of Current Design

The current design of the application was evaluated using Nielsen's 10 Heuristics for usability [22] (see Section 3.3.1). Usually, a heuristic evaluation requires multiple people to evaluate a system and then the findings are cross-referenced to ensure that every part of the system is covered. Due to a lack of time and resources, however, the application has only been evaluated by the author of this thesis. The evaluation involved systematically navigating through the application with one heuristic in mind at a time, and recording both positive and negative findings.

4.1.2 User Survey

To gain intel on the actual user needs in these kinds of applications, a user survey was created and sent out to potential users. The aim of the survey was to identify real users' needs of these applications, as well as investigating how they currently use these apps in their everyday life. The participants of the user survey were owners or drivers of electric vehicles. Apart from that, no demographical data was collected.

The user survey was divided into various sections, and depending on the participant's answer to the questions, different sections were viewed. There were three main sections of the survey, these concerned electric cars, charging an electric car and, mobile applications for electric car charging stations.

In the first main section, the participant was asked questions concerning what kind of electric car they usually drive, as well as their motivations and hesitations regarding selecting to own an electric car before a petrol fuelled car. These questions were open-ended.

The second main section contained questions focused on charging an electric car. The questions in this section were multiple-choice questions, listed below:

- How do you usually locate charging stations when you arrive at a new place?
    - The navigation system of the car
    - Mobile applications for charging stations
    - Navigation mobile applications
    - Other. . .
- What payment method do you usually use when you pay for the charging of your car?
    - Card payment
    - Special tag

- Special card

- Via mobile phone

- Other...

- Do you ever use a mobile application to find charging stations?

    - Yes

    - No

    - I've tried, but I do not use them

The third main section of the survey contained questions that were more specific to the user needs of a mobile application for charging systems. The questions asked in this section were a mixture of open-ended and multiple-choice questions, as listed below:

- Do you ever use a mobile application to view your charging history?

    - Yes

    - No

    - I don't know

    - Other...

- Why do you use the specific mobile application(s) for charging stations that you are currently using?

- Which three functionalities do you find most important in mobile applications for charging stations?

    - Overview of charging stations

    - Status of charging station (available, active, etc.)

    - Charging costs

    - Charging history

    - Reservation of a charging station

    - Charging status (battery percentage, current cost, etc.)

    - Payment via the app

    - Other...

- Is there any functionality that you are missing in the application(s) you use today?

The survey ended with a question asking the participants whether it was okay to contact them for further questions and possible user tests. Since the target group for this project primarily speaks Swedish, the survey was written in Swedish and then translated into English for this report. All the questions were designed to be unbiased, and give participants the freedom to answer freely. This was achieved by avoiding the use of subjective language in the questions, and by using a mix of multiple-choice and open-ended questions.

The quantitative data collected from the survey was directly included in the results. On the other hand, the qualitative data obtained from the open-ended questions required analysis using content analysis [27]. Content analysis involves systematically going through the responses and categorizing them based on their content. The objective is to condense lengthy answers into more concise and specific categories, while also discovering new and interesting connections among the data.

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4.2 Design Proposal

Based on the knowledge gathered from the preliminary study, a new design proposal was created. This design was created using an iterative process of designing, testing and evaluating.

4.2.1 Design Sketches

The first iteration of the design proposal consisted of creating sketches of a new design. This method is known as paper prototyping. Paper prototyping is a widely accepted method in HCI to kick off a design process [28]. An advantage of paper prototyping is that it is quick, and it allows for testing early on in the process. The sketches can also act as valuable blueprints for the future prototyping. This method was selected as a suitable method to start creating the design proposal due to its efficiency and because it acts as a valuable foundation for the upcoming, more advanced prototyping.

The design sketches were based on the application's current design as well as the findings from the preliminary study (see Section 5.1). Because of these findings, it was prioritized to include more distinctive feedback in the new design, and to provide the user with more information than is currently available. Making the new design intuitive and easy to use was also prioritized in order to reduce stress from the sometimes complicated charging process.

The design sketches were created digitally using a graphics tablet, and the art application SketchbookPro. The process began by mapping out the necessary screens of the application. The usage of the application can be divided into five different user activities:

1. Signing up as a first-time user or signing back in after being logged out.
2. Finding a charging station and initiating charging.
3. Managing cars and browsing charging history.
4. Managing user account.
5. Managing payment tags.

These activities acted as the foundation for the paper prototype. The sketches created during this phase were not presented to potential users, but were instead conformed with both Rejlers and Greencharge Infra, the stakeholders of this project, to ensure that they were satisfactory. No changes in the sketches were suggested at this point.

4.2.2 Prototyping

Once the design sketches were completed, a more advanced mock-up of the mobile application was created using the design tool Figma. This process was divided into four steps, creating design components, creating a black and white design, adding colour and details, and lastly making the design clickable (see Figure 6).

The structure of the design process described above facilitates the creation of a flexible design that can be easily modified as needed. This approach was well-suited for this project, since the design requirements called for an adaptable design that could be tailored to different companies' needs and visual languages. However, the process was not completely linear as depicted above. The creation of the design required iterations and adjustments along the way.

Based on the user activities identified during the sketching phase, a couple of user tasks were created. Since prototyping every aspect of the mock-up can be time-consuming and ultimately unnecessary, only the screens needed to complete the user tasks were made clickable.
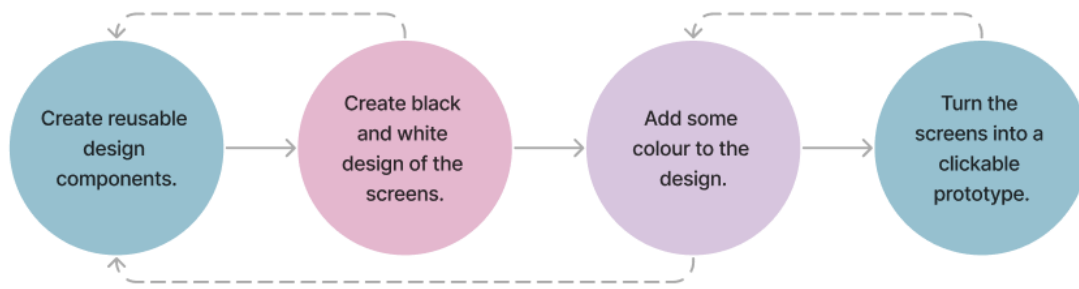
Figure 6: An illustration showing the prototyping process.

4.3   Usability testing

To investigate whether the new design proficiently support usability, a usability test was performed. As mentioned in the theory section, Nielsen [9] argues that there are five pillars of usability. These are learnability, efficiency, memorability, errors, and satisfaction. During the usability test, three of these aspects were evaluated, namely efficiency, errors, and satisfaction. Learnability and memorability were evaluated through a post-test assessment, in which the participants were asked if they would feel comfortable using the application in the future, considering the limited time they had to familiarize themselves with it during the testing.

The usability test was task-oriented, meaning that the participants of the test were asked to perform a set of predefined tasks. Efficiency of a user interface, is dependent on two things, how accurately a user complete a task, and the resources spent in order to achieve this [29]. A common measurement of efficiency in user interfaces is to measure the completion time of a task. This method of measuring efficiency was adopted in this usability test. To avoid causing stress, the participant was not made aware that the time taken to complete each task was being measured. The user interface was deemed efficient if the majority of the participants managed to complete the task within a predefined timeframe. Due to the lack of industry data, or other potential thresholds, the threshold determining if a task was efficiently completed or not was set as the average time it took for the participants to complete the tasks.

The tasks selected for this usability test were designed to cover different parts of the application and thus prompting the user to navigate through the app. Additionally, the tasks were designed to address some potential weak spots in the design in order to investigate how the users perceive these areas. To lessen mental load, the tasks were also crafted to be relatively short. The user tasks were:

- Create a new account.
- Find a charging station and initiate charging.
- Find the charging history.
- Change pin code and sign out from the application.
- Activate a new tag.

While a participant performed a task, they were encouraged to share their spontaneous thoughts as they navigated the application, thereby applying the usability test method *thinking aloud* [30]. Meanwhile, the test facilitator observed what the participant was doing, and how they acted while performing the tasks. Observing the user while they use the application can reveal more information about how the user is actually

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using the app, rather than the information gained when only asking them [31]. Observing the participant can also give visual cues such as body language and facial expressions, which can aid in understanding how the participant experience the application [32].

In order to identify where on the screen the participants were pressing, screen recording and touch indicators were active during the tests. This knowledge was later used to identify the number of errors the participant performed while trying to complete the tasks.

Following each task, the participant was asked to answer a couple of questions related to the task they just completed. The questions followed the structure of a semistructured interview. That is, a set of predefined questions acted as a base for the interview, however, deviations from these questions were allowed [33]. The questions were focused on identifying how the user experienced the given tasks, and whether the features of the application were functioning according to their desires and expectations. The purpose of these questions was to determine whether the application was satisfactory and pleasant to use. The participant was given access to the prototype while answering the questions to allow them to go back and revisit specific screens that were discussed, rather than having to rely on memory. Below follows a more detailed outline of the tasks, and the questions asked after each task.

1. Creating a new account.

To create a new account was chosen as a task to validate that this process is not too tedious for the first-time user. This aligns with the design requirements of this thesis (see Section 2.1).

After the task was completed, the participant was asked to answer the following questions:

- What did you think when you first viewed the starting page of the application?
- How did you experience the task of signing up to the application?

2. Find a charging station and initiate charging.

Since the primary activity of the application is finding a charging station and initiating charging, a task was specifically designed to test this activity. This task provided an opportunity to assess whether the information provided in the charging dialogue was sufficient for the user, or whether they desired more or less information regarding the charging process.

The questions correlating to this task were:

- What are your thoughts about the home screen (the map-view)?
- If you are to describe the functionality of the buttons and icons you see on the home screen, what do you think the different buttons or icons do?
- How would you describe the process of finding a charging station and initiating charging?
- Was there any information or anything else that you were missing in the screens you just saw?

3. Find the charging history

The third task was dedicated to finding the charging history. This was to investigate whether the navigation to and from the charging history page was intuitive and logical. Additionally, the task was designed to identify whether the new design adequately addressed everything the user might need from this feature.

After the task was completed, the participant got to answer the following questions:

- How would you describe the process of finding the charging history?

- Is this a feature that you usually use? If so, what do you use it for?

- Is there any information that you are missing? Is there any of the provided information that you find unnecessary?

4. Change pin code and sign out from the application.

The fourth task focused on the participant locating and using the edit profile and sign-out features. This task was designed to assess whether the new placement of the edit profile and sign-out buttons was intuitive for the user, and to identify any potential usability issues with this change.

The questions asked after this task were:

- How would you describe the process of changing your pin code and signing out from the application?

- What motivated you to press the pen-icon to edit your pin code?

- Is there anything you are missing on the profile side? Is there anything you find superfluous?

5. Activate a new tag.

The last task was to activate a new tag. This task was designed to explore if the participant could find the tag-page, and to find out how the participant experienced this view.

- How did it feel to perform this task?

- Do you see any advantages or disadvantages with this kind of overview of tags in the application?

Before the testing commenced, the testing process was explained to the participant. The participant was also asked to answer some introductory questions, concerning their EV and usage of mobile applications for charging purposes.

When the test was completed, the participant was asked to relay their overall experience and opinions of the application. Lastly, they were thanked for their participation.

In accordance with Nielsen [26], it was decided to test the application on five representative participants. To qualify as a representative participant, the only criterion was that the person had to be an owner, or frequent driver, of an electric vehicle. The test participants were recruited using social media channels aimed at EV drivers. All participants had previously partaken in the user survey, thus they were already familiar with the project. None, however, had any prior experience of the Greencharge Infra application.

The usability tests were carried out online using the conference tool Zoom. Each session was recorded using the built-in recording functionality available in Zoom. The audio was later transcribed using the transcribing services provided by Microsoft Word online. During the test, the participant viewed the prototype in their web browser on their computer. They were also asked to share their screen so that the test facilitator could monitor what the participant was doing. Each test session lasted for about 30 minutes.

The data collected from the questions asked during the usability test was analysed and summarized using content analysis [27].

5 Results

This thesis consisted of a preliminary study and the creation and testing of a design proposal. The preliminary study aimed to identify user needs in electric car mobile applications, and to evaluate the usability in the current Greencharge Infra application. The design proposal consisted of three phases, sketching, prototyping and testing. In the following section, the result from both the preliminary study and the design proposal will be presented.

5.1 Preliminary Study Results

The preliminary study resulted in a list of positive and negative usability features that were discovered during the heuristic evaluation of the current application and, the results from the user survey.

