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Development of a charging information tool for heavy-duty trucks

How to make the person responsible for charging feel in control of the process

Christine Arkbo

Civilingenjörsprogrammet i system i teknik och samhälle

UPPSALA UNIVERSITET

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Abstract

The aim of this thesis project is to contribute to an understanding of which charging monitoring solutions for mobile phones are valuable and possible for Scania to implement. These solutions are intended to make the person responsible for charging feel in control of the process.

This project focuses on the implementation of a graphical user interface (GUI), with the possible integration of a server that is developed by another thesis worker at Scania. The scope is set to looking at the possibilities and limitations for one charging station, one vehicle and one driver.

Designing good user interfaces is more than mapping user needs to solutions. To design good interfaces, the technological possibilities and limitations must also be considered. This has partly been done by integrating and testing some relevant features with Scania's battery electric trucks.

In terms of creating value for the user, the driver, a contextual design approach, developed by Hugh Beyer and Karen Holtzblatt, has been chosen. In this way, different solutions can be designed in a user-centered way.

One of the results of this project is a minimum viable product (MVP) that Scania or other thesis workers can continue to develop. This MVP has mainly one feature that has been implemented and tested briefly.

The conclusion is that charging monitoring solutions that make drivers feel in control of the charging process have interfaces and interactions that are perceived as relevant by the driver. The relevant features are those that drivers would expect to have access to.

Teknisk-naturvetenskapliga fakulteten

Uppsala universitet, Utgivningsort Uppsala/Visby

Handledare: Jonatan Fjellström Ämnesgranskare: Anders Arweström Jansson

Examinator: Elísabet Andrésdóttir

Populärvetenskaplig sammanfattning

Transportsektorn är den största källan till växthusgas i EU. Dessutom står åkeribranschen för en stor del utsläpp. EU har som mål att minska växthusgasutsläppen från lastbilar med 15% år 2025 och med 30% år 2030. För att kunna minska utsläppen behöver användningen av fossila bränslen minska drastiskt. De mest förekommande lastbilarna ute på vägarna drivs med hjälp av diesel. TRATON som Scania är en del av har som mål att inom 10 till 15 år kraftigt öka antalet eldrivna lastbilar ute på marknaden. Dock behöver laddningsinfrastrukturen också hinna med. Som det ser ut just nu kan det vara svårt att hitta bra laddningslösningar. I och med att branschen för både laddningsstationer och eldrivna fordon är under omfattande utveckling är det möjligt att dessa problem kommer att vara lösta om inte allt för lång tid. Mycket tyder på att det kan komma ytterligare krav som pressar transportsektorn i riktning mot fossilfria alternativ.

Scania och flertalet konkurrenter, som exempelvis Tesla och Volvo, har börjat erbjuda så kallade battery electric vehicles (BEVs). Detta görs för att i framtiden kunna möta de krav som ställs från bland annat EU, men också för att kunna erbjuda kunder ett mer hållbart alternativ. Den senaste serien med eldrivna lastbilar från Scania är bland annat en helt elektrisk lastbil och en plug-in hybrid. De här varianterna fungerar dock bäst i stadsmiljö. För lastbilar som åker längre transportsträckor har Scania även planer på att släppa en serie med snabbladdade lastbilar.

Laddning är ett exempel på en process som är under stor utveckling. Det händer ännu att fel uppstår under laddningen. Många förare laddar lastbilarna under sin paus, men om laddningen har avbrutits under pausen går föraren miste om körtid. Det vore önskvärt om föraren fick information om problemen för att kunna spara på sin egen tid. Förslaget är då att utveckla en lösning eller ett system som gör att föraren eller en annan person som ansvarar för laddningen ska känna att de har kontroll över laddningsprocessen. Ett lämpligt medium för det här systemet är en mobiltelefon, då de flesta antas ha tillgång till en. Dessutom kommer systemet sannolikt att användas under privattid och därför är mobiltelefonen mer tillgänglig.

Scania erbjuder redan flertalet mobilapplikationer för lastbilar och släppte nyligen en uppdatering för Scania Fleet, som är en app som gör det möjligt att bland annat justera temperaturen inne i fordonet innan avgång, samt utvärdera förares beteende. Uppdateringen som släpptes den 18 april 2022 har även stöd för BEV. Det finns även andra appar för eldrivna fordon som exempelvis Teslas *stats app* och *a better routeplanner*.

Syftet med det här examensarbetet är att upptäcka behov hos användaren, alltså föraren. De här behoven kommer att analyseras för att hitta möjliga designalternativ. I det här arbetet ska också nuvarande teknologi testas genom att implementera någon av de lösningarna som tagits fram. På så vis går det att ta reda på vad som är tekniskt genomförbart. Frågeställningen som arbetet hoppas kunna besvara är: Hur kan ett kontrollsystem för laddning bidra till att BEV operatörer har en känsla av kontroll under laddningen? BEV operatörerna är alltså förarna.

Slutsatsen är att lösningar som förare anser vara relevanta vid användningstillfället gör att BEV operatörer känner kontroll över laddningsprocessen. Det som föraren förväntar sig ha tillgång till är det som är relevant, eftersom det kopplar till förarens behov. Föraren bör ha tillgång till all information, men för att undvika ett rörigt intryck bör lösningen belysa det som är viktigast och filtrera det som är mindre viktigt.

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Glossary

Battery electric vehicle (BEV) – A type of electric vehicle (EV) that uses electric motors instead of internal combustion engines (ICEs). Energy is stored in batteries that are possible to charge.

BEV operator – The person operating the BEV. In this thesis, the BEV operator is most often assumed to be the truck driver.

Charging monitoring system – A system that follows an ongoing charging session

Charging station management system (CSMS) – The CSMS is responsible for transferring information for authorising users of the charging station

Compile – Converting a program into machine-code

Drivetrain – Components that together deliver distribute power to drive the wheels forward

Editor – A program for editing source code of computer programs

Emulator – A program simulating a mobile phone device on a computer

Graphical user interface (GUI) – A program that allows users to interact by using visualisations and symbols

Green house gas (GHG) – A gas that contributes to the greenhouse effect

Haulage firm – A firm that transport goods by truck

Heavy goods vehicles (HGVs) – A large heavy motor vehicle

kW – It is a power unit. 1 kW = 1000W

kWh – It is a measurement of energy dispensed per hour

Minimum viable product (MVP) – It is an early version of a product with some useful functionality, mostly used for providing feedback for further development

Native code – Programming code that runs on a specific processor

Native-cross-platform application – Has code that can be used on multiple platforms

Plug-in – A software component that is added to existing software or program

Powertrain (efficiency) – How energy efficiently a vehicle completes a drive cycle

Software development kit (SDK) – A set of software tools used for creating software on certain platforms

The state of charge (SOC) – Available capacity of an electric battery. It is between 0% and 100%.

Uniform resource identifier (URI) – It is an address that identifies different objects of the CSMS on the web. The object in this project is a JSON file containing information from the charging station. The URI is used for setting up a connection between the CSMS and the mobile phone application.

1. Introduction

The transportation sector is the largest source of green house gas (GHG) in the EU. Since 1990 emissions have increased and the heavy-duty transport sector, composed of shipping, aviation and haulage, is the largest contributor. Decarbonisation of the entire transportation sector is therefore necessary to reduce GHG emissions, although each transportation unit presents unique challenges. [1, pp. 1-2, 7] The road haulage and distribution industry is responsible for transportation of goods by road. It is an industry that is said to account for approximately 20% of total global oil demand. [1, pp. 1-2]

The increased adoption of battery electric vehicles (BEVs) has the potential to highly reduce the GHG emissions by the transportation sector. [2, p. 1] Most of the emissions related to BEVs occur during manufacturing, especially the production of batteries, and from generating electricity for charging the BEVs. For diesel trucks, most emissions occur during the operational phase. Thus, for BEVs to be a greener option, it has been shown that BEV operators require the incentives for charging with renewable energy. However, the possibilities for vehicle operators to do so may vary across different regions. [2, pp. 1, 6]

Monitoring the charging process is an example of an activity that can potentially increase operators' incentives to operate BEVs and to do so in an environmentally friendly and cost-effective way. At Scania, charging is an operation critical activity that is undergoing considerable amount of development. In case anything would go wrong during charging, operators should be able to notice the problems and act on them in reasonable amount of time. In addition, allowing operators to take charging related actions when not being in direct contact with the BEV, could apart from saving time for the operator also increase satisfaction with Scania's BEVs. Therefore, allowing operators to gain further control of the charging process could be beneficiary in terms of saving both time and money for the haulage firms.

One way of giving operators further control of the charging process is by giving them access to a charging monitoring system. Since most BEV operators can be assumed to always have access to a mobile phone, it is considered a suitable medium for this type of system.

1.1 Project Aim

The project aim is to contribute with an understanding of what charging monitoring solutions for mobile phones are valuable and possible for Scania to implement. This project will yield solutions intended to make a person responsible for charging feel in control of the process. This involves a user-centered approach to discover needs from the perspective of the vehicle operator for which design solutions can be brought about.

Moreover, the design process also requires some testing of current technology and implementation of some design solutions to evaluate them. The following section is the research question that has been proposed.

1.1.1 Research Question

How can a charging monitoring solution make BEV operators feel in control of the charging process?

1.2 Project Scope and Delimitations

This Master's thesis project is done at Scania in Södertälje in collaboration with Xiaoying Sun from KTH Royal Institute of Technology. The work should be looked upon as two separate thesis projects with a common starting point. It means that the immediate connections are the project scope and the possible integration of results. The duration is approximately 20 weeks, where equal time is distributed to planning and reading literature, realisation of project aims as well as evaluation of the process and writing the thesis report. The project scope was determined in co-operation with Xiaoying and supervisors at Scania.

1.2.1 One Charging Station, One Vehicle and One Driver

Charging stations are in possession of information that could be interesting for BEV operators or drivers to access. For instance, valuable information about the charging state can be communicated and visualised for a BEV driver. A charging station is a system that delivers electricity to electrical vehicles. [3, p. 29] It is possible to monitor charging sessions by using information that is communicated between the charging station and a charging station management system (CSMS). The CSMS is responsible for transferring information for authorising users of the charging station. [4] Xiaoying is responsible for implementing the CSMS. To simplify the project, it was decided that the implementation should work with one charging station, one vehicle and one driver. It means that the implementation will not be able to keep track of multiple users and charging stations.

1.2.2 Graphical User Interface for Mobile Phone

This project will focus on the design and implementation of the graphical user interface (GUI) for a mobile phone because this is the part of the system that BEV operators will interact with. Design and implementation will be done using the Windows operating system. Therefore, the solution will only be compatible with Android devices, because Apple only allows development of iOS applications using a device running macOS. [5] However, since development will take place using the Flutter framework, that is described later in this report, the same codebase can be used for later development of iOS applications. In that case, apart from the macOS, Xcode will be needed for building and releasing the application. [5]

1.3 Thesis Outline

1.3.1 Introduction

The introducing chapter covers the purpose of the project with a review of the subject matter. It also gives a short description of the methods used and some delimitations of the project aims.

1.3.2 Background

This chapter consists of background information related to Scania and the battery electric truck (BEV) industry.

1.3.3 Theoretical Framework

This chapter carries descriptions of existing theories and knowledge within the fields of human computer interaction (HCI), user-centered agile methods and application development.

1.3.4 Method: Design Process and Implementation

This chapter describes and motivates the entire process required to achieve the aims of this thesis.

1.3.5 Results

Results concerned with discovering needs for which design solutions can be brought are presented in this chapter. Results concerned with testing current technology and implementing some design solutions are also presented in this chapter.

1.3.6 Discussion

This chapter outlines the implications of the results achieved in the project.

1.3.7 Conclusion

In this chapter, conclusions associated with the project aims are drawn.

2. Background

Haulage firms, specifically those operating in the EU, are required to follow strict laws and regulations. The laws and regulations cover for instance the working hours for drivers, minimum resting periods and different fines for not adhering to specific rules. [6], [7] Therefore, emerging technology that has the potential to improve customer satisfaction within the road haulage industry should consider these limitations. One way of doing this is by designing cost-effective technology, that could save money for haulage firms, and at the same time facilitates the truck operators work.

For the haulage sector, fuel comprises of 38% of operating costs, which is also a significant portion of total costs. Other costs involve the cost for maintenance, other operating costs etc. Many of the alternative fuels have a hard time competing with the price for diesel. Although, some tests show that operating costs for BEVs may still be smaller due to higher powertrain efficiency. However, the future costs of these influencing factors are still not very certain due to possible technological advancements. [1, p. 14]

2.1 Battery Electric Truck

A lot of development has been made within the area of electrification and a lot is still ongoing. Currently, if BEVs were assumed to have the same range as diesel trucks, then the cargo capacity would be significantly reduced due to the size and the weight of the batteries required. So, it is not possible to build some truck models, because of the total weight getting too high. However, future development of batteries and increased cost-efficiency could impact the use of BEVs and the haulage sector. [1, p. 8]

To limit the size taken by batteries, availability of charging stations is necessary. In 2021, two main charging options are being investigated in Germany, Sweden, and the USA. One of the future options is conductive power transfer via overhead catenary lines, also referred to as pantograph. The other option is conductive power transfer via coils installed in the road. Both options have been thought of as optimal for BEVs that operate on fixed routes, for example buses. [1, p. 8] Anyhow, since haulage firms often need some flexibility in planning of routes, other charging solutions than the ones mentioned or fuels with higher energy density will be required. [1, p. 20]

2.2 Scania

The first series of electric trucks that Scania has released include a full electric truck and a plug-in hybrid. These are mainly focused on urban applications. Soon, Scania has plans on launching a series of fast-charging long-distance heavy goods vehicles (HGVs). These trucks will enable fast-charging during the regulated 45-minute resting period for drivers. [8]

2.3 Competitors

Some of Scania's battery electric vehicle competitors are Volvo and Mercedes-Benz. Volvo recently announced the scheduled production of their FM electric tractor that is said to have 300 km range when fully charged. [9] Mercedes-Benz claims that the sales of full-electric-battery vehicles has tripled since last year and that they are "ready to go all-electric early next decade". [10] There is a lot of activity in the BEV industry.

Another company that has slightly different market focus than the companies already mentioned is Tevva. Compared to the other companies, Tevva is focused on smaller distribution. Tevva Truck has recently been launched and is Tevva's third generation vehicle. Tevva is said to be looking into technology that will enable the Tevva Truck to be fully charged within an hour. The benefit of this new truck is lower cost of ownership, which is currently said to be on the same level as diesel trucks. [9]

2.4 Future Outlook

The EU has a goal of reducing GHG emissions from trucks by 15% in 2025 and by 30% in 2030. The TRATON group, which Scania is a part of, has declared that to reach the 30% target, the sales of BEVs must significantly increase. Andreas Renschler, the former CEO of TRATON, stated in 2019 that in the 10 to 15 years to come, one third of TRATON group's trucks will have an alternative drivetrain and most of them will be fully electric. However, he also mentions that this requires further development of the charging infrastructure across Europe. TRATON also believes that the demand for electric vehicles will increase and with time they will become more cost-effective. Thus, the costs of owning a BEV will be comparable to a diesel truck. [11]

2.5 Scania Mobile Phone Applications

Scania has launched several mobile phone applications. Some of the applications launched are Scania Go, Scania World, Scania Start and Scania Fleet. Scania Go is an application that employees at Scania use to get easy access to transportation alternatives offered by Scania, such as shuttle busses, ebikes, Scania Job Express and Komfort cabs. [12] Scania World contains information related to Scania that can be of interest for customers, employees and business partners. [13] Scania Start is an application that uses video to demonstrate the operation of Scania's vehicles and the different features. [14] With Scania Fleet it is possible to control the temperature of the vehicle before working hours begin, evaluate driving behaviour, and as an office employee get an overview of the entire fleet, such as data related to each and every vehicle. The latest version of Scania Fleet, 6.4, that was released on April 18th 2022 has support for BEVs. In this version, charging related information is displayed. [15]

2.6 Competitor EV Applications

Many of the competing mobile phone applications for cars share similar features, such as charging status, charging percentage and the state of charge (SOC). The applications usually offer some variety, for instance Tesla's mobile phone application Tesla App that allows the user to program departure time, so that the vehicle is warm by charging close to departure. [16]

3. Theoretical Framework

The theoretical framework chapter gives some background knowledge within the fields of human computer interaction (HCI), user-centered agile methods and application development. Knowledge within these fields have been used during the entire project, especially when considering how to design and implement prototypes and when discussing the results of this project.

3.1 Main Principles of Human Computer Interaction

This thesis project is done within the area of human computer interaction (HCI), which is a cross-disciplinary field encompassing theory, design, implementation, and evaluation concentrated on the relation between humans and technology. The I in HCI stands for both interaction and interface, although these two terms mean slightly different things. [17]

Interaction involves the abstract model that humans use to interact with a device, whereas an interface, which can be either a hardware or a software, is the technological realisation that is related to a certain interaction model. See figure 1 for an illustration of these two concepts. Within the field of HCI, much focus has been put on designing and implementing interactions and interfaces with high usability as well as making crucial functionality available. High usability is defined as easy and safe to use, efficient and task related interfaces. [17]

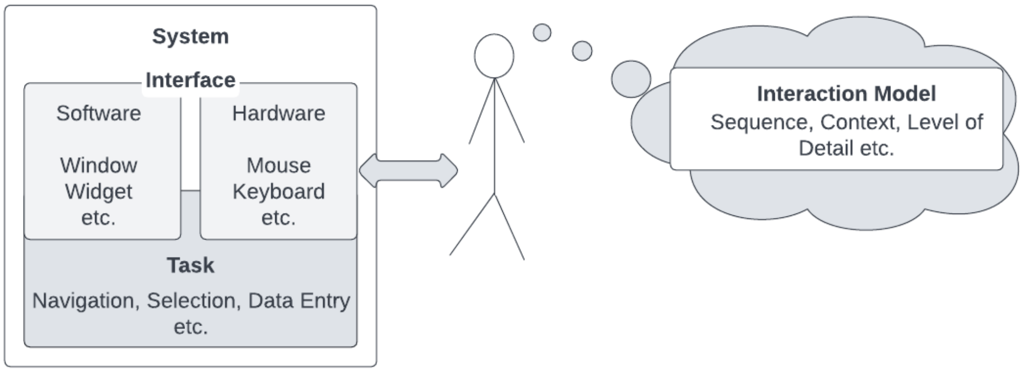

Figure 1. Illustration of concepts interaction and interface, inspired by G. J Kim [17, p. 1]

It is believed that the concept of user experience (UX) has become a “buzzword”. [17, pp. 1-2] It covers functional integrity, usability, aesthetics of the artifact, as well as the “seamless integration [of the artifact] into one’s lifestyle or even creating a new one around it”. [17, pp. 1-2]

HCI has to a large extent affected computing and how different devices are used in our everyday lives. G. J. Kim states that “HCI still continues to redefine how we view, absorb, exchange, create, and manipulate information to our advantage”. [17, p. 3] . For instance, the introduction of action-oriented tools such as the mouse and the touch screen has made computer technology more intuitive and therefore easier to use. [17, p. 3] The following outlines the main HCI principles as described by G.J. Kim.

3.1.1 Identify Users

Target users of a specific system must be identified to design interactions and interfaces that satisfy real users’ needs. It is often the case that developers do not possess adequate understanding of the target user and therefore proceed by making assumptions based on guesses. Thus, when using this approach, it is likely that user needs will not be met by the finished design. [17, pp. 3-5]

Subsequently, information that is of value for identifying the target user should be gathered and interpreted to accurately decide interactions and interface solutions. There should be thorough information such as gender, age, level of education, as well as outlined preferences, inclination, skills, and abilities. [17, pp. 3-5]

3.1.2 Know the Task

Users perform tasks that can be managed using interactive systems. More of the users’ work can be understood by breaking down tasks that are common to target users into subtasks and laying out the structure of these in interaction models. Moreover, it is good to be aware that users are likely to perform tasks differently due to different mental models of a task. In this case, the mental model is essentially the same as the interaction model. Moreover, it is appropriate that the design considers all these possible interactions that users might engage in when completing tasks. [17, pp. 6-7]

Since humans in most cases are flexible, the best solution should not always be to model interactions based on users' mental models. It is also possible to generate new interaction models and thus solutions that fit with overall human abilities. [17, pp. 6-7]

3.1.3 Decrease Memory Load

Humans have restricted capacity to memorise many pieces of information in the short run. It means that humans perform better at tasks with little demand on the short-term memory. The role of the interface is to simplify the work of the user and one way of doing this is by decreasing users' short term memory load. It is estimated that humans short term memory capacity is about 5-9 pieces of information. This is sometimes referred to as the "magic number". [17, p. 7] For instance, adapting the pieces of information on the screen to this number will enable users to carry out tasks with fewer errors. To mitigate problems with short term memory load, reminders and status information can be provided during interactions. [17, p. 7]

3.1.4 Maintain Consistency

Another way of decreasing memory load is by applying consistency throughout the interactions. Consistency is addressed when comparing the target application to similar applications, but it should also be addressed when generating interaction models and designing and implementing the interface. Practising consistency will enable users to recognise what to do in each situation. Furthermore, consistent, and familiar interactions are often easily approved and preferred among humans. [17, pp. 7-8]

3.1.5 Support User's Memory

It is now clear that humans often have problems remembering many pieces of information. Therefore, it is helpful to refresh users' memory by utilising reminders of various kinds. By alerting the user with appropriate feedback during interactions, the user will be able to finish tasks more successfully. The goal is to map the user's mental model with the current interactive process. [17, pp. 8-9] For example, if a user has finished typing its username and password, the use of check symbols should remind the user whether the typed information is valid before the user attempts to sign in.