5.1.1 Evaluation of the Current Design

To test for usability, a heuristic evaluation (see Section 3.3.1) of the current design was performed. The system was systematically evaluated, with one usability heuristic in focus at a time. The evaluation resulted in tables listing the positive and negative findings that were discovered.

During the first walkthrough of the system, the first heuristic, *visibility of the system*, was the main focus (see Table 1). It was discovered that the system does provide some visibility of the system status, such as loading symbols. However, it was also found that the system needs to be more visible.

Table 1: Nielsen's first usability heuristic.

1. Visibility of the System	
Positive:	**Negative:**
The system provides a loading symbol when the system is not ready.	No distinction between selected charging station and other stations.
An underline is used to indicate where the user is in the sub-menus.	Missing heading at the charging history page.
	No difference between available and unavailable charging points if they are not explicitly clicked on.
	No indication whether the car is charging or not.

When focusing on the second heuristic, *matches between the system and the real world*, it was established that most of the icons used in the system are well known and accepted icons (see Table 2). However, some icons were found to be used in a faulty or confusing way.

Table 2: Nielsen's second usability heuristic.

2. Match between system and the Real World	
Positive:	**Negative:**
Most of the icons used are common.	Sign-out-icon and support-icon are less known
Real world representations of the type of the connectors.	Complicated names of the charging stations.
Real world representations of licence plates.	

The third heuristic to be applied on the system was *user control and freedom* (see Table 3). During this evaluation, it was uncovered that the system provides the user with the option to "go back" from every page. It was, on the other hand, discovered that the menu is only available from the start page, leading to it being impossible to navigate directly from the pages of the menu.

Table 3: Nielsen's third usability heuristic.

3. User Control and Freedom	
Positive:	**Negative:**
Possibility to "go back" from every page.	No possibility to go from a subpage to a subpage without going back to start. E.g. it is not possible to navigate directly from Cars to My Account.

When it comes to the fourth heuristic, *consistency and standards*, it was detected that the system suffer from a lack of internal consistency, (see Table 4). Meaning that there is a lack of consistency within the system. For example, the button design varies throughout the system.

Table 4: Nielsen's fourth usability heuristic.

4. Consistency and Standards	
Positive:	**Negative:**
Recognized symbols are used in the correct way.	Inconsistency in button design. E.g. sign-out button, charge button.
Consistent with the company brand and website graphical profile.	Some "swipe-indicators" are clickable, others are not.
	Swipe-indicator for register new user looks different, swipe-down indicator is missing.
	The icon for my account is an icon associated with settings.
	The usage of solely capital letters or solely lower case letters are interchanged in an inconsistent manner.

Regarding the fifth heuristic, *error prevention*, the system provides the user with the possibility to "go back", and exit before making high-cost decisions, such as ordering a tag (see Table 5).

Table 5: Nielsen's fifth usability heuristic.

5. Error Prevention	
Positive:	**Negative:**
Possibility to exit before ordering a tag.	No confirmation before signing out.
	No way of cancelling a order of tag.

When searching for usability findings concerning the sixth heuristic, *recognition rather than recall,* only one thing was noted (see Table 6). It was observed that the charging history feature is not intuitive to find, and therefore it forces the user to remember where it is rather than recognizing it. The same can be said about the features concerning payment tags.

Table 6: Nielsen's sixth usability heuristic.

6. Recognition rather than recall	
Positive:	Negative:
	Some features, like charging history, are hard to find.

Concerning the seventh heuristic, *flexibility and efficiency of use*, it was established that the system is not very flexible, e.g. there is no possibility for the user to customize which charging stations should be visible on the map or not (see Table 7). The system does however provide some efficiency by making the closest charging station preselected when the user opens up the application.

Table 7: Nielsen's seventh usability heuristic.

7. Flexibility and Efficiency of Use	
Positive:	Negative:
The closest charging point is automatically selected.	No possibility to filter out uninteresting charging stations.

Regarding the eighth heuristic, *aesthetic and minimalistic design*, the application performs well when it comes to minimalistic design (see Table 8). It does, however, not entirely fulfil usability when it comes to other visual aspects of the application.

Table 8: Nielsen's eighth usability heuristic.

8. Aesthetic and minimalist design	
Positive:	Negative:
Not much cluttering or unnecessary information.	Low contrast with white text on turquoise background.
When zooming out, map-points are clustered, leading to a clean design.	It is not always clear when something is clickable or not.

When it comes to the ninth heuristic, *help users recognize, diagnose and recover from error*, the application is found lacking (see Table 9). Some error messages do exist, with the aim to help the user recover from something going wrong. However, most of these messages were found inadequate in providing a clear explanation of the issue to the user.

Table 9: Nielsen's ninth usability heuristic.

9. Help users recognize, diagnose, and recover from errors	
Positive:	**Negative:**
When trying to delete a car, and only one car is active, an error message occurs saying that at least one car needs to be active.	No strict restrictions on license-plate format.
Error message when license-plate include "illegal" symbols.	When trying to charge while not at a charging station, an error-message sometimes appears, but the error is only referred to as "unknown error".
	Error messages for input fields only indicate that an error occurred, without specifying the nature of the error.

The tenth and last heuristic to be evaluated was *Help and documentation*. During this evaluation, it was found that the system does not provide much help nor documentation (see Table 10).

Table 10: Nielsen's tenth usability heuristic.

10. Help and Documentation	
Positive:	**Negative:**
Telephone number and opening-hours to customer support is available in the application.	No Q/A or other documentation is provided.
On the tag-page, if there are currently no active tags, there is an explanatory text guiding new users to order tags.	

5.1.2 User Survey

A user survey (see Section 3.3.2) was conducted in order to collect data concerning the user needs in mobile applications for electric car charging stations. The user survey resulted in 34 responses, all from EV owners or drivers. Among them, 33 participants owned battery electric vehicles, and one drove a plug-in hybrid electric vehicle. It is worth noting that not all questions in the survey were mandatory and some were dependent on previous answers, leading to varying response rates for each question. As a result, some questions received less than 34 responses. Since many of the questions were open-ended, it was also possible for one participant to give multiple answers, which means that sometimes more than 34 replies were collected.

What made you choose to drive or own an EV before a fossil fuelled car?

When asked about why the participants had selected an EV before a fossil fuelled car, 21 out of 34 participants mentioned the environment as the main reason (see Figure 7. On a close second, with 15 mentions, were economic reasons. Additionally, the exciting technology associated with EVs was mentioned 12 times.
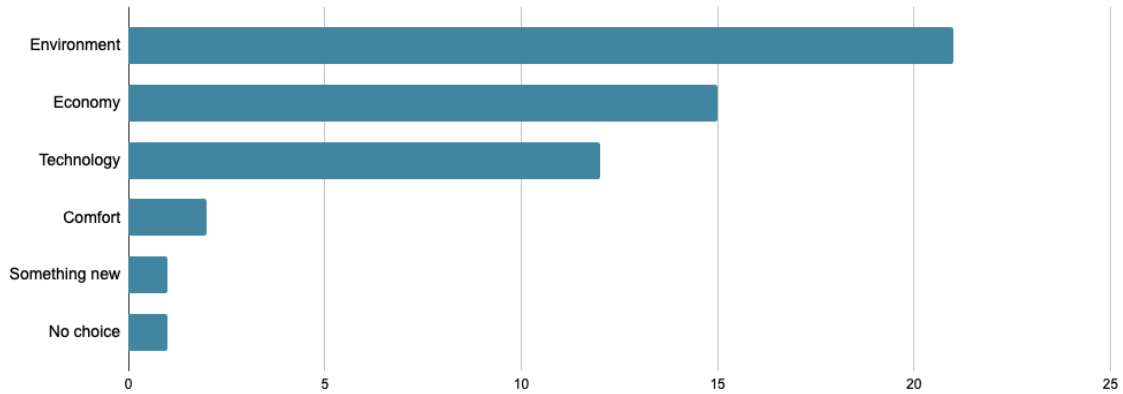

Figure 7: Bar graph depicting the reasons behind why participants decided to buy an electric car, and the number of participants conveying each reason.

Was there anything that made you hesitate before you bought your electric car?

On this question, the majority, 12 out of 34, of the participants answered that they had not hesitated before buying an EV (see Figure 8). The other participants expressed concerns regarding the purchase price, the range, the lack of charging stations, and the hassle of needing to charge the car.
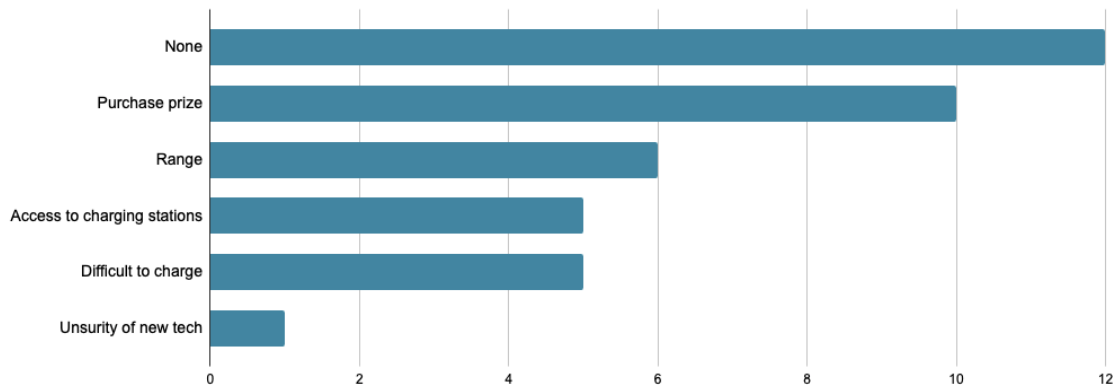
Figure 8: Bar graph of illustrating why some participants hesitated before buying their electric car.

How do you usually locate charging stations when you arrive at a new place?

19 out of 34 participants answered that they are using some kind of mobile application to find charging stations when they arrive somewhere new (see Figure 9). The second most popular option, with 11 votes, was using the navigation system in the car.
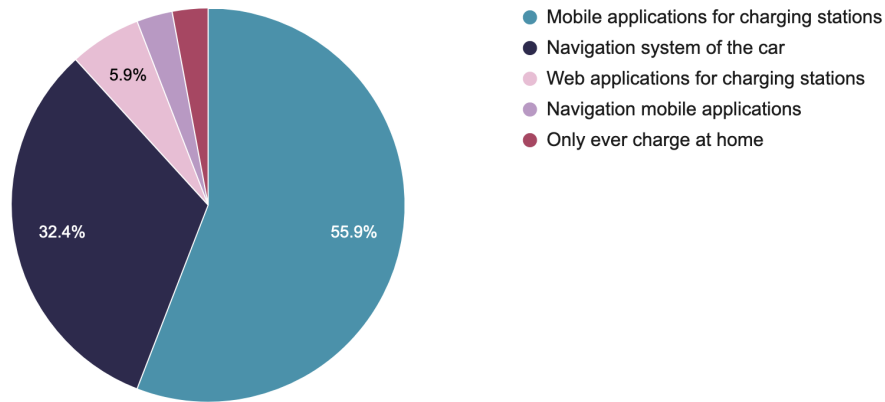

Figure 9: Pie chart showing how the participants locate charging stations when they arrive at a new place.

What payment method do you usually use when you pay for the charging of your car?

The question concerning payment methods generated a variation of replies (see Figure 10). The most common payment method was via the mobile phone, ca 30%, either directly in an application, or indirectly via digital bank cards. The second most common payment method was via special charging station cards, ca 24%. The "other"-category included free charging via work, or that the car automatically registers the payment without external usage of cards, tags, or applications.
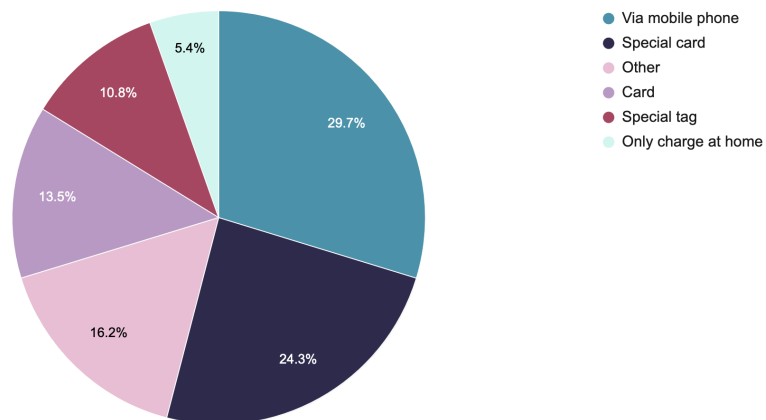

Figure 10: Pie chart displaying the most common payment methods used when charging an EV.