3.1.6 Manage Misguided Actions

Only as much information as is needed should be presented for users to avoid unnecessary distractions that lead to mistakes. The same goes for actions that should be available for users given a specific interaction. An example of this is to disable actions and communicate this to the user using muted colours. Nevertheless, users will make mistakes. Therefore, it is important to allow users to reverse or cancel actions. [17, pp. 9-10]

3.1.7 "Naturalness"

Some interactions and interfaces might be more natural than others. Naturalness is defined by G.J. Kim as "a trait that is reflective of various operations in our everyday life." [17, pp. 10-11] However, it is suggested that it is usually a better idea to model naturalness by eliciting essential concepts and core aspects of user tasks. An example of a natural interaction is to scroll up and down to view different pieces of information on a display. Scrolling right and left is considered less natural but can still be used in some implementations. [17, pp. 10-11]

3.2 A Meaning Processing Approach

One of the aims of this project is to yield solutions that make users feel in control of the charging process. It can sometimes be difficult to know what design decisions to make but understanding what is meaningful in the context of the design can aid in managing this problem. Recall the previous sections in HCI regarding knowing the target user's tasks. Then it was not always optimal to design solutions based on users' mental models. Moreover, two contemporaries, Ferdinand Saussure (1857-1913) and Charles Peirce (1839-1914), have had slightly different views on how to frame this problem in general terms. The biggest difference between their frameworks concerns the construction of meaning. In the following sections, the dyadic sign/semiotic model by Saussure and the triadic model by Peirce will be explained and illustrated, apart from explaining the connections to interface design. [18, pp. 16-18]

3.2.1 The Dyadic Paradigm

Saussure's dyadic sign/semiotic model is focused on interpretation, which is defined as a mental construct that involves a connection between a representation (signified) and some relevant concept (signifier), see figure 2. In Saussure's model, meaning is not separated from interpretation; they are essentially the same. Meaning is believed to become a construct of the mind. In the case of interface design, meaning is formed using mental models. Different mental models would imply different interpretations and hence also different meanings. [18, pp. 16-18]

Apart from establishing the model mentioned above, Saussure is recognised by many for establishing modern linguistics, a field that has significantly impacted cognitive psychology. Traditional methods for information processing have mainly been dyadic, for instance focusing on connections between human (signified) and interface (signifier). [18, pp. 16-17]

The signifier and the signified form the basis of the semiotic problem, which is illustrated by the enclosed rectangle in figure 2. In terms of interface design, the signified is a mental concept or a mental model related to users' tasks. The signifier is a representation that is connected to this mental model through the means of interpretation. [18, pp. 16-17]

At large, the semiotic problem enables analysis of possible connections between the signifier and the signified, such as binding computer symbols with relevant mental concepts. However, Saussure's model it is argued, does not give a complete perception of how meaning should be understood. Saussure's model does not enable analysis of connections between the representation and overall knowledge and concepts within a specific work domain. This work domain is also referred to as the ecology, see figure 2. [18, pp. 16-17]

When it comes to solving problems within HCI, Bennet and Flach state that "the target design is often framed as a requirement to match the operator's mental model." However, since every target user possess different mental models, some might even be wrong, which could lead to faulty interpretations. The question is whether some mental models actually are better and why that is the case, since many design decisions tend to depend on these. This issue of designing solutions that also consider the work domain gives rise to the triadic model, which will be discussed in the following section. [18, pp. 21-22]

3.2.2 The Triadic Paradigm

The triadic approach has historically been neglected in favour of the traditional dyadic approach. In contrast to Saussure's model, Peirce's triadic model separates meaning from interpretation. Combining Saussure's model, which encompasses the objects of the world (the signified and the signifier), with the ecology, representing the object of experience, gives Peirce's model. See figure 2 for a full illustration of Peirce's model. [18, pp. 17-18]

Meaning is defined as the connection between the ecology and the signifier. In the case of interface design, it would mean that consistency between the interpretation and the meaning would likely yield more successful solutions. [18, pp. 17-18]

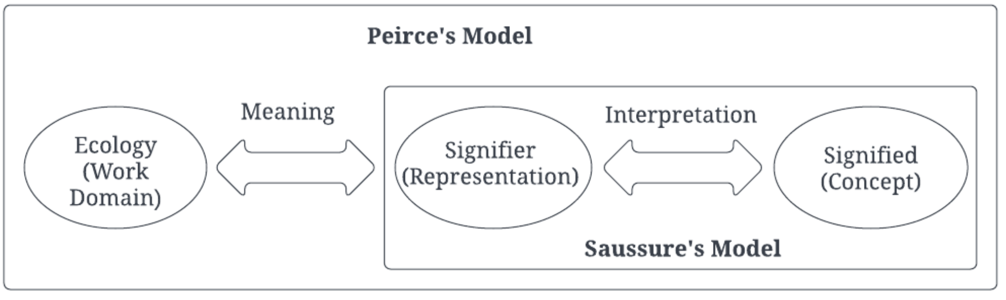

Figure 2. Saussure's dyadic/semiotic model and Peirce's triadic model, inspired by Bennet and Flach [18, p. 18]

3.2.3 Information Processing Versus Meaning Processing

It is argued that the conventional information processing approach is inexact, due to focus being directed at probability theory rather than information theory. [18, pp. 26-28] It is possible that the numerous experiments conducted after the Second World War, showing that human performance depends on availability of information, have been an influencing factor. Indeed, probability theory enables the mapping of some possibilities, but it is not always sufficient in modelling the space of possibilities within a certain area or work domain. Characterising the space of possibilities is one key to understanding human-machine systems. For instance, some situations demand physical laws for mapping of possibilities to be done accurately. The physical laws will enable identifying constraints on the space of possibilities. This is referred to as an ecological approach to interface design. [18, pp. 26-28]

In contrast to the information processing approach, a meaning processing approach is introduced. Apart from understanding the space of possibilities, the consequences and values associated with the mapped possibilities (outcomes) must also be understood. These consequences and values are associated with meaning, and some might be positive (e.g., achieving goals) and some might be negative (e.g., causing risks). Subsequently, it is appropriate to try to minimise the probability of the negative outcomes and at the same time maximise the probability of the positive outcomes. [18, p. 29]

3.2.4 Interface Design

It is stated that "the goal of interface design is to develop representations that specify the meaningful properties of a work domain (or problem space) so that operators can discover these meaningful properties and guide their actions appropriately (increasing the likelihood of positive consequences and minimizing the risk of negative consequences)." [18, p. 26] Thus, meaning is an attribute that cognitive processing allows operators to discover. It refers to properties associated with the possibilities and consequences of dealing with a situation or a functional problem. [18, p. 26] The representation or the interface should therefore be interpreted by the operator in a way that reflects meaning in the work domain. [18, p. 18]

So, in any given situation, the interface design should aid operators in finding meaningfulness in that situation; hence, finding out what the possibilities and the corresponding consequences are. [18, p. 26] Operators that are in control of their actions have high correspondence between their interpretation of the situation and the meaning of the situation. [18, p. 26]

3.3 User-Centered Agile Methods

To realise the aim of this thesis, which is to discover needs from which design solutions can be brought about, a framework that is focused on understanding users is needed.

User-centered agile methods is about combining user-centered techniques with agile methods. Agile methods separate the development process into smaller processes called iterations, enabling continuous evaluation, and encouraging flexibility [19, p. 2] Requirements often change and therefore it is unnecessary to do a lot of documentation that will never be used. The idea is to develop something quick without an overall plan, to learn something from it by getting additional feedback, and then continue building on the solution. [19, pp. 10-11] However, Hugh Beyer stresses that using agile methods is not enough. He mentions that it is not possible to get “a complete understanding of users and their needs; no way to invent and structure a coherent solution; and no way to design a consistent user experience, interaction paradigm, and appearance across the product.” using only agile methods. Hence, a user-centered process is essential to achieve these objectives. [19, p. 11]

The ideal agile procedure would be to hire the user on the development team and let the user sit next to developers when they are building the solution. In most cases this is not possible, because one cannot assume that users know how to articulate their needs and that they are able to give feedback on ideas that are not yet familiar to them. [19, p. 12] Essentially, agile methods do not address ideation, which is about explaining how to design the actual product. [19, p. 11] User-centered agile methods involve activities, such as conducting user-research, designing the system, writing specifications of system behaviour and interactions, as well as testing the suggested design with users. Then, developers simply iterate design solutions with users until the product is considered successful. [19, pp. 19-20]

3.3.1 Users

Recall the description of target users in the section regarding the main principles of HCI. In user-centered agile methods, user or end-user is referred to as a person using the product to achieve some goal. Developers want to address this user’s needs when designing a solution. Designing for a user can sometimes be problematic, especially if the user’s role has not been carefully considered. It is not recommended to use so called surrogate users as stand-ins for real end-users, because needs will often in that case be based on assumptions. [19, pp. 11, 17-18]

3.4 Designing for Mobile

To fulfil the aim of contributing with an understanding of what charging monitoring solutions for mobile phones are valuable and possible for Scania to implement, some insights regarding development of mobile phone applications are needed. Knowledge about already existing technology within application design can aid in understanding some limitations of the work domain, which is a concept introduced in the section about *a meaning processing approach*. The work domain in this thesis project is the activities related to charging.

Meaning in the perspective of designing for mobile phones is about discovering what design solutions are possible and what the consequence of using them in each situation is. The most optimal solutions are those that increase the likelihood of positive outcomes and that also correspond to users' interpretation of the situation. Therefore, the following section will explain what types of user needs exist and how to map them to design solutions. In addition, the following will inform about some constraints that exist within visual design for mobile phones and what some of the possibilities are. Also, the effect of choosing different visuals in each situation will be explained.

3.4.1 UX Design for Mobile Phone

Users have needs and one key aspect of design is to find solutions to those needs. People have needs related to being human beings. For example, humans perceive an application with rounded visuals as more cheerful than an application with straight corners. People have needs due to general expectations. For instance, people always have some general expectations of a given product, even if they have never used it. One way of meeting these expectations is to allow users to explore and figure out the product while using it, with minimal mental effort required on behalf of the user. Lastly, people also have needs in specific contexts. To meet the needs that users have in specific contexts, it is also necessary to make the user feel in control. For example, when users perform actions, they want some type of confirmation that the action has taken place. When a message has been sent to someone, users want to be able to see the status of the message to make sure that it has been delivered. Ultimately, UX design should focus on displaying information in a way that is easily perceived and understood by users. [20]

3.4.2 The Noriaki Kano Model

It can be difficult to separate a need and from a solution. The Noriaki Kano model can be used to distinguish needs from solutions by showing patterns of user satisfaction. [21] The model in figure 3 illustrates different needs that users may have, such as must-have needs, linear needs, and latent needs. Must-have needs are expected to be supported by a product and if they are not, users will get frustrated. Linear needs are something that will generate more value as they get better support. An example of this is a search engine generating faster results, which saves time for the user. A latent need is something that users do not know that they have until there is a product that begins supporting that need. Doing user research is one way to establish latent needs. Since users are unaware of these needs, they will not get frustrated if the needs are not met. However, providing a solution for these needs will lead to increased satisfaction. [20] The vertical axis in figure 3 illustrates the customer satisfaction, which range between more or less satisfied. The horizontal axis illustrates the presence of desired characteristics, which range between more or less support. [21]