Do you ever use a mobile application to find charging stations?

27 out of 34 participants answered that they use mobile apps to find charging stations, while 2 out of 34 answered that they have tried apps but do not use them, and the remaining 5 answered that they do not use any mobile apps for this purpose.

Do you ever use a mobile application to view your charging history?

Slightly less than half, 10 out of 25, answered that they use mobile applications to view their charging history. However, 13 out of 25 answered that they do not use this functionality, and the remaining 4 were hesitant or said that they occasionally use this functionality.

Why do you use the specific mobile application(s) for charging stations that you are currently using?

When asked about the mobile applications that the participants use today, 11 out of 27 answered that they use that specific app because of its ease of use. 5 out of 27 expressed that they appreciate that the application is supporting multiple suppliers. 2 participants argued that they use the application because it provides updated and reliable information about the charging stations. 3 participants mentioned the access to extensive information about the charging station and charging process to be the reason as to why they use an application before others.

Which functionalities do you find most important in mobile applications for charging stations?

According to the participants of the survey, the most important functionality of these kinds of mobile applications is being able to see an overview of the charging stations and, being able to see the status of the charging stations (see Figure 11).
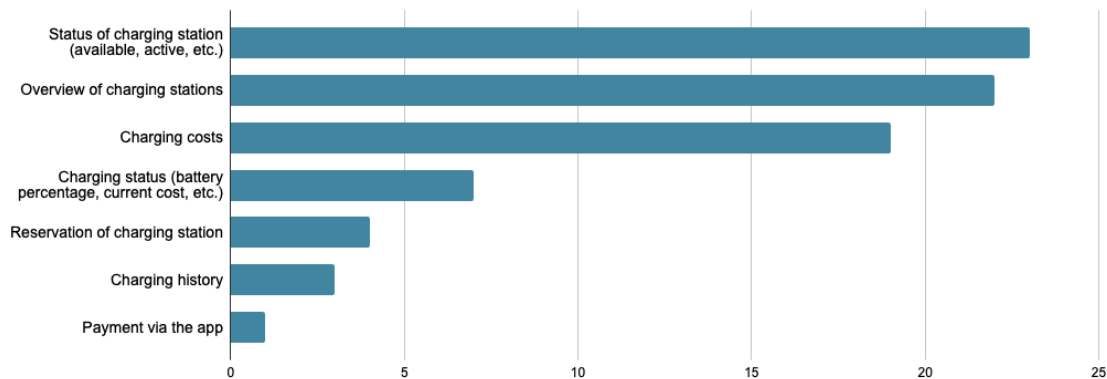

Figure 11: Bar graph illustrating which functionalities the participants found most important in mobile applications for charging stations.

Is there any functionality that you are missing in the application(s) you use today?

The most prominent flaw, mentioned 6 times, in current applications was that the applications lack support for multiple suppliers. Apart from that, the participants expressed a desire for more information and, more reliable information and better usability.

Why do you not use any mobile applications for charging stations?

When asked why they do not use any mobile applications for finding charging stations, all 7 participants who fell into this category replied that they did not find them useful as they either charged their EVs at home, or relied on the built-in navigation system of their vehicles.

5.2   Design Proposal

A design proposal for the Greencharge Infra mobile application was created, and later tested on representative users (see Section 4.2). In this section, the proposal, in its various stages, will be presented. In addition to the design proposal, a design system for the application was created consisting of various UI elements, like icons, input fields and buttons. A selection of this design system, the design sketches, and a complete set of wireframes can be found Appendix A.

5.2.1   Design of the Mobile Application

The design of the mobile application was an iterative process which consisted of creating lo-fi sketches and then transform those sketches into a clickable hi-fi prototype. The hi-fi prototype is mostly a refined version of the sketches from the sketching phase. Some pages, however, such as the profile page, has been more prominently changed from the lo-fi stage to the hi-fi stage. These changes are not based on tests, but rather due to new design ideas that came up during the prototyping phase.

In the preface of the design sketching phase, five user activities were identified:

1. Signing up as a first-time user or signing back in after being logged out.

2. Finding a charging station and initiating charging.

3. Managing cars and browsing charging history.

4. Managing user account.

5. Managing payment tags.

The prototype for the application was designed based on these activities. The result of each activity will be presented in the same order as previously outlined, starting with the Sign-up and Sign-in screens.

1. Signing up as a first-time user or signing back in after being logged out.

For first-time users, an important user activity is signing up to the application. For returning users, it is crucial that the signing in process is quick and easy. This was also one of the design requirements from the company, that was agreed upon in the beginning of this thesis (See Section 2.1). The screens for this user activity are heavily inspired by the current application, with only minor alterations.

The Sign-in screen is similar to that of the original application, but the "forgot your pin"-link has been moved closer to the pin code-input field, in accordance with the gestalt law of proximity (See Figure 12). The pin code input field has been changed into four smaller fields to better communicate what kind of input the system is expecting.
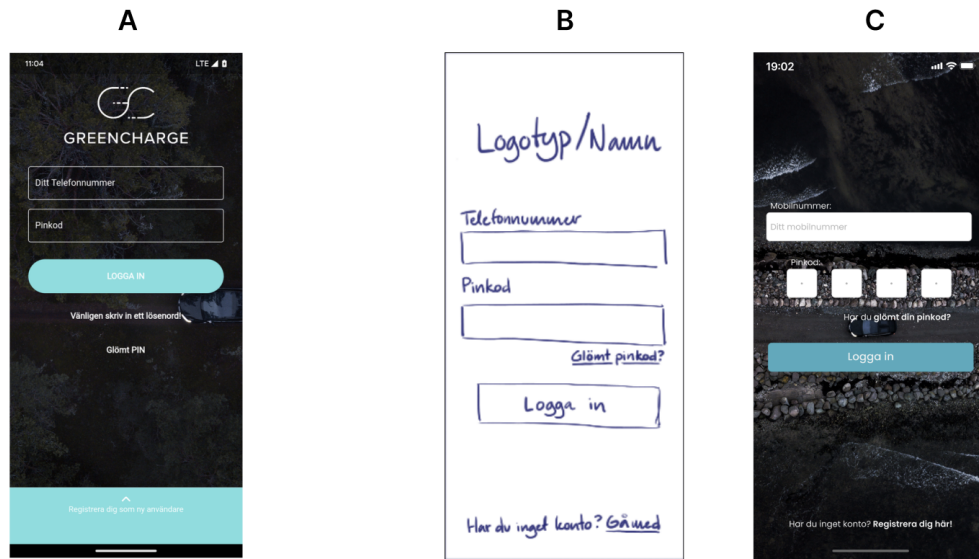
Figure 12: Three variations of the sign-in page of the Greencharge Infra mobile application. Variation *A* is a screenshot of the current application [34], *B* is the sketch for the design proposal, and variation *C* is the hi-fi prototype for the design proposal.

Before the first-time user can sign in, they need to select their home town in order to set a start point for the map-feature. In the current application, this is accomplished with a modal window. In the new design proposal, however, the Select home town-screen has been moved to a separate screen to better utilize the screen size.

The new Sign-up screen includes more instructions to aid the user, as well as a more obvious way to exit the process. The new confirmation-screen comes with the possibility to ask for another code if issues occur.

2. Finding a charging station and initiating charging.

The primary user activity of the Greencharge Infra mobile application is finding a charging station and initiating charging. To minimize the number of clicks required to reach this activity, it is directly accessible from the home screen, i.e. the starting point of the application. The navigation in the new design is a bottom-bar, instead of the hamburger-menu found in the current application (See Figure 13). It was decided to switch navigation-system to make the different pages more accessible to the user. The bottom-bar menu is also inspired by other popular, albeit different, mobile applications such as various social media apps.

Figure 13: four variations of the home screen. Variation *A* is the current application [35], *B* is the current application with an expanded menu [36], *C* is the sketch for the design proposal, and variation *D* is the hi-fi prototype for the design proposal.

A filter function was added to the home screen which, when clicked, opens up as an overlay on the screen. This functionality allows the user to customize which charging stations are to be visible in the map-view. Possible ways to filter are to filter by type of connector, availability of the station, and charging effect. This functionality was added to the application because it enables the possibility for the user to personalize the application to better fit their needs, which conforms with Nielsen's seventh usability heuristic (see Section 3.3.1). Another feature that has been added to the application is a help-button, which contains some useful information that can guide and aid the user in their endeavours.

Due to the findings of the preliminary study, prioritizing more visible feedback and providing more information about the charging stations and the charging process was necessary. This was achieved by distinguishing between the selected charging station and the remaining stations. Additionally, it was achieved by providing more information, and charging status-indicators on the charging dialogue screen (See Figure 14). Furthermore, efforts were made into making it more visible whether a UI element is clickable or not. For instance, the button to start charging is dimmed until the user has selected which connector to charge from, indicating that it is not clickable yet.
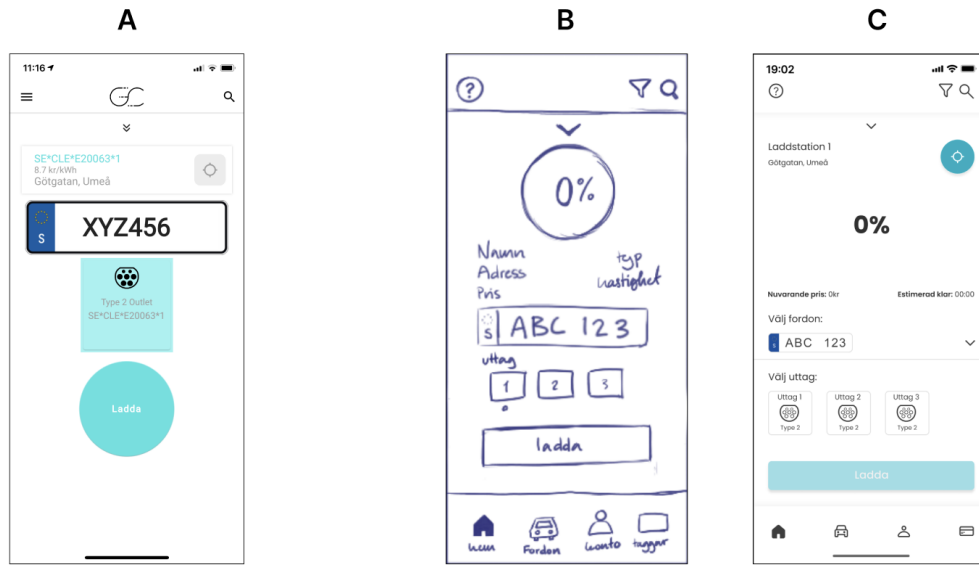
Figure 14: Three variations of the charging dialogue. Variation *A* is the current application [37], *B* is the sketch for the design proposal, and variation *C* is the hi-fi prototype for the design proposal.

3. Managing cars and browsing charging history.

The third user activity is managing cars and browsing charging history. The design proposal for these screens were once again inspired by the current application. However, the charging history feature is now more visible and easy to access than it was before. This was achieved by making the navigation to the charging history prominent and always visible, rather than hiding the feature behind the licence plates of the electric vehicles.

4. Managing user account.

The fourth user activity is managing user account (see Figure 15). This activity has been divided into two screens. One general information screen, where the user information is displayed, and one editing screen, where the user can edit their information and change their pin code.
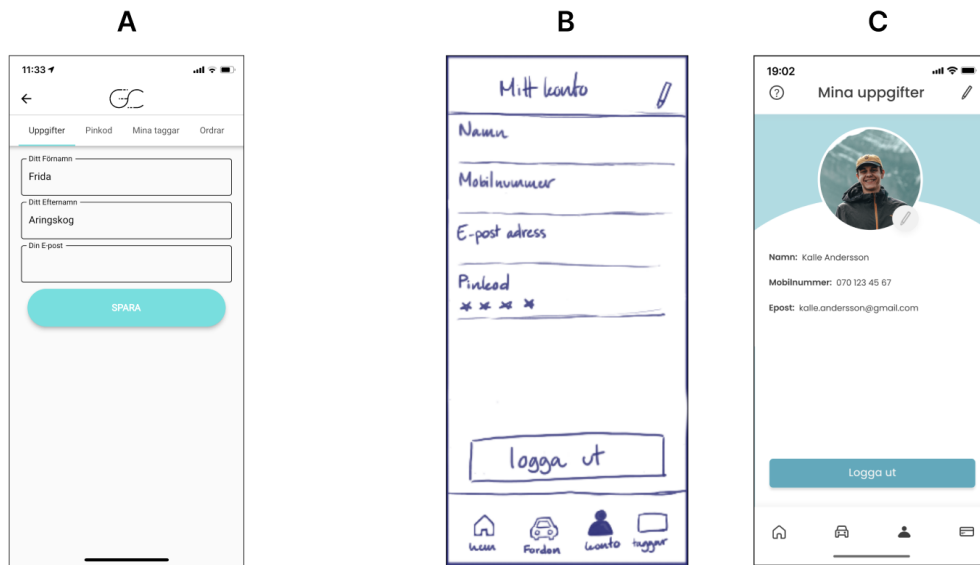
Figure 15: Three variations of the user profile. Variation *A* is the current application [38], *B* is the sketch for the design proposal, and variation *C* is the hi-fi prototype for the design proposal.

5. Managing payments tags.

The fifth and last user activity is managing payment tags. In the current application, this functionality is found under User account. In the design proposal, however, this feature has been given its own place in the menu bar. This decision was made because the managing tags feature is standalone and deserves a prominent position, rather than being hidden behind the user account. Other differences between this feature in the design proposal compared to the current design, is the usage of full pages for the add tag and order tag features instead of using modal windows. This was done to make better use of the space of the screen, considering the small screen size of a mobile device.

5.3 Usability Test

The design phase concluded with a usability test. During the test, five participants performed a set of predefined tasks in the prototype for the new Greencharge Infra mobile application. After every task, the participants conveyed their thoughts and feelings concerning the design of the application. Everyone who partook in the test was a driver of an electric vehicle. However, the usage and attitude towards mobile applications for charging EVs varied between the participants. About half of the participant group were positive towards using apps to find and initiate charging. The rest expressed that they mostly rely on the built-in functionality in the car when it comes to finding charging stations and charging the car.

The goal of the usability test was to measure the usability of the new design proposal. This was achieved by evaluating five criteria of usability: learnability, efficiency, memorability, errors, and satisfaction.

5.3.1 Efficiency

Efficiency in a user interface refers to how quickly and painlessly a user can achieve their goals. The efficiency of the new design proposal was assessed by measuring the time it took each participant to complete a task. A participant's completion time was later compared to the average completion time of each task (see Figure 16). If a participant completed a task within the preferred timeframe, it was considered efficient.
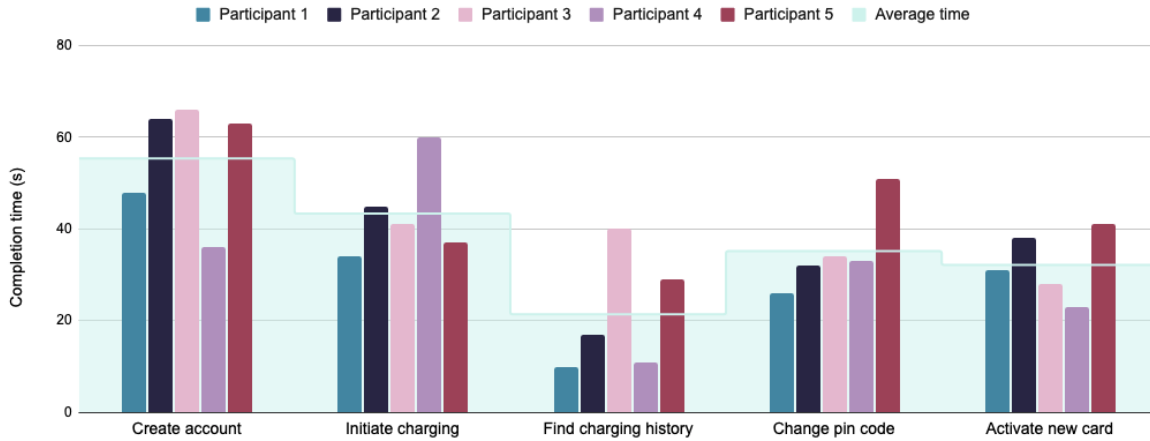

Figure 16: A bar graph illustrating the completion times of each task, with a blue threshold line indicating the preferred completion time for efficiency. If the completion time falls below the threshold line, it is considered an efficient completion of the task.

All participants managed to complete each task, and many of the tasks were completed within the preferred timeframe. I.e. most tasks were efficiently completed. However, there is one instance where the majority of the participants failed to complete the task within the preferred time. Namely, the first task of the test, creating a new account, where only two out of five participants were successful.

5.3.2 Errors

Errors refer to the mistakes a user commits while trying to reach their goal. In this thesis, errors were quantified by counting the number of faulty clicks made by each participant while performing a task (see Figure 17). Furthermore, it was identified where on the user interface the participants clicked in order to determine whether the errors were randomly distributed across the interface, or if certain parts of the user interface were more prone to cause errors.
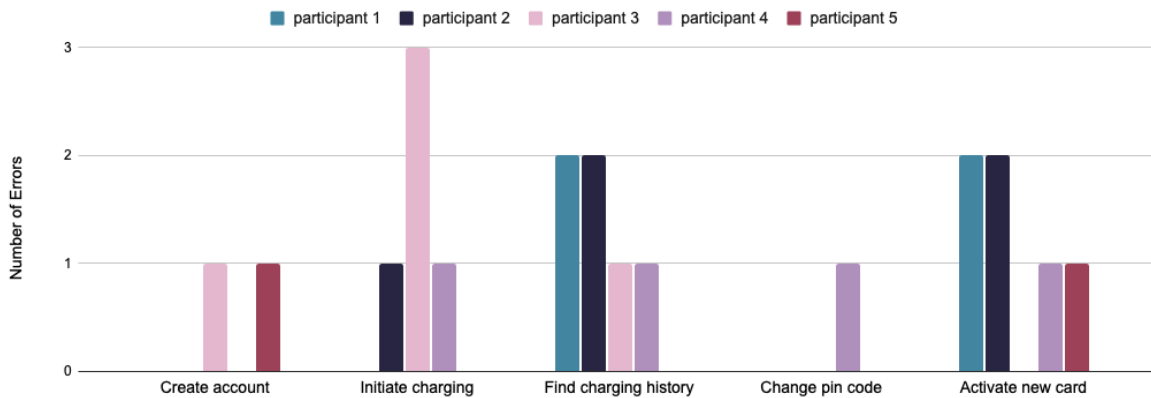
Figure 17: A bar graph depicting the number of errors each participant commited during each task.

The most error-prone tasks were task 3, finding the charging history, and task 5, activating a new charging card. Each of these tasks resulted in a total of 6 errors. In the case of task 3, finding the charging history, the errors occurred because the participants did initially not realize that the functionality was located under the car-icon. Three participants mistakenly believed that the functionality was found on the profile page, while one believed the functionality to be on the payments page.

The errors committed during task 5 happened when the participant was supposed to enter a card number. As a default, the application is set to activate a tag, prompting the input field to ask for an RFID number. However, specifically required activating a card, not a tag. The participants did not notice that they needed to change from tag to card before attempting to enter the card-number, resulting in the faulty clicks.

5.3.3 Satisfaction

Satisfaction in user interface design refers to how pleasant a user interface is to use. In this thesis, satisfaction was evaluated by collecting feedback from the participants regarding their experience with the application and how they felt while performing the tasks.

The overall experience of the application, was predominantly positive. The participants expressed that they found the application easy to use and that it seemed to cover everything they might need in a mobile app for charging stations. One participant specifically highlighted the use of recognizable symbols and icons throughout the application, which greatly contributed to its ease of use. However, another participant mentioned that they felt the application lacked some branding elements. They suggested that incorporating a logo and other brand-specific graphics would give the prototype a more cohesive and complete feel.

Below follows more specific opinions concerning each individual task:

Task 1: Create a new account

All participants expressed that it was easy to perform the task. However, one participant expressed that they were missing some kind of disclaimer about how personal data is treated in the system. The same participant wondered why it was necessary to enter one's home town when it is possible to use location services on the mobile device to gain one's location. Another participant expressed that they did not see the point in dividing the sign-up process on so many pages. No other concerns were raised.

Task 2: Find a charging station and initiate charging

When tasked with finding a charging station and initiating charging, all participants managed the task with only minor issues. The general consensus was that this task felt familiar and intuitive. However, one participant struggled with choosing the connector, and expressed a desire to select the connector in an earlier stage of the process. Another participant mentioned that they would probably use the user interface at the physical charging station to initiate charging, rather than via the mobile app. Only one participant used the search-function to find the charging station, the remaining participants relied on trial and error and simply clicked on an available station on the map.

Regarding the information available in the charging dialogue, all participants expressed positive opinions. They emphasized the importance of knowing the cost, and charging effect before charging. One participant said that knowing the estimated finished time was an interesting and useful feature.

Task 3: Find the charging history

The participants were intrigued by the charging history functionality, and expressed that it could be a useful feature of the app. Two participants mentioned that even more information, or the ability to see a receipt of the charging session, would be a good addition if the functionality is to be used for accounting purposes. The remaining participants were happy with the information on display, and said that the cost, charging effect and time were the most important pieces of information. However, the task of finding the charging history proved to be a bit challenging for the participants. Four out of five participants did not immediately realize that the charging history could be found under the *My cars* page.

Task 4: Change pin code and sign out from the application

Most participants managed to change the pin code without any issues, and all participants expressed that they found the task easy to perform. Additionally, all participants found the edit-profile icon to be easily recognizable and located in a logical place. The presence of the sign-out button on the profile page was also deemed appropriate by the participants, as it is related to account management. Two participant specifically appreciated the confirmation before signing out, since it makes it possible to abort the action if one clicked the sign-out button by mistake. However, two participants mentioned that the button might be a bit too big, noting that its larger size increases the likelihood of accidentally clicking on it. One participant mentioned that they did not see the point of the profile picture, the remaining participants did not comment on this.

Task 5: Activate a new card

All participants found it relatively easy to activate a new card. They also considered the overview of charging tags and cards as advantageous since it provides a clear visual representations of the cards or tags at hand. However, one participant expressed concern regarding the naming of the page, which is currently named *My tags*. The participant found the title *My tags* to be misleading, since it is possible to add both tags and cards.

5.3.4 Learnability and Memorability

Learnability and memorability, in user interface design, pertains to how easy a user interface is to learn, and how easy it is to remember how tho use the interface after a time of disuse. The Learnability and memorability of the design proposal were assessed by asking the participants how comfortable they felt to use the application in a real life situation, solely based on the minor interaction they had with the application during the test.

All participants answered that yes, they would feel comfortable using the application in a real life situation without further exploring of the app.

5.3.5 Additional Findings from the Usability Tests

The usability test also proved to be an opportunity to ask EV drivers about their experiences, thoughts, and ideas concerning EV's and the charging process. During the interviews before, and after the tasks, some additional findings were made:

- Driving an EV is not always by choice, the workplace sometimes demands it.

- Many use the apps they do, or charge the way to do, simply because they find it the least troublesome.

- A solution with support for multiple operators and suppliers would be the best solution for the user.

- A lot is happening in the electric vehicle world, and there is an ongoing effort to make the charging process less of a hassle for the EV driver.

- No two EV drivers are alike, and charging habits varies a lot from driver to driver, regardless of what brand of car they drive.

6 Discussion

In this section, some key findings from the preliminary study and the usability tests are highlighted and discussed. Additionally, the more substantial design decisions made during this thesis are discussed and evaluated. Lastly, the section ends with a discussion concerning the method used in this thesis, as well as some areas of improvements in the method.

6.1 Key findings

The result from the preliminary study and usability test can be funnelled down into some key findings. The key findings from the preliminary study were used to guide the design decisions made during the creation of the design proposal. The findings from the usability study were used to formulate suggestion for future design and development of the Greencharge Infra app.

User Survey

- Drivers of EVs use mobile applications as a tool to find and utilize charging stations.

- Other than the location of the charging station, users find it important to know the availability, price, and technological specifications, such as charging velocity and type of connector, of the charging station. It is also important that the information is updated and reliable.

- Some participants expressed that the charging process can be a hassle, and that it might even be a cause for some people to refrain from buying an electric car. Therefore, it is important that the tools used for charging are made easy and intuitive.

- Most of the users wished for a universal solution, unbounded by different brands, and with support for multiple suppliers and operators.

Heuristic Evaluation

- Although the application provides error messages when issues occur, the messages were sometimes insufficient and not specific enough to actually aid the user.

- The application lacks when it comes to consistency, both internal and external.

- Some functionality is hidden and hard to find.

- The application sometimes lack of confirmation and ways to exit before committing to processes.

Usability Test

- All participants managed to complete every task of the usability test with only minor errors.