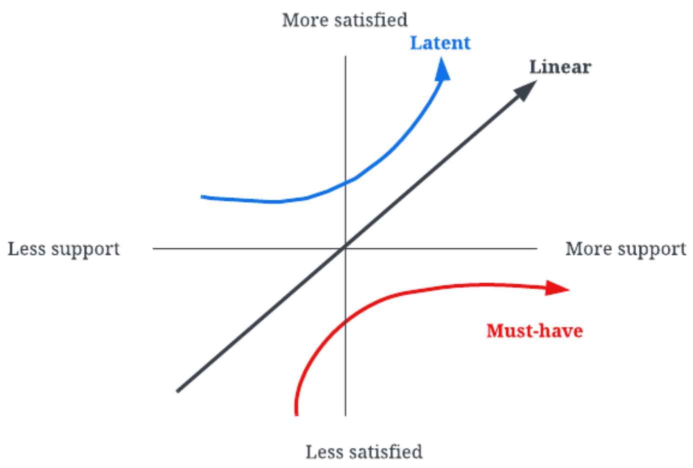

Figure 3. The Kano Model

When designing applications, it is not unusual that conflicting needs occur. Pablo Perea and Pau Giner state that "[d]esign is about finding optimal balances between conflicting interests." [20] They suggest three solutions to handling conflicting needs. The first is *adjusting the prominence level based on frequency and impact*. Different functions that are used more often should have a bigger impact, whereas functions that are not used as much should have lesser impact. One example of this is the shutter button, which is often a notable feature in camera applications. The second suggestion is about *identifying what to optimise and what to just allow*. In other words, it should be more of an interest to prioritise and give full support of the critical needs, instead of doing many things partially. Lastly, the third solution is to *keep things simple*. If there are multiple possible solutions to a given problem, the simplest solution should be chosen even if it means cutting out on some features. That is because it is easier to understand and to operate easier solutions. [20]

3.4.3 Data Visualisation

Data analysis is about identifying trends using predictive models to be able to make relevant assumptions and conclusions. Data visualisation is about representing these conclusions in a way that is easy for a specific audience to understand quickly. The main aspects of data visualisation in relation to this thesis is to *keep things simple*, *design intuitively*, *pay attention to detail*, *design for an audience* and *plan the layout from a mobile phone perspective*. [22]

The first aspect, keeping things simple, is about making messages easier for the audience to understand. This can be achieved by using clear and uncluttered visualisations. As a result, the visualisation will also have a bigger impact. The design choices should be derived from the needs of the audience, such as needs for colours representing some conditions held within the data or font size. Also, it is often better to use simple visuals because they are often easier to understand than very creative ones. This is especially true in the case of designing for mobile phones. [22]

The second aspect, designing intuitively, is about guiding the audience while processing the visualisation. This is done by designing visuals in a way that is familiar and convenient for the audience. For example, in many parts of the world, the reading pattern is from top left to bottom right. Some colours can also symbolise different things depending on the topic of the data, such as bright or muted colours. Using colours is a way of drawing attention to something and should be used carefully. One rule of thumb is that the visualisation should be able to answer a specific question. [22]

The third aspect is paying attention to detail. This is about considering the purpose of every visual, such as the choice of font size, what colours to use and the choice of alignment. [22]

The fourth aspect is designing for an audience. The visualisation should preferably have a title with a question that should be answered by the visualisation. Moreover, the visualisation should aid the audience in the decision-making process. Therefore, the design must be organised and consistent. This includes displaying relevant numbers and units that are easy to refer to. [22]

The fifth and last aspect is about planning the layout from a mobile phone perspective. General layout planning involves choosing a title for the visualisation, deciding what charts or graphs to use, adding explanations or annotations etc. However, all these things do not have to be included in every type of visualisation. [22]

Designing for a mobile phone should also involve accounting for the possibilities of a touch screen as well as the limitations of a smaller screen. The touch screen allows for interactions with the visuals, while the smaller screen limits the number of details that can be illustrated. Therefore, careful design choices must be made to capture the expectations from the audience as well as not missing out on the relevant details in the information that must be conveyed. [22]

When designing solutions for a mobile phone, the use of space must be efficient. Sometimes, a text works better than a chart. In most cases, human brains have an easier time processing a visual, but if a text is expected it can be just as useful. However, this text should preferably be placed close to a visual so that it does not cause distractions. In addition, a way of giving the user control without losing information, is to allow the user to filter different options. If filters are used, they should be placed next to each other, since the *natural* way of navigating a mobile phone is scrolling up and down. This lowers the risk of choosing the wrong option. Also, if white space is used, it can reduce the risks of clicking on and dragging the wrong item. [22]

4. Method: Design Process and Implementation

This chapter outlines the realisation of the project. Beginning with a brief insight into relevant methods in the chapter named *Contextual Design*, the implication of using these methods in the project will be easily understood. Moreover, any assumptions made during the project are described and motivated.

4.1 Contextual Design

The key method chosen for the design part of this thesis project is contextual design (CD). CD is a user-centered design process that was introduced by Hugh Beyer and Karen Holtzblatt. The main tasks involved in this process is contextual inquiry, interpretation sessions and work modeling, model consolidation and affinity diagram building, personas, visioning, story boarding, user environment design, paper prototypes and mock-up interviews. [23] Conducting real user research is fundamental to any user-centered agile process. The objective is to identify who the end-users are and their work practices, understand their tasks and strategies to accomplish them, receive feedback on design solutions and testing whether the design is successful or not. [19, p. 19]

Designing a mobile phone application in a user-centered way contrary to a technology-centered approach is about making life easier for users. The user-centered way is to first identify user needs, map these user needs with possible solutions and then implement the solution, whereas the technology-centered approach would be to let technology dictate the possibilities, which leads to limited solutions that would not satisfy the users' needs. [20] The following is a brief description of each task in a CD process and whether they are used in the project or not. Later, sections 4.2 – 4.8 have descriptions of the CD process in this project.

4.1.1 Contextual Inquiry

Field interviews will give information about work practices that would have gone unnoticed in a structured interview. Unlike a formal interview, which focuses on naming some problems, a contextual interview is focused on the user's work practice. [19] Interviews are conducted with real users in their workplace and are performed by observing and asking questions. It is important that designers understand users and details about their work practice to get a representative idea of who the end-users are. [23] An agile assumption is that "everyone is on the team" and in charge of the process. However, from a user-centered agile perspective, users cannot be assumed to be a part of the team. [19, pp. 18, 24]

4.1.2 Interpretation Sessions and Work Modeling

During the interpretation session, the development team organises the notes taken during the contextual interview and try to capture key insights and observations. After the interpretation session, these insights are accessible for the entire team and can be used for building the product. [19, pp. 28-29] Team members discuss details from the interview and notes with valuable points are written. When technicalities from the interviews have been interpreted, it is time to produce work models that demonstrate some of these interpretations. [23]

4.1.3 Model Consolidation and Affinity Diagram Building

All data from the interpretation session is unified to get an overview of the target user population. Afterwards, an affinity diagram that organises information from interviews is constructed. They are usually built in one or two days and help establish issues and insights from all users into a hierarchical diagram. [19, p. 30], [23]

4.1.4 Personas

The data from the interpretation session is also used to build personas. Personas are representations of typical users and aid in the understanding of users. [19, pp. 33-34] They are described as if they were real users, without being based on one single user. Personas represent user populations and are typically written on a single page. They have descriptions of a task they perform, goals they might have and a description of their role at work. Furthermore, the personas should be given names, a head-shot photo and a shorter description that summarises their background. [23]

4.1.5 Visioning

After creating personas, a big representation of what the solution should do to support users' work can be formulated. [23] A vision is a high-level concept of the system, which explains what the system is able to do. [19, pp. 34-35] One way to do this is by writing a vision statement, which supports the overall expectation of the product. [24]

4.1.6 Story Boarding

Story boarding visualises the re-organisation of user tasks. So, the story boards showcase future scenarios, and some user interface concepts. Moreover, user stories are based on these story boards. The re-organisation can be derived from the vision, which guides the design process. Story boarding will not be done in this project, because of time constraints. [23]

4.1.7 User Environmental Design (UED)

Story boards make it possible to create one separate model that show the organisation of all parts of the system. Since UED is recommended and essential for larger systems, UED will not be a part of this project. [23]

4.1.8 Paper Prototypes and Mock-Up Interviews

Constructing paper prototypes is an easy and less expensive way to iterate and validate design ideas with users. Making quick paper sketches and testing the ideas with users is faster than implementing advanced solutions with complex code structures. Instead of wasting time implementing something that must be re-done after receiving user feedback, paper prototypes can be used to quickly validate ideas with users. Furthermore, the paper prototype is used to validate the vision. Because the vision is built on interpretation of user data it must be confirmed by users. The paper prototype is therefore iterated with users during mock-up interviews by making changes after each session. [19, pp. 36, 40]

4.1.9 What is a Prototype?

A common misconception is that a prototype is an early version of a product. In some cases, it might be true, although that is not why a prototype is produced. A prototype is produced to test ideas in a specific context. [20] When making a prototype, there are three important aspects one should consider. First, there must be a goal with the prototype. The goal should explain what you need to learn with the prototype. Secondly, there must be an audience in mind. Who is the person you will learn things from? The audience is important because the prototype will reveal important information about the user experience. Lastly, the prototype should be pictured in some specific scenario. Designers need to decide what activity the prototype is going to support in that specific context. What features the product will support is not as interesting as the problems that the design is going to solve. In conclusion, prototyping is a way of explaining how a product will support users' tasks. [20]

4.2 Contextual Inquiry

In this project, interviews are held, but not precisely as suggested by Holtzblatt and Beyer. Before conducting interviews, it is a good idea to think about what you as a designer need to learn about users, because this will influence the making of the prototypes. In some cases, you might need to get a deeper understanding on the level of tacit knowledge. Then, a field interview is probably necessary to fulfil this requirement. However, in other cases a semi-structure interview should be enough to capture valuable user input. This project involves the development of a product that is not yet available for users. They are assumed to not be in possession of technology that enables them to carry out tasks that the final product would do. Therefore, it is more interesting to structure the interviews around the users' experiences as truck drivers and try to capture struggles that drivers might have to identify real user value.

When conducting field interviews it is crucial to let users know why the interview is held and what the goal is. Users are often helpful, but they are not the experts on designing products. However, they are usually experts in terms of their work. Ultimately, one must bear in mind that users cannot be assumed to answer questions about design ideas, because they are not fully aware of what is possible to achieve with technology. It is during the field interviews that most of the design data is gathered, so planning and conducting the interviews are very important for the quality of work. [23]

4.2.1 LP-drivers Representing Users

We recall that it was not recommended to use stand-in users. However, depending on the importance of understanding real end-users and their work practices, it is possible to use stand-in users if they are sufficiently qualified. It means that the stand-in users should be able to speak from experience rather than imagining themselves as users. LP-drivers working at Scania have been selected as users, because they possess a lot of knowledge about real drivers. In addition, many of Scania's LP-drivers have previously been working in the road haulage and distribution industry. Therefore, many of Scania's LP-drivers have real life work experience as truck drivers for various haulage companies. LP-drivers are specialised in testing Scania's vehicles on the test track. The reason for choosing LP-drivers was partly due to the flexibility of planning interviews and test sessions, but also because the usual contextual interview would not be necessary.

4.2.2 Interviews

In some projects it is crucial to perform contextual interviews, to be able to capture tacit knowledge and workarounds. [19, p. 28] A disadvantage of not doing contextual interviews is that one misses out on the real-life experience of a user's work practice. That is why the interviews that were conducted instead of the usual contextual interview had to emulate this experience.

A part of emulating the contextual interview involved LP-drivers talking freely about their experiences as truck drivers. See appendix A for interview questions. Three drivers were interviewed one at a time at a cafeteria located at Scania. The interviews took approximately 90 minutes each. Apart from asking questions, the LP-drivers also had a walk-through of printed screens of already existing applications. They discussed how they would, why they would and why they would not use different features in them. In addition, they contributed with valuable insights from the driver's perspective. See appendix B for a summary of the three interviews.