- The application can be considered efficient since the majority of the participants managed to complete the majority of tasks within the preferred timeframe. Moreover, almost every task was completed in less than a minute, which can be considered a very good result for first-time users.

- There is a correlation between errors and efficiency in two contradictory ways. On one hand, a slow completion time can be a result of many errors, as errors can lead to delays while trying to complete a task. On the other hand, a slow completion time can equal few errors, as the participant might take a meticulous approach to the task, ensuring accuracy and thereby minimizing errors.

- The sign-up process is intuitive, but there is potential for further streamlining to make the process even more effortless.

- The charging history was not intuitive to find. Only one out of four participants found the functionality on the first try.

- All participants expressed that being able to view charging history was a good and useful feature of the app.

- All participants expressed that they felt comfortable to use the application in a real life situation based on the short interaction they had with the application during the usability tests.

- The fact that many of the participants did not distinguish between tags and cards, as well as the somewhat misleading title of the page *My tags*, indicates that some further clarification on the tags and cards-page is necessary.

6.2 Design Decisions

Creating a design proposal involves making numerous design decisions, ranging from minor details like the shape of a button to more significant choices that directly impact the usability, such as deciding on the activity flows of the application. Throughout the creation of the design proposal for the Greencharge Infra mobile app, the author strived to make informed decisions based on usability principles and the findings from the preliminary study. Below, some of the more impactful design decisions are highlighted and discussed.

Based on the findings from the preliminary study, it was determined that the information available in the current Greencharge Infra application was not enough. Therefore, efforts were made to provide more, and better structured, information in the new design proposal. This change is particularly prominent in the screens for the charging dialogue (see Figure 14) which in the new proposal contains more dynamic information, including the current charging percentage, cost, and estimated completion time.

During the usability test, the participants were asked to give their opinion on the information present in the charging dialogue. The aim of this question was to ensure that the new design lived up to the participants' expectations regarding the information in the charging dialogue. The majority of participants were satisfied with the information provided, indicating that the new design was successful. However, one participant had an interesting suggestion regarding unavailable connectors. Rather than only showing that a connector is occupied, the battery percentage of the car using that connector could also be displayed. This would allow users to determine if it is worth waiting for a connector to become available. For example, if a car currently charging have a low battery percentage, it might not be worth waiting for that connector to become free. If the car have a higher percentage, however, it might be worth waiting for the connector to become available.

The preliminary study uncovered that the current application lack in consistency, in terms of both external and internal [13]. Internal consistency issues included inconsistent capitalization, different button styles for similar actions, and a lack of visual cues for clickable elements. External consistency issues involved using unknown icons or symbols, as well as using known symbols in an unexpected way. Because of these findings, both internal and external consistency was considered during the creation of the design proposal.

During the usability tests, the internal consistency of the design proposal went largely unnoticed by the participants. However, one could argue that this is a positive outcome. Internal consistency is often subtle and is best reflected in users' ability to understand and navigate the various parts of the user interface. An internally inconsistent user interface is prone to cause confusion and frustration [13]. The lack of these emotions during the usability tests indicate that the design proposal exhibited satisfactory internal consistency.

External consistency, particularly the usage of recognizable symbols and language, was easier to assess during the usability tests. Participants demonstrated a clear understanding of the meaning behind the symbols used

in the design proposal. When asked to explain what motivated them to click on a symbol, all participants mentioned that they did so because they understood its intended meaning. At the end of the test, one participant specifically mentioned that the usage of clear symbols and icons was something they appreciated in the new design. These observations indicate that the design proposal successfully addressed the issue of external consistency.

Another significant design decision was to alter the way of navigation. Previously, the application used a hamburger menu, but in the new design proposal the hamburger menu was replaced with a bottom bar menu (see Figure 13). One drawback of hamburger menus is that they conceal the application's content, whereas a bar navigation allows the content to be visible at first glance [39]. The decision to change the navigation stemmed from wanting to make the various parts of the application more visible and accessible for the user, while also providing more freedom in navigating the app. Therefore, a bottom bar menu was selected, as it immediately conveys the available pages to the user [12]. During the usability test, every participant seemed comfortable using the bottom bar to navigate between the pages of the application. One participant even explicitly mentioned that they liked the bottom bar menu because it provided clarity.

During the preliminary study, it became evident that the current application lacks sufficient error management. Not enough effort is made to prevent the user from committing errors, e.g. there are no confirmations before committing to processes. Additionally, the error messages that appear when an error in the system has occurred, or when a user has triggered an error, are not specific enough to be of any actual aid to the user. According to Nielsen [22], it is highly recommended to provide clear error messages and work towards error prevention, which are associated with two of his 10 Heuristics of Usability. Because of this, error prevention and clear error messages was something that was to be highly prioritized in the new design of the application. However, anticipating errors is a difficult task, and it can therefore be challenging to design to prevent and manage errors. Although attempts were made to include error management in the new design proposal, it might not have been enough to surpass the current application.

Beyond clear error messages when an error has occurred, it is important to investigate how errors might be prevented. One way to prevent errors is by providing the user with feedback about what is happening in the system [14]. Therefore, efforts were made to incorporate useful feedback in the design proposal.

One example of feedback used in the design proposal was making the selected charging station appear larger than the surrounding charging stations. The larger size intended to communicate which charging station was selected. Another, more obvious kind of feedback is the progress wheel present in the charging dialogue, which is used to show how much the car has charged. During the usability tests, it was observed that these feedback features went largely unnoticed by the participants. There are two possible explanations for this. Firstly, the feedback was insufficient or not visible enough. Secondly, the feedback might have been provided in such a natural way that participants did not think to remark on it.

The sign-up flow of the design proposal is based on the flow of the current application (see Figure 18). However, during the usability test, it became evident that it might be possible to alter the sign-up flow to make it even more compact. For instance, it could be possible to choose home town at the end of the sign-up form instead of on a separate page. It might even be possible to remove the select home town and instead rely on location services of the mobile device. Additionally, the comments regarding a disclaimer concerning how personal data is being handled by the system is an important aspect that should be added to the system before the application is made public.
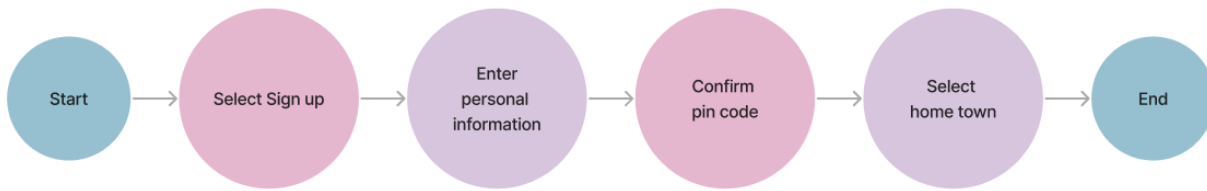
Figure 18: An illustration of the current sign-up flow.

During the usability test, the task to create a new account was the only task where the majority of participants did not complete the task within the preferred timespan. However, this result does not necessarily mean that the sign-up process is poorly designed or lacks usability. It is important to note that this was the first task of the usability test. This might have led to the participants being unfamiliar with the prototyping tool, and thus the completion time for this task is unusually uneven.

It is also worth noting that signing up to the application is a process the user goes through once. Therefore, it might not be as crucial for this process to be intuitive and efficient compared to other activities in the application, such as finding a charging station or viewing the charging history.

6.3   Design Requirements

At the outset of this thesis, a set of design requirements was established (see Section 2.1). The purpose of these requirements was to guide the creation of the design proposal to ensure that the design proposal align with the expectations of the company who have sanctioned the project. Although the initial idea was to fulfil each of these requirements, the result of the study show that not every criterion was fully met.

The application should be modern and minimalistic.

The aesthetics of the design proposal was not explicitly evaluated during the design phase, nor during the usability tests. It is therefore not possible to assess whether this requirement was fulfilled or not. However, there were no negative comments concerning the aesthetics of the application during the tests, therefore one could argue that the participants were satisfied with the visual language of the application.

The application should be intuitive and easy to use while being mobile.

Since all participants of the usability test expressed that they found the application intuitive and easy to use, one could argue that this requirement has been fulfilled. However, it is worth noting that the prototype has only been tested in a controlled environment, where the user were stationary while performing the tasks. It is therefore not possible to surmise how well the application fares when the user is being mobile.

The application should provide the user with feedback about the system's current status.

Efforts were made to provide the user with feedback about the ongoings in the system. However, none of the participants commented on the feedback during the tests. It is therefore difficult to determine whether this requirement was fulfilled or not.

The application should provide the user with sufficient feedback to help them identify and re- cover from errors.

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Error management was under consideration during the entire design process. However, it is important to note that the usability test did not include a specific evaluation of how users reacted to error messages and whether the messages were effective in assisting users in recovering from errors. It is therefore not possible to surmise if this requirement was fulfilled or not, and further work with error management is recommended in the future development of the application.

The process of signing in and signing up should be quick and easy.

The result of the usability test shows that the process of signing up was the most time-consuming task that the participants performed during the test. The result also shows that the majority of the participants made less than one error while performing this task. These results indicate that it might be possible to optimize the sign-up process to make it more efficient. While this is true, one has to remember that it only took about 66s for the slowest participant to complete the task, which is still rather fast. The low error-rate is a successful result, which indicate that the process was easy for the participants to perform.

The visual language of the design should be flexible and easily adaptable to different companies or graphical profiles.

This was achieved by using a neutral visual language and being sparse on brand identity and vivid colours. While this did comply with the requirements and resulted in a design that felt simple and flexible, one participant of the usability test commented that they were missing some kind of brand identification to make the prototype feel more like a real app.

6.4   Areas for Improvement in the Method

As with any study, it is possible to identify potential limitations, or areas for improvement, in the selected methods for this thesis, and in the execution of said methods.

The new design proposal relies on the preliminary study and on known usability principles. When it comes to the preliminary study, one limitation is the fact that the heuristic evaluation was only performed by one individual. The application was also only evaluated in a test environment, and not in a real world situation. These limitations may have led to some usability issues not being identified. As for the user survey, the limited number of participants, namely 34, might not have been enough to fully understand the problem situation, and the user needs in these kinds of applications [24]. The user survey could also have been more thorough in its descriptions of what kind of mobile application the project was aiming to improve, as to not confuse it with other charging related mobile applications such as route planners or travel guides. However, the user survey did provide the writer with an initial insight of the field, and the result of the survey was therefore deemed sufficient for the scope of this thesis. The aim of the survey was, after all, not to make any strong statistical claims, it was only to create an understanding of the problem situation.

Initially, it was planned to conduct the usability tests in person, however it was soon discovered that it would be difficult to arrange this, and it was instead decided to conduct the tests online. Online testing enabled the possibility to reach users that otherwise would have been unreachable due to travel distance [33]. It also eliminated the need for a physical test space, and recording equipment.

Using an online format rather than face to face comes with both advantages and disadvantages. An advantage is that it is generally easier to conduct the test with only one test facilitator. Instead of needing to use multiple tools, one computer equipped with a camera is enough to carry through the test. However, external factors such as internet connection, the participant's device, and the inability to fully control the test environment may affect the consistency of the tests, leading to not every participant having the same test experience.

Another disadvantage with the online format is that the test is performed on a desktop computer, rather than a mobile device, which is not the intended platform for the app that is being tested (see Figure 19). As mentioned in the theory section (see Section 3.1), the way of interacting with a device differs a lot between desktop and mobile devices [11]. Not being able to view the prototype on the correct platform, as well as not being able to interact with the prototype in the intended way, may have led to incomplete or misguiding results of the usability testing.
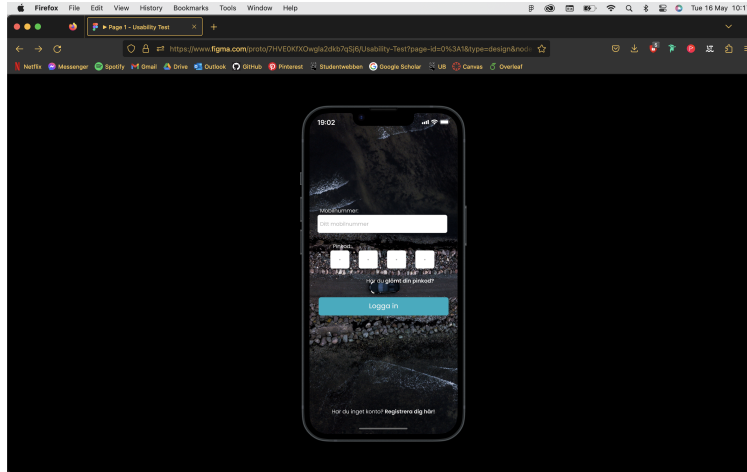
Figure 19: A screenshot showing what the prototype looks like in a desktop window.

The layout of the test is in theory well-suited to measure usability, but, in practice, the method has some limitations. For instance, measuring the efficiency of the application by measuring the completion time of the tasks might not be the best method. Especially not when paired with the thinking aloud method. This is because some participants might pause while performing a task to express spontaneous thoughts or ideas, which might prolong their completion time. It can also be difficult to determine a suitable threshold for efficiency, since it varies depending on the complexity of the task [29]. If one is to assess the efficiency of the entire application based on the completion time of certain tasks, it is also important to note that not every task should be considered equal. For instance, the task of creating a new account, which is a task that is usually only performed once. To better measure the efficiency of an entire application, one needs to weight the various tasked based on how often the user is likely to perform the task in their everyday usage of the application, as well as how important efficiency is in comparison to effectiveness and satisfaction. Some tasks might cost a bit of extra time, but instead they cause very few errors, or are satisfactory for the user to perform [40].

To find a suitable threshold for efficiency, a good practice is to look at industry standards, or data from other similar applications. However, this kind of data can be hard to come by. Another way to assess efficiency might be to compare the completion time between various applications, or between various versions of one application, as demonstrated in the article *A structured methodology for comparative evaluation of user interface designs using usability criteria and measures* [40]. In the context of this thesis, comparing the completion time of tasks between the current application and the new design proposal would have been an effective way to measure whether the efficiency of the app had improved or not. Unfortunately, due to resource constraints, this comparison was not conducted. Instead, the threshold to measure efficiency was set as the average completion time of each task. Meaning that every task that was completed in below average time was deemed efficient. Using the average completion time as a threshold was in this thesis considered to be a good starting point because of its accessibility and representativeness. It is accessible since it is rather easy

to calculate, and does not rely on any additional data. Representative, since it provides a value based on the overall performance of the task.

Regarding error detecting, solely achieving this by counting faulty clicks does indicate that an error was committed. It does not, however, give any information regarding how severe the error was.

When it comes to asking the participants about their experience, in an attempt to gather if they found the application satisfactory and pleasant to use, it is often quite easy to gain vague answers such as "nice" or "good" or "bad". Although such answers are not to be ignored, they do not fully explain what the participant truly thought about the application or, more importantly, why they considered it "good" or "bad". To obtain a quantified measure of satisfaction, it would have been possible to utilize scale ratings or other metrics to measure satisfaction [41].

7 Conclusion

This thesis set out to implement known usability principles in order to improve usability in a mobile application for charging of an electric vehicle (EV). The application of the gestalt laws to structure information and the emphasis on external and internal consistency were identified as vital components of creating a successful design proposal. Furthermore, the thesis emphasized the importance of adhering to and adapting the design to better align with user needs. Through the implementation of usability principles in the mobile realm, this thesis has demonstrated that the principles are effective in the work with mobile applications.

The research has highlighted how important it is to implement usability in mobile applications for charging electric vehicles. Although electric vehicles have become more common on our roads, there is still a resistance towards fully committing to replacing fossil-fuelled cars with electric vehicles. A resistance originated in the insufficient range of EVs and the hassle of needing to charge the car. Therefore, it is essential that the tools for charging and managing electric vehicles are made as easy and intuitive to use as possible. Improving the usability of these applications might relieve some resistance towards the transition to electric vehicles, and thereby contribute to a more sustainable future.

The results of both the user survey and usability test indicated that the electric vehicle drivers desired a universal solution that supports multiple suppliers and operators, and car brands. Although this would ultimately be the best solution for the drivers, it is not really realistic since multiple companies with different stakes and monetary interests are involved in the creation of these apps and charging stations. However, establishing standards for the operation of these apps and stations may alleviate the need for drivers to learn how to use each specific app or charging station. Therefore, finding a standard, or a common ground, should be considered a next step in the development of apps for charging stations.

8   Future Work

The electric vehicle market is rapidly evolving. Therefore, the complementary technology, such as mobile applications for charging electric vehicles, need to follow suit. As mentioned in the conclusion, the next step for mobile apps concerning charging stations is to find some common ground by standardizing, for example, available payment methods, symbols and language, or activity flows in the application. Common standards and recognizable features can make it easier for the users to alternate between the various apps they might need.

Concerning the Greencharge Infra application, during the usability test it became prominent that although the design proposal can be considered efficient, and easy to learn and remember, there are still some work to be done to improve the usability of the application even further. Some suggestions for improvement is to rethink the card and tags page. By providing more instructions and information, it might be possible to clarify this feature of the application.

Another suggestion is to reevaluate the sign-up process, or more specifically, reevaluate the importance of entering one's home town. It is also important to add information concerning privacy and how personal data is being handled in the system.

Lastly, managing errors and preventing errors is an aspect of the application that needs further consideration. In order to prevent errors, it could be good to add more instructions concerning the expected input of fields. For instance, it should be visible whether an input is mandatory or not. The error messages are not yet designed, but they should be considered in the future development of the application. As it was noted during the heuristic evaluation, it is important that the error messages are constructed with the user in mind. Use language that the user can process, and help them understand and recover from the errors.

The future work of the Greencharge Infra app will also involve implementing the application and thereafter continue to test and evaluate its usability. Moreover, in this thesis, the application has been tested in a controlled environment and only in the prototyping stage of development. Future work would therefore include testing how well the implemented application fares in real-world situations.

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A Appendix: Design Proposal

A.1 Design Sketches
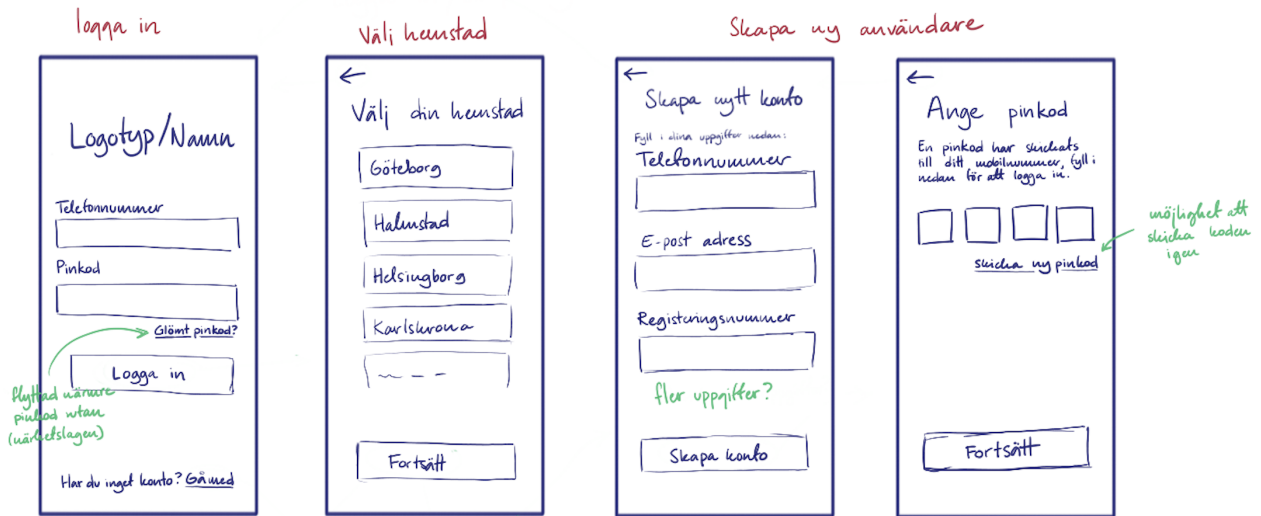
Figure 20: Sketches of the sign-up process created during the design phase, with commentary about the design choices.
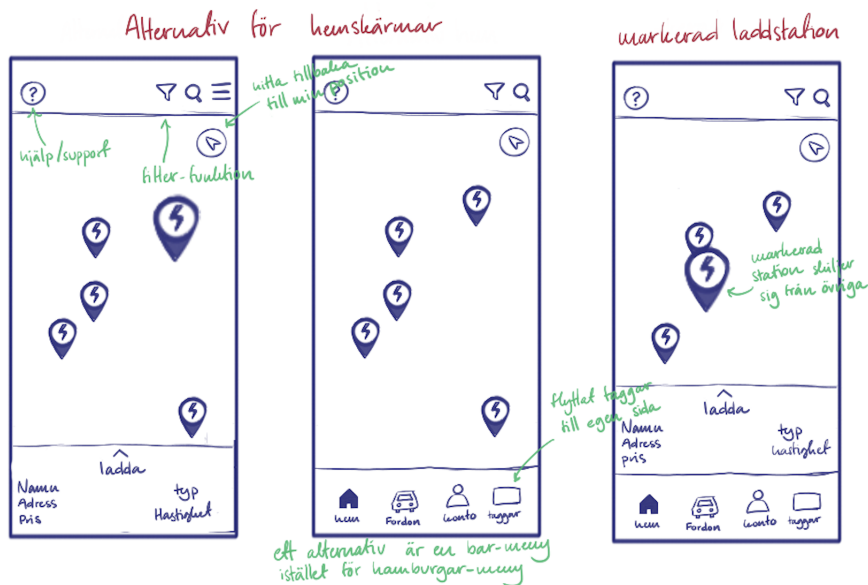
Figure 21: Sketches of the home screen created during the design phase, with commentary about the design choices.
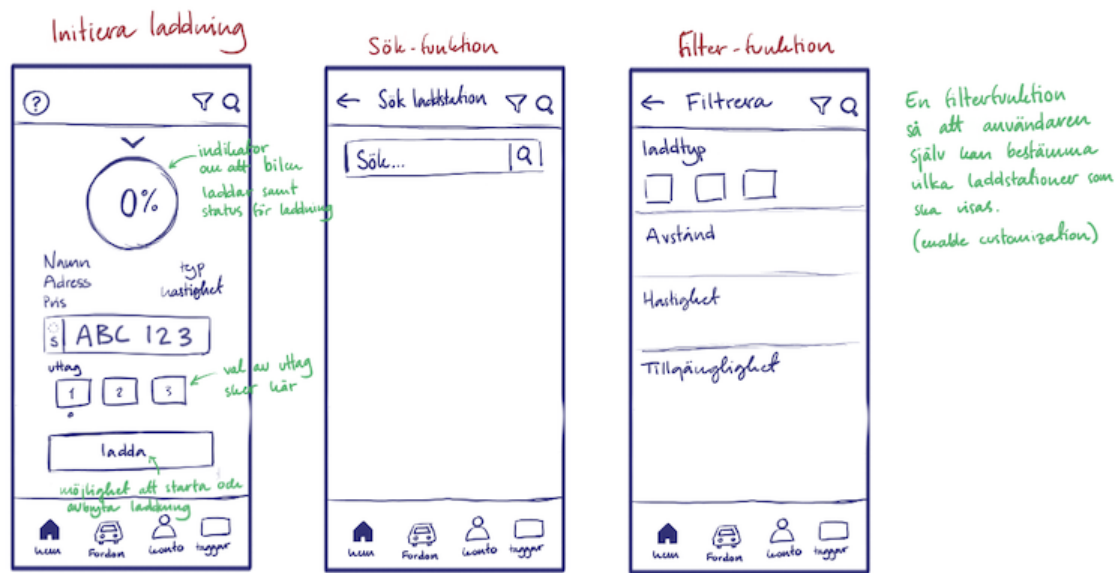
Figure 22: Sketches of the charging dialogue created during the design phase, with commentary about the design choices.
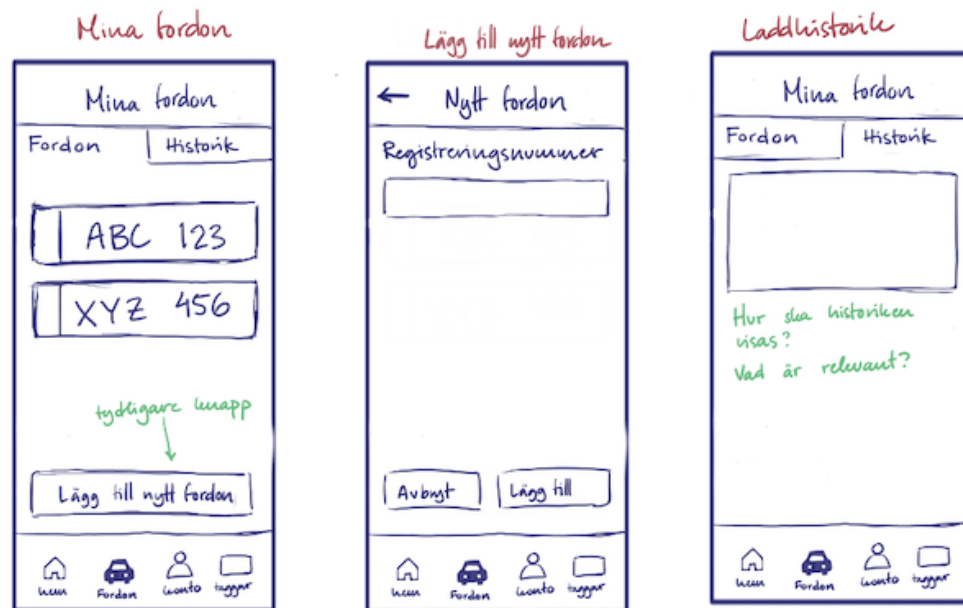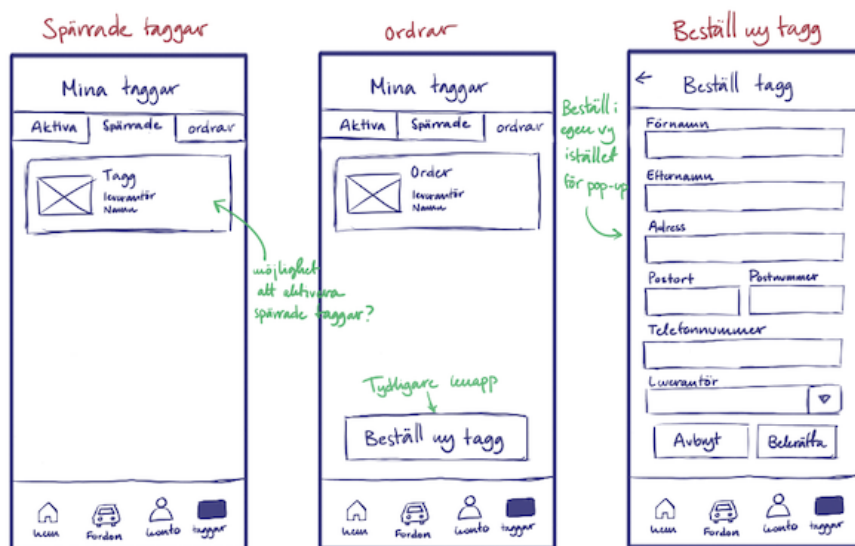