4.2.3 Existing Applications and their Screens

This section shows the different screens that were used during the contextual interviews. These screens were printed on different numbered pages. Moreover, how these printed screens were used during the design process is also explained.

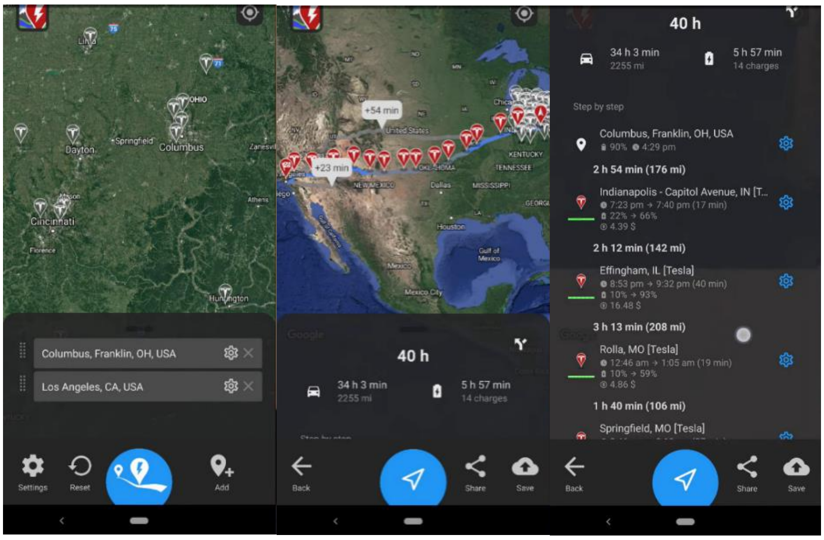

Figure 4. A better Routeplanner app in page 1 [25]

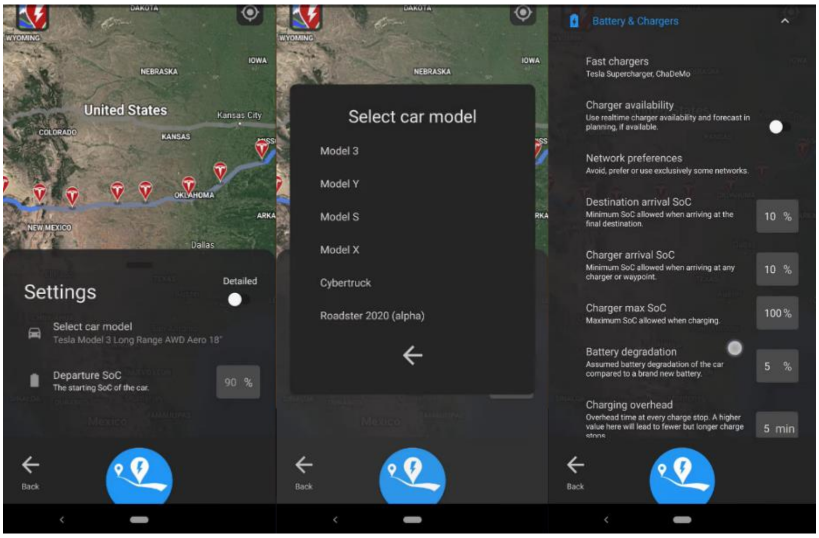

Figure 5. A better Routeplanner app in page 2 [25]

The “A better routeplanner app” in figure 4 and figure 5 was the first application that was shown during the contextual interview. The sole purpose of showing this application was to start a conversation about charging stations.

Figure 6. Tesla's Stats app in page 3 [26]

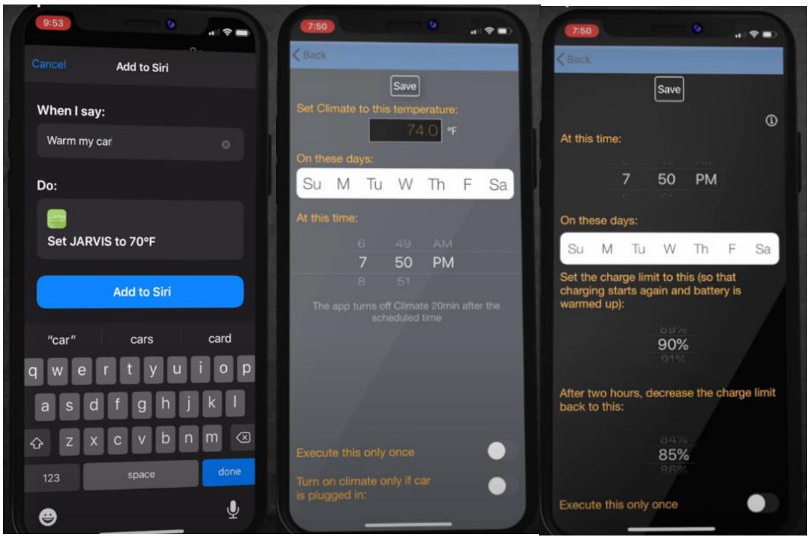

Figure 7. Tesla's Stats app in page 4 [26]

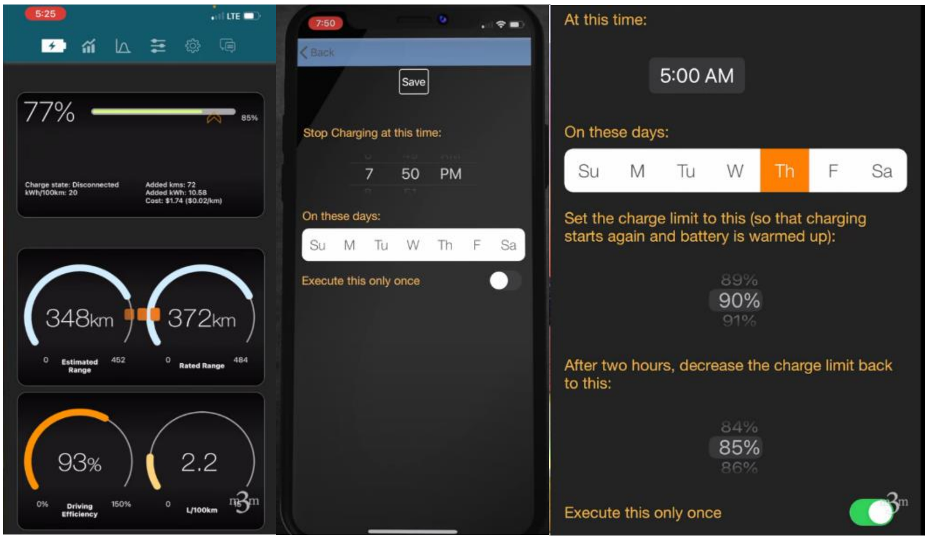

Figure 8. Tesla's Stats app in page 5 [26]

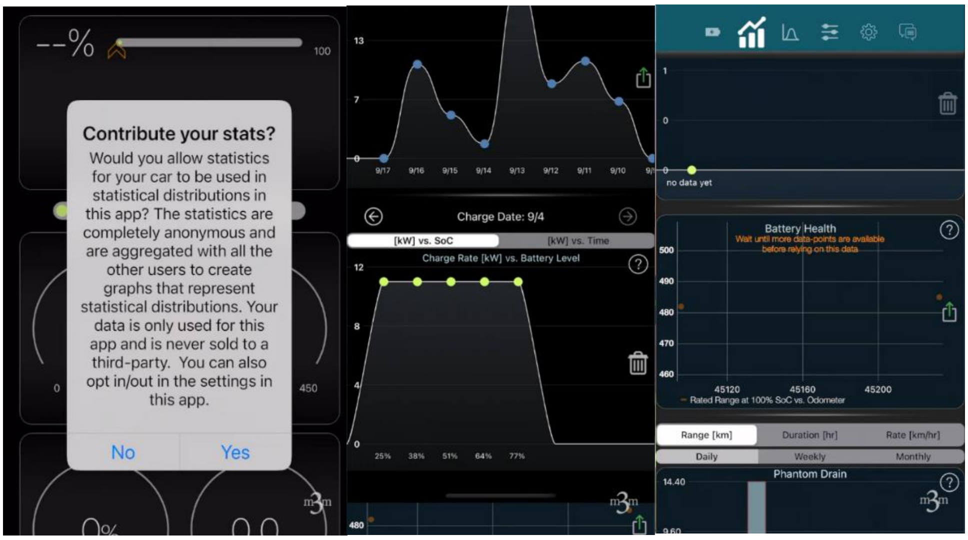

Figure 9. Tesla's Stats app in page 6 [26]

Figure 10. Tesla app in page 7 [25]

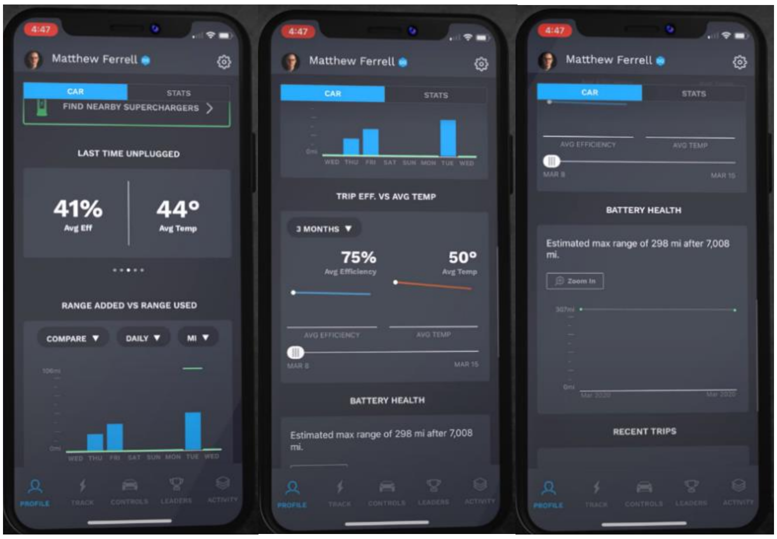

Figure 11. Tesla app in page 8 [25]

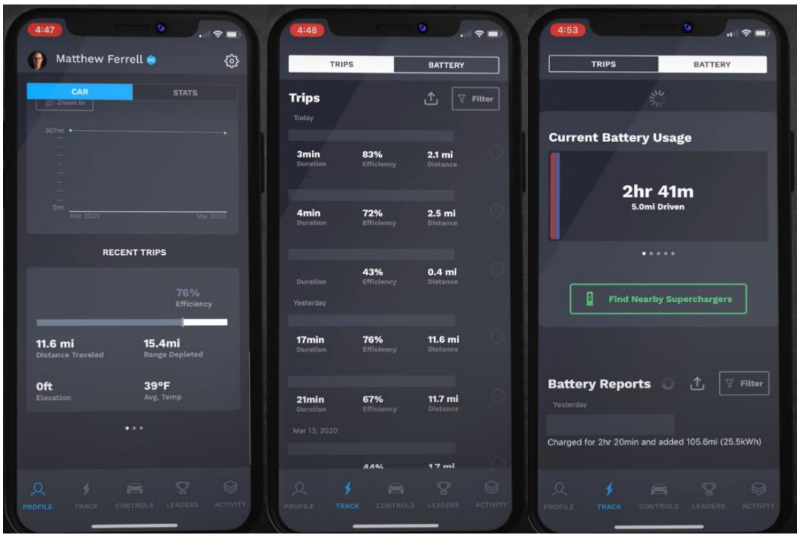

Figure 12. Tesla app in page 9 [25]

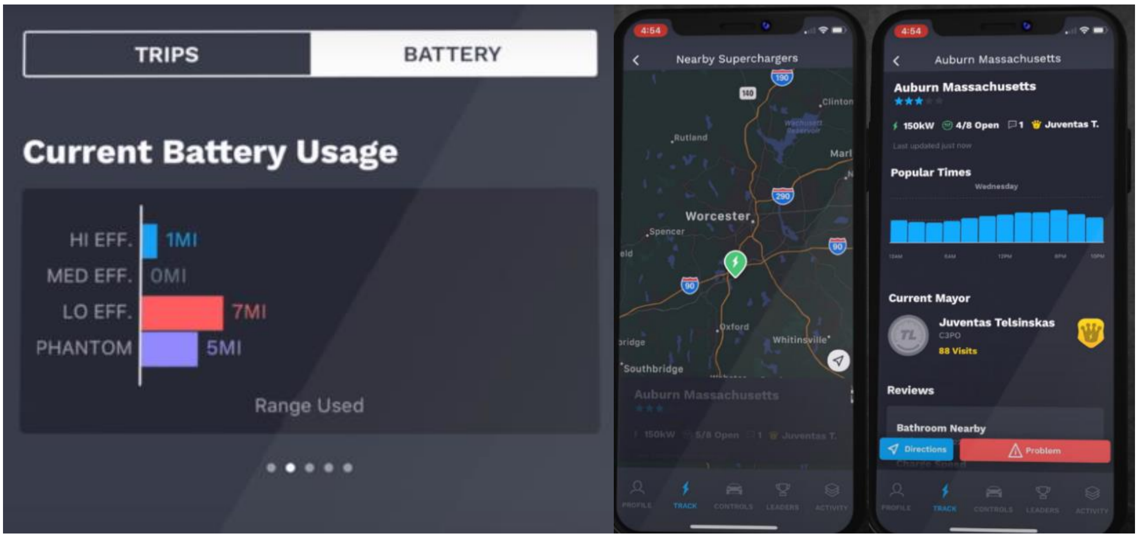

Figure 13. Tesla app in page 10 [25]

Figure 14. Tesla app in page 11 [25]

Figure 15. Tesla app in page 12 [25]

The applications for Tesla, seen in figure 6-15, were shown during the contextual interview to start a conversation around the topic of data visualisation. The large variety of screens allowed for comparison between designs that were related to data visualisation.

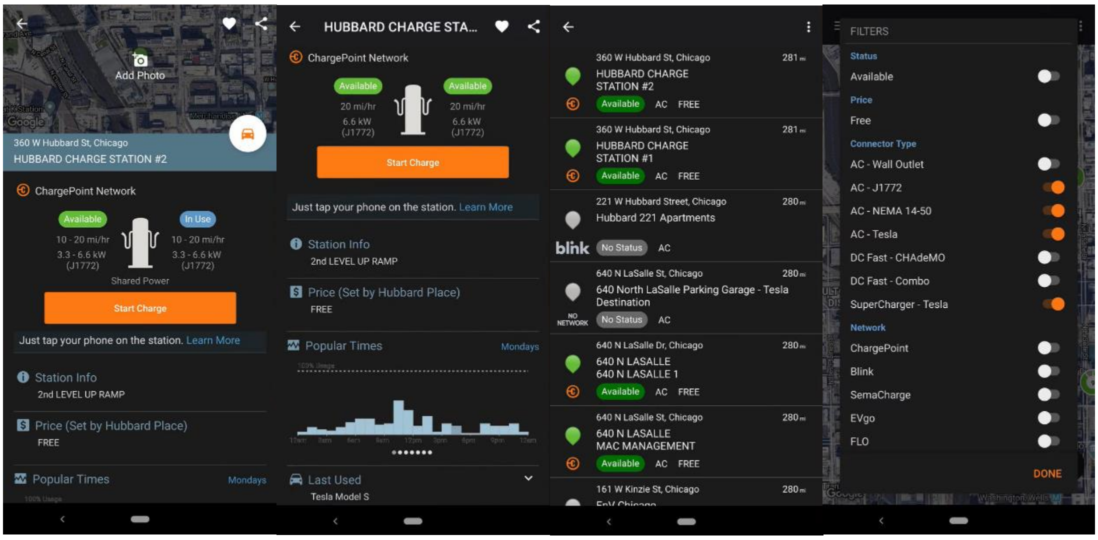

Figure 16. Chargepoint app in page 13 and 14 [27]

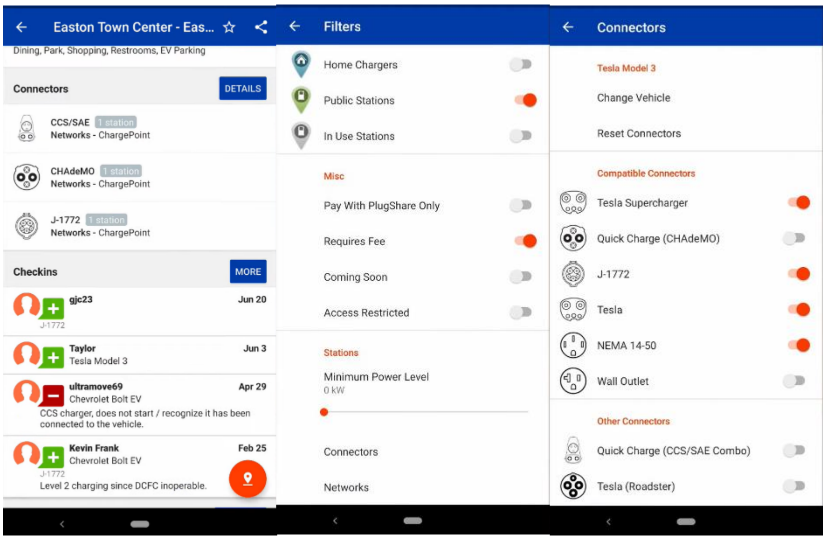

Figure 17. PlugShare app in page 15 [27]

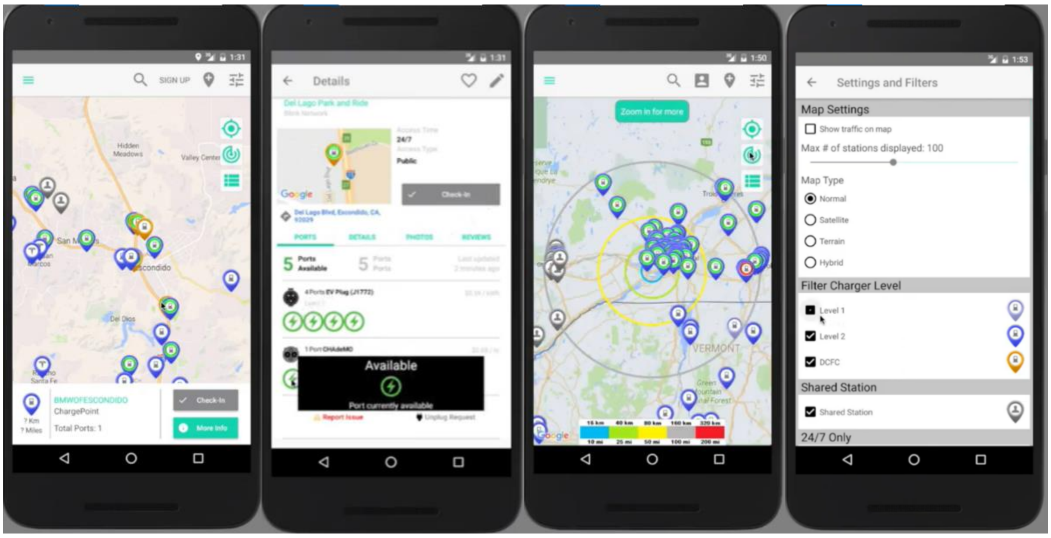

Figure 18. ChargeHub app in page 16 [28]

The applications in figure 16-18 were used during the contextual interview to show how information related to charging stations is sometimes displayed.

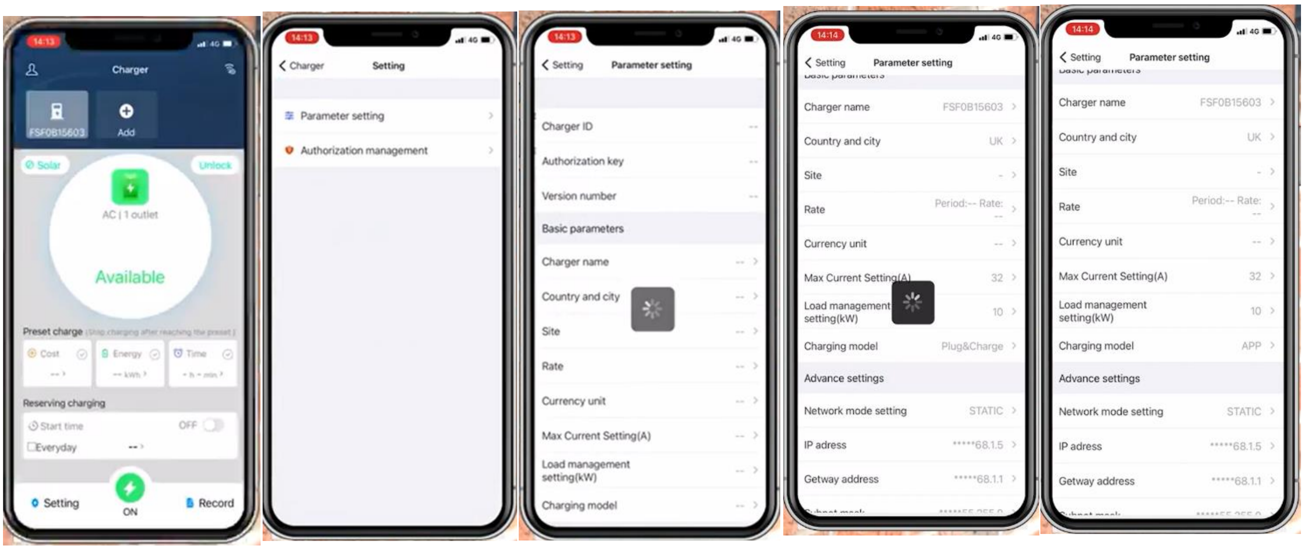

Figure 19. Project EV Free app in page 17 and 18 [29]