Figure 23: Sketches of vehicle and vehicle history screens created during the design phase, with commentary about the design choices.
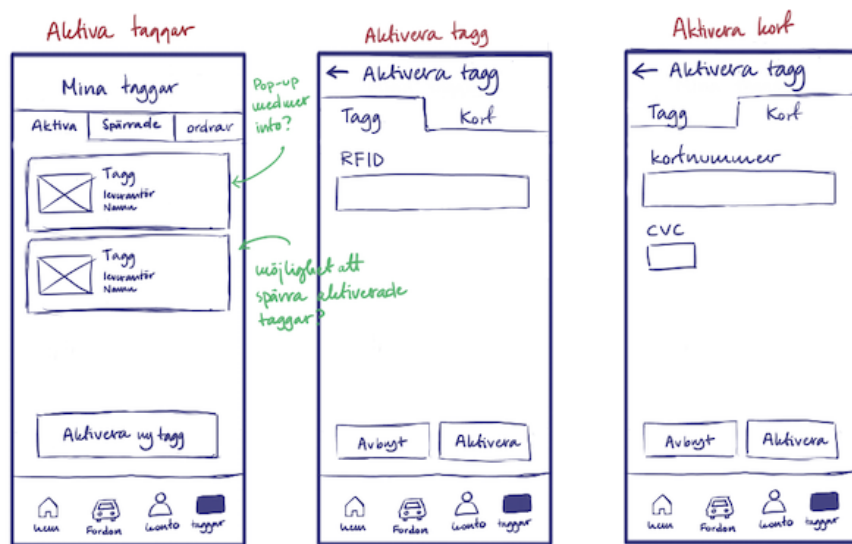
Figure 24: Sketches of tags and activating a tag created during the design phase, with commentary about the design choices.

Figure 25: Sketches of tags and ordering a tag created during the design phase, with commentary about the design choices.
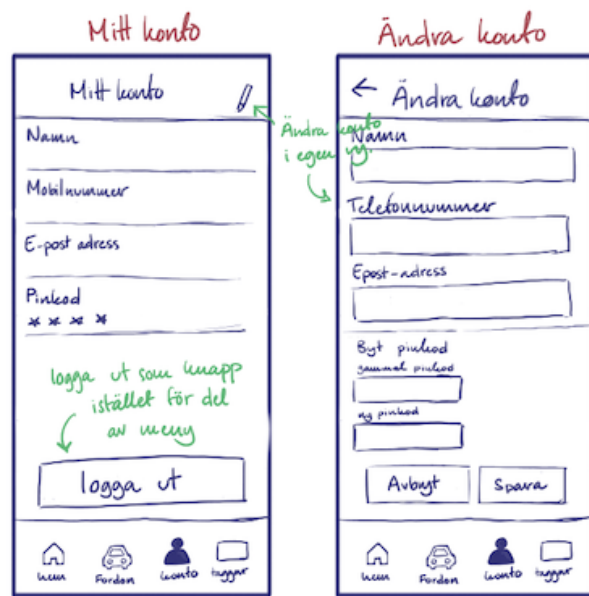
Figure 26: Sketches of profile screen created during the design phase, with commentary about the design choices.

A.2 Design System

Figure 27: Custom-made icons used in the design proposal.
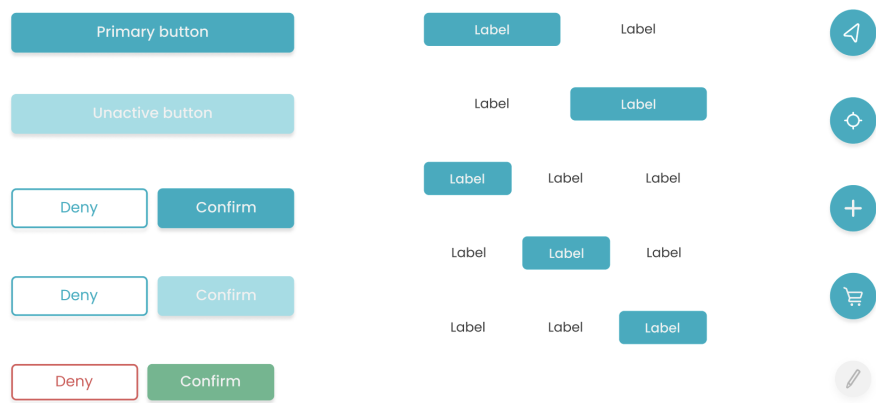
Figure 28: Various types of buttons used in the design proposal.
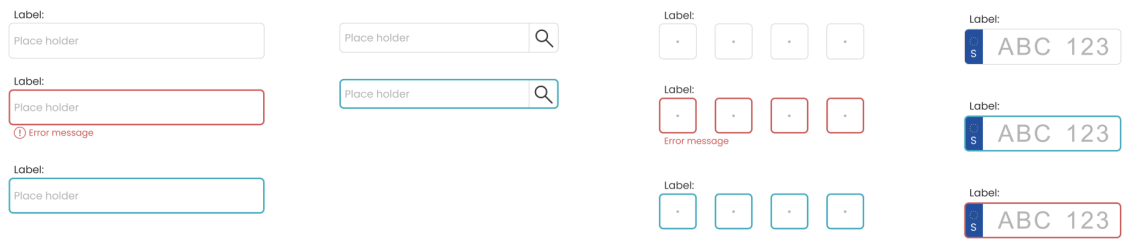
Figure 29: Various types of input-fields used in the design proposal.