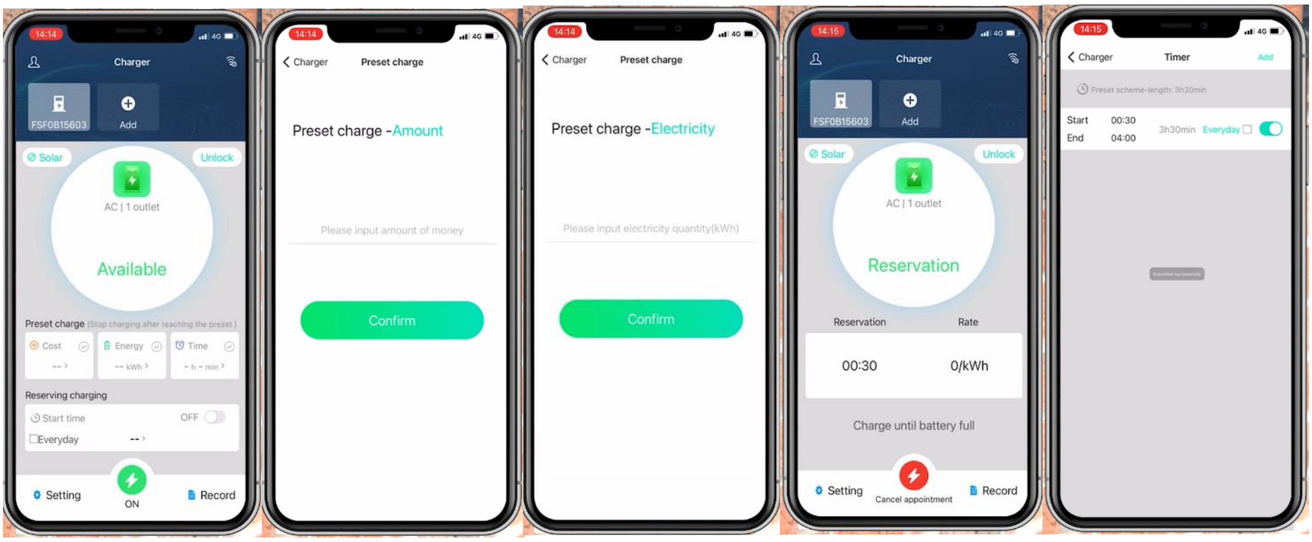

Figure 20. Project EV Free app in page 18 and 19 [29]

The application in figure 19-20 was used to start a conversation around the topic of charging monitoring solutions during the contextual interview.

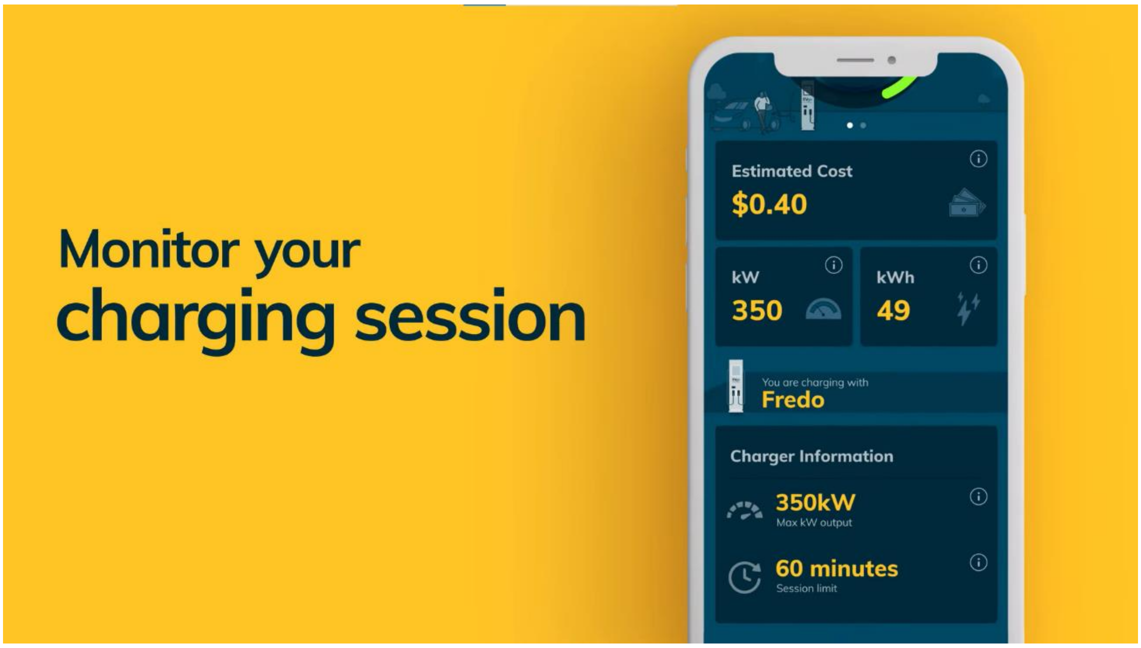

Figure 21. EVgo app in page 20 [30]

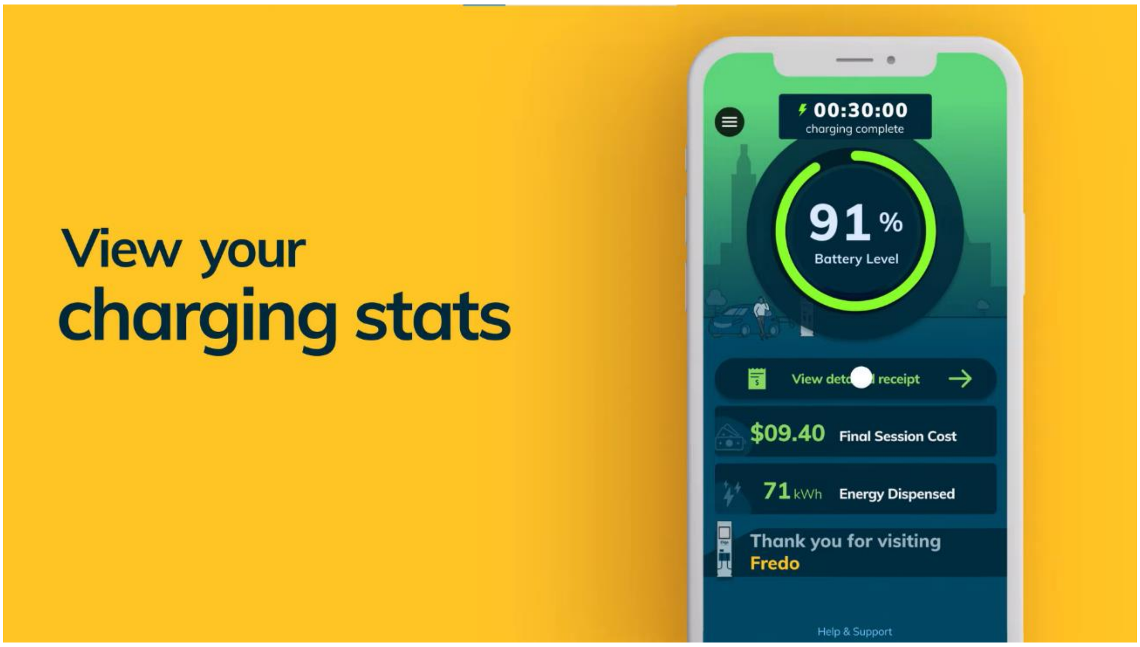

Figure 22. EVgo app in page 21 [30]

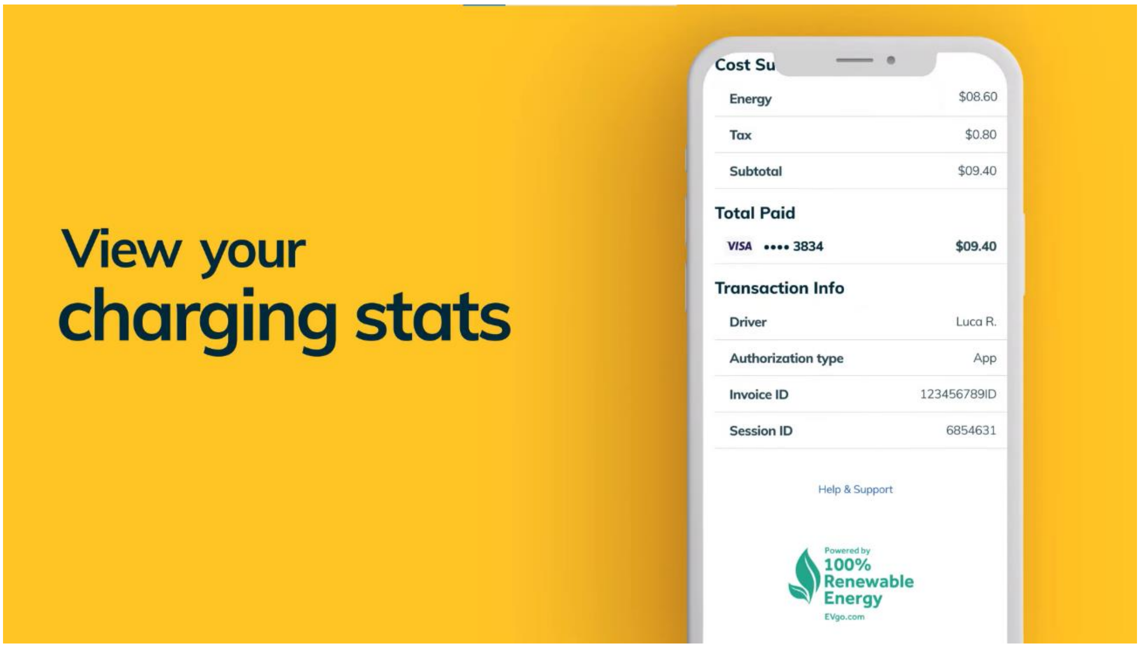

Figure 23. EVgo app in page 22 [30]

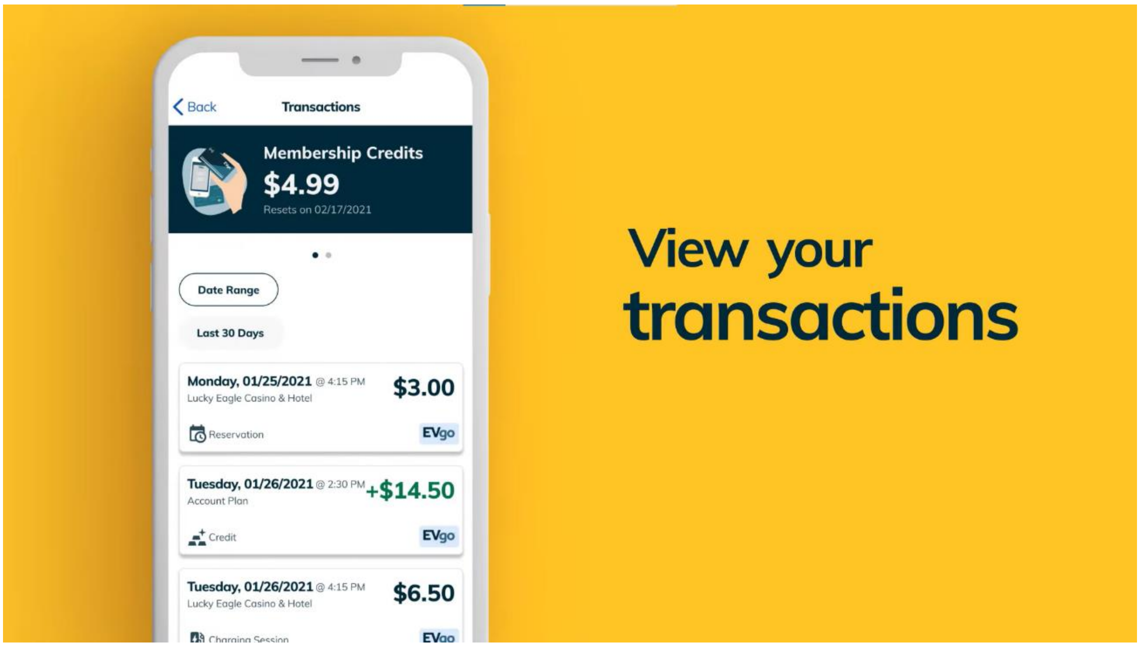

Figure 24. EVgo app in page 23 [30]