A.3 Wireframes
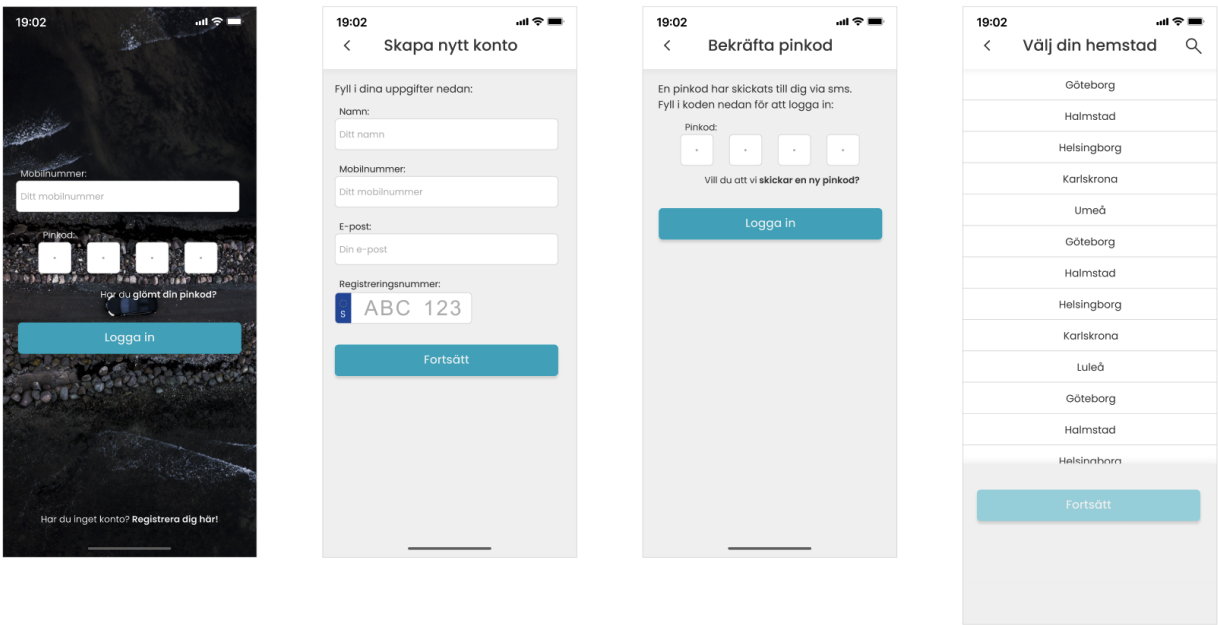
Figure 30: Wireframes of the sign-in and sign-up screens.
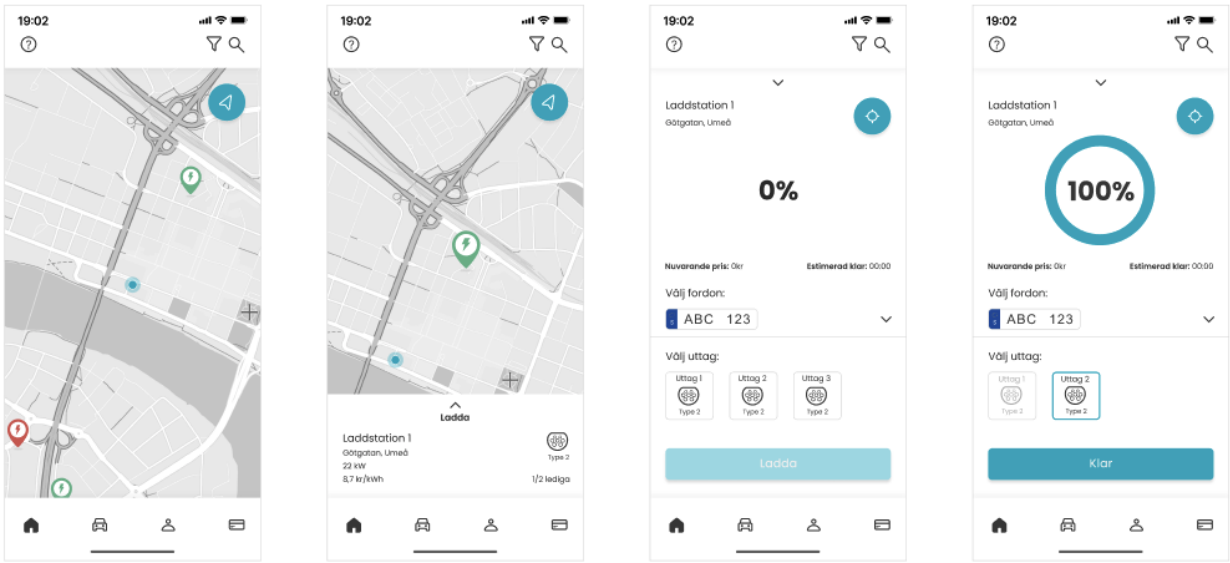
Figure 31: Wireframes of the home screen and charging dialogue.
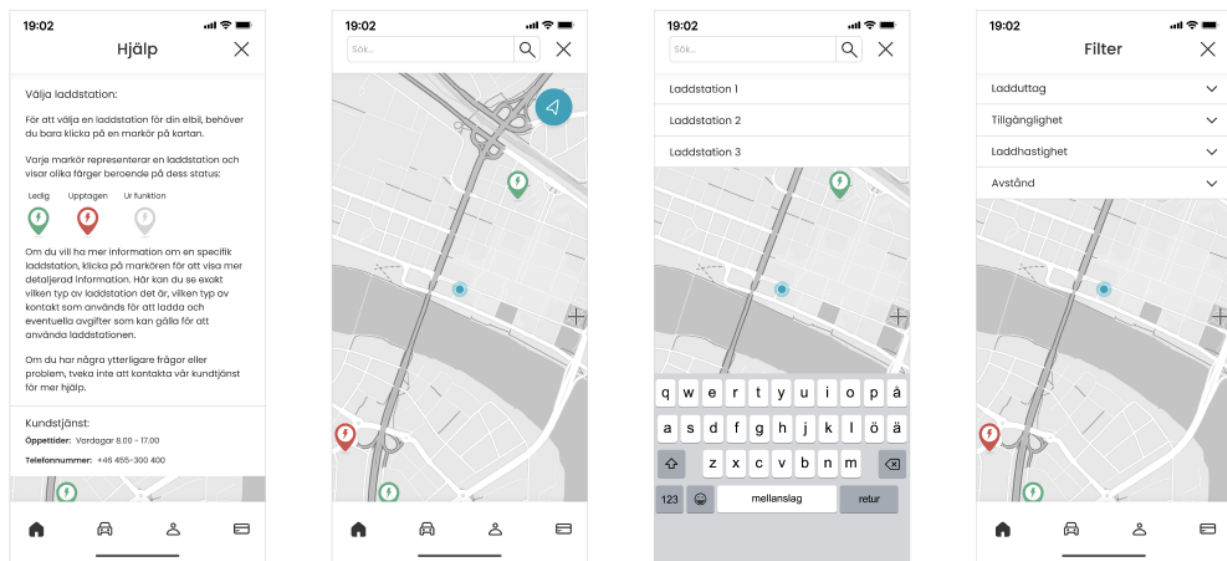
Figure 32: Wireframes of home screen functionality such as help, search and filter.
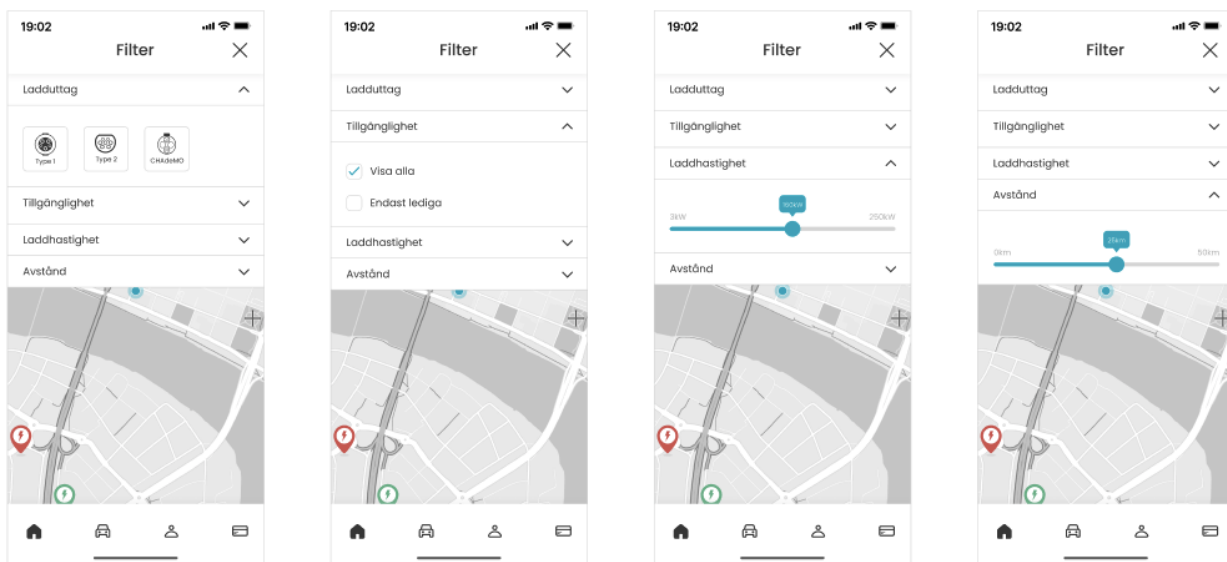
Figure 33: Wireframes of home screen functionality filter.
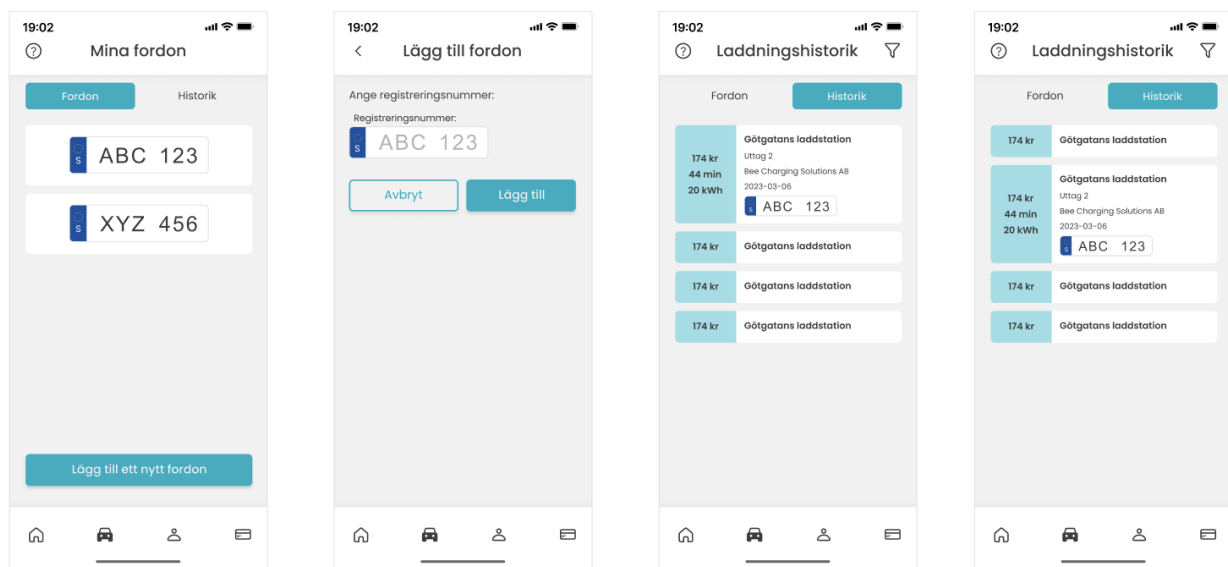
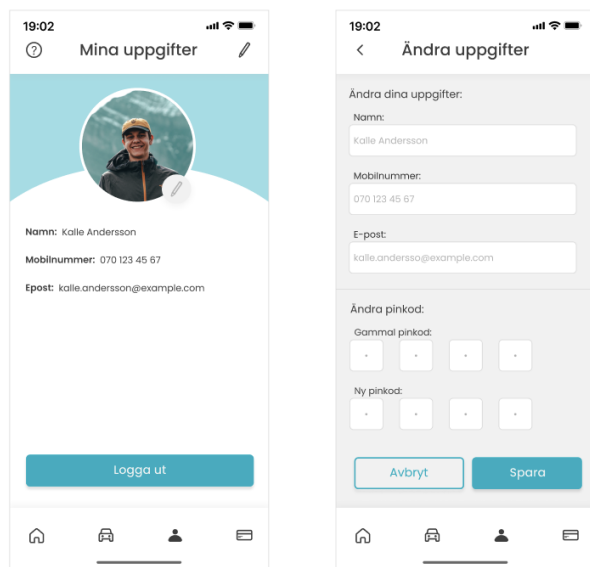Figure 34: Wireframes of vehicle overview and charging history.
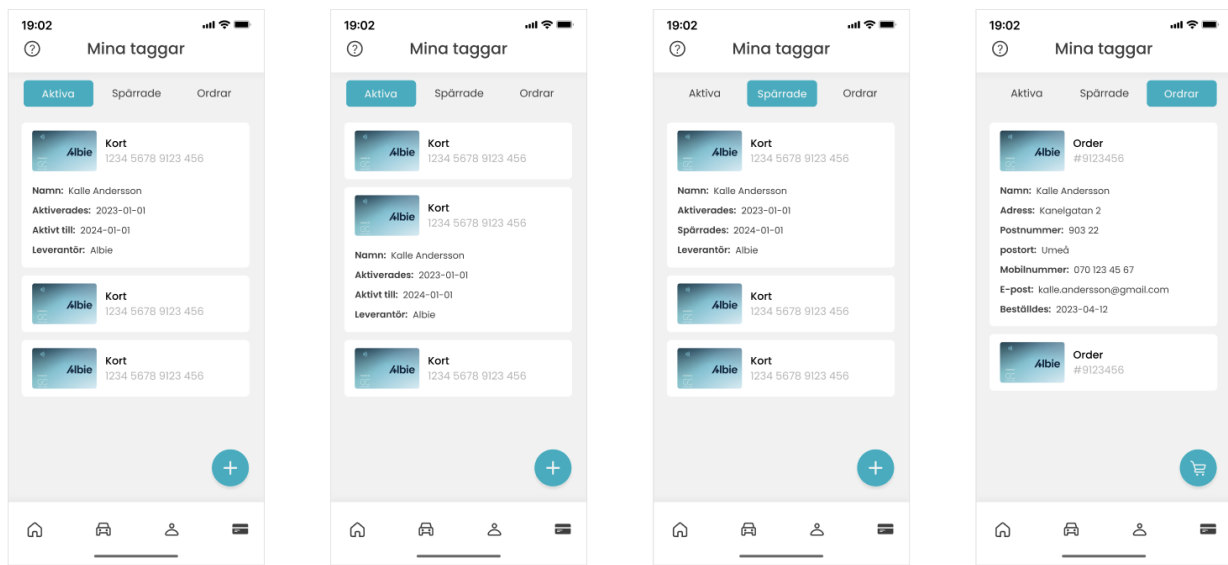

Figure 35: Wireframes of user profile.

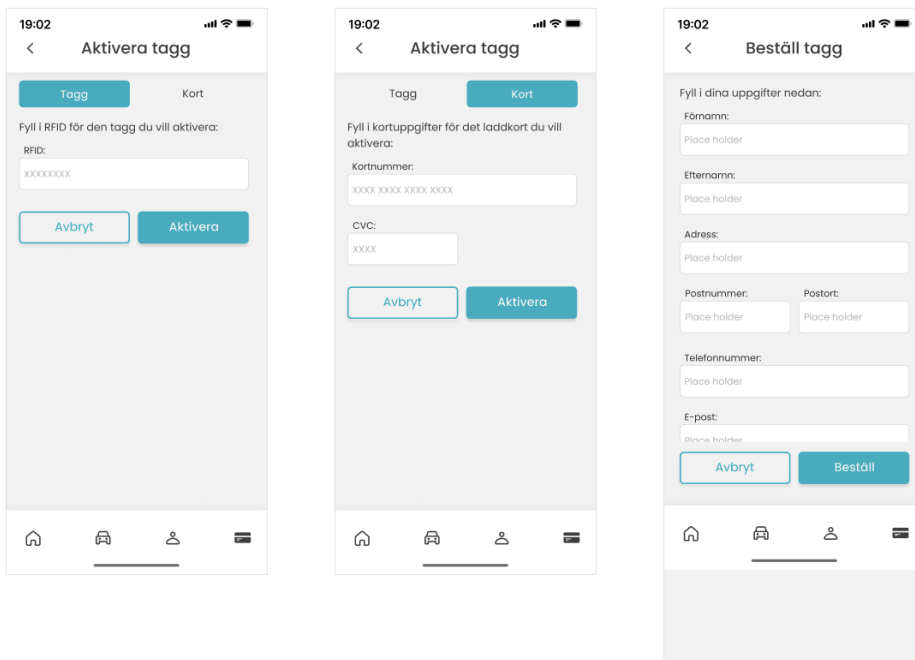Figure 36: Wireframes of card and tags overview.

Figure 37: Wireframes of activating card or tag screens and ordering a tag screen.