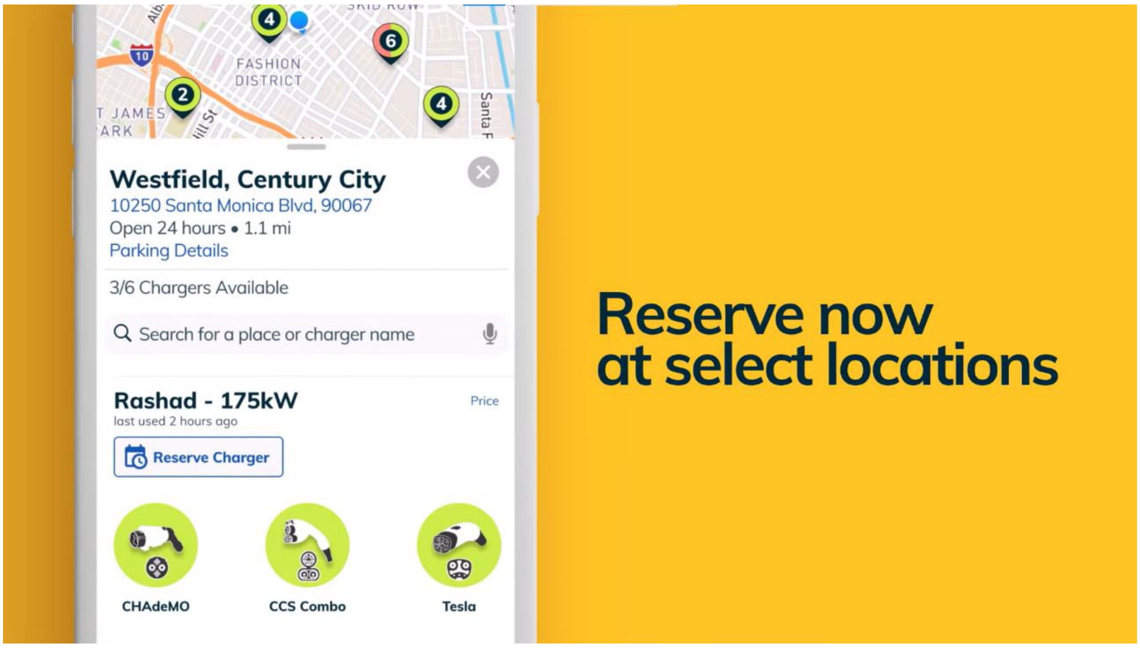

Figure 25. EVgo app in page 24 [30]

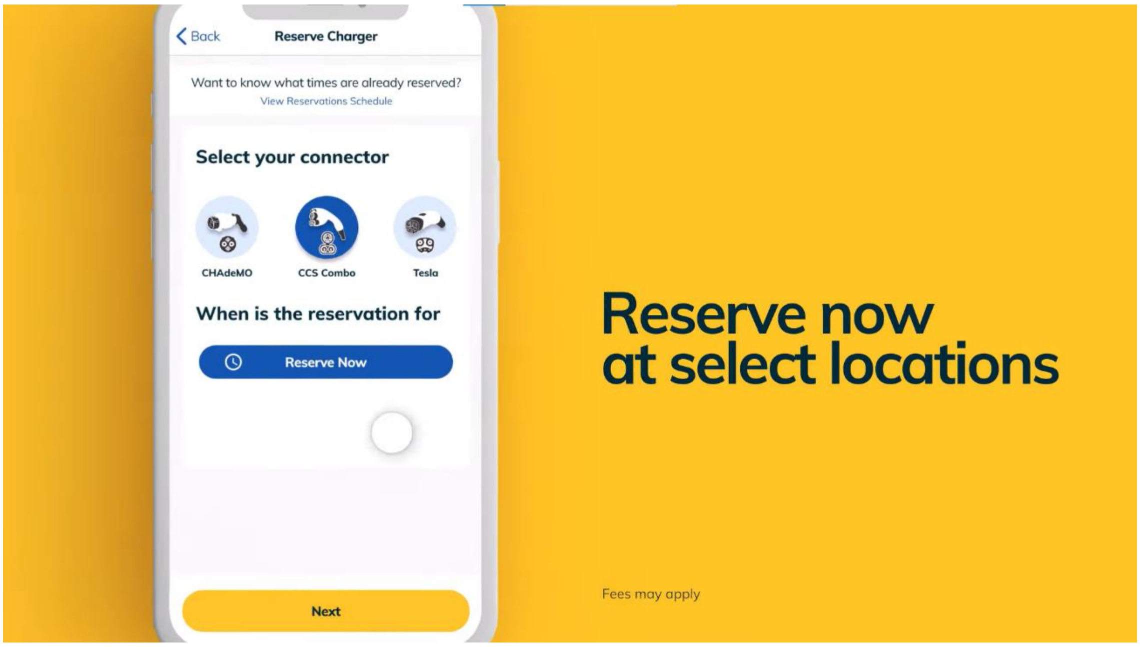

Figure 26. EVgo app in page 25 [30]

The application in figure 21-26 was discussed during the contextual interview. This application was also used for inspiration during the making of the first prototype.

Figure 27. Chargeway app in page 26 [31]

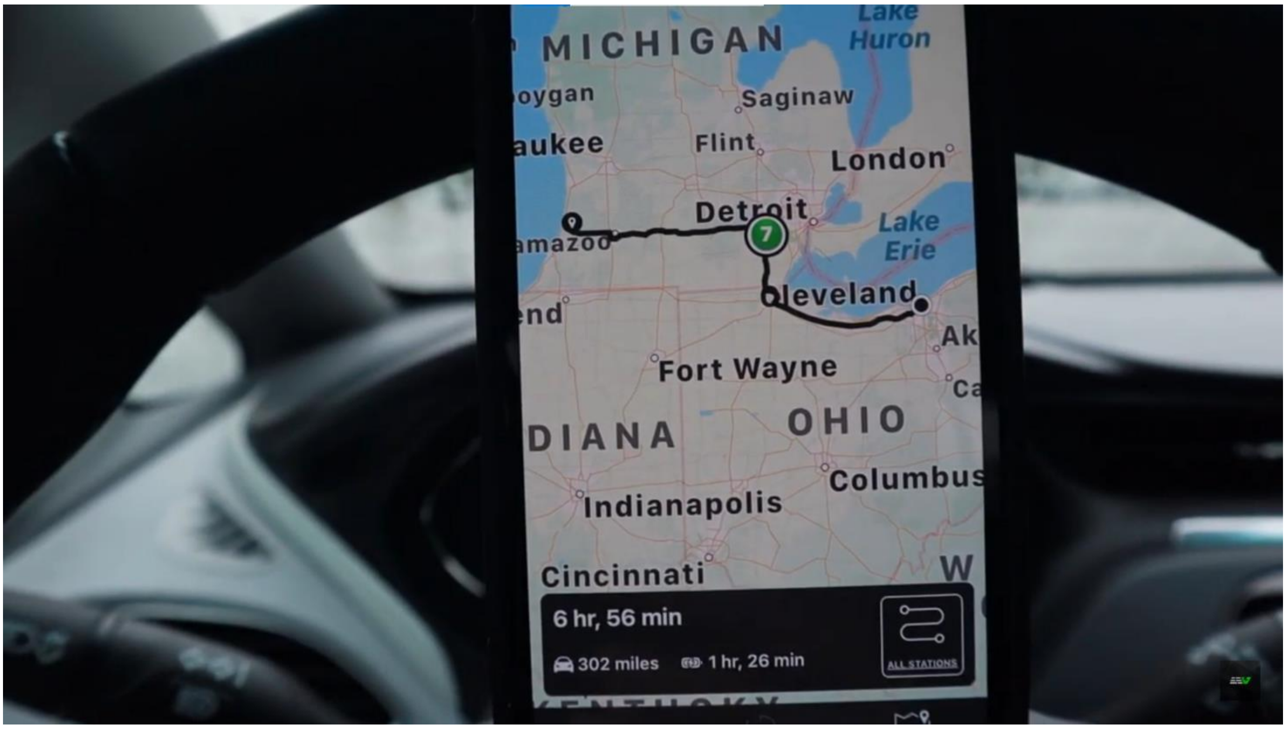

Figure 28. Chargeway app in page 26 [31]

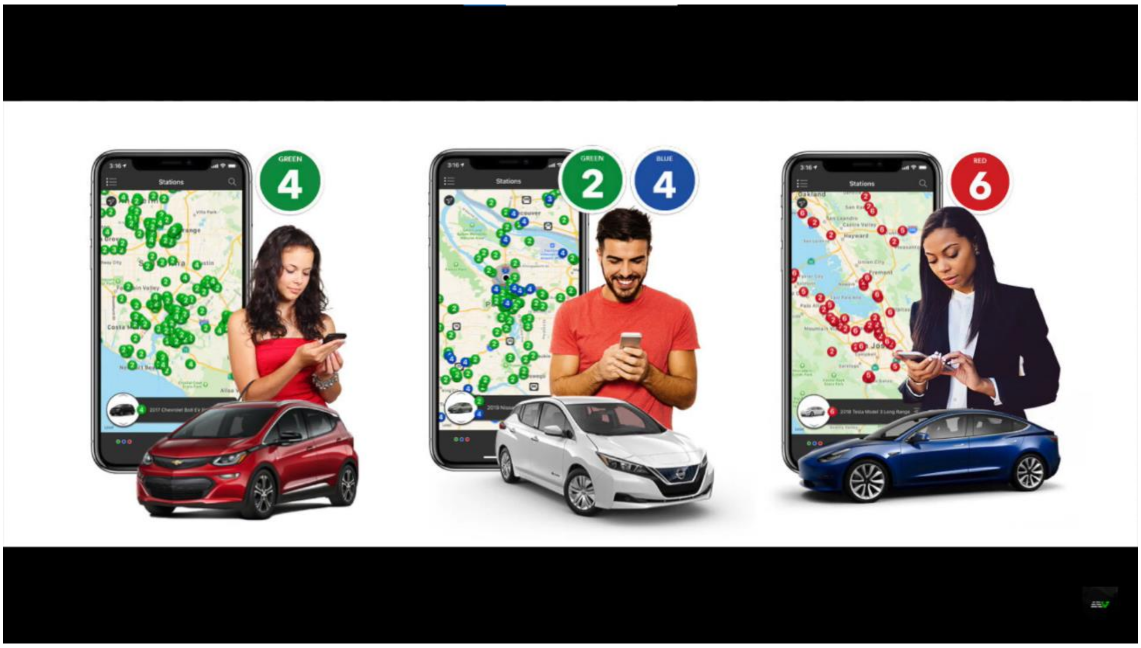

Figure 29. Chargeway app in page 27 [31]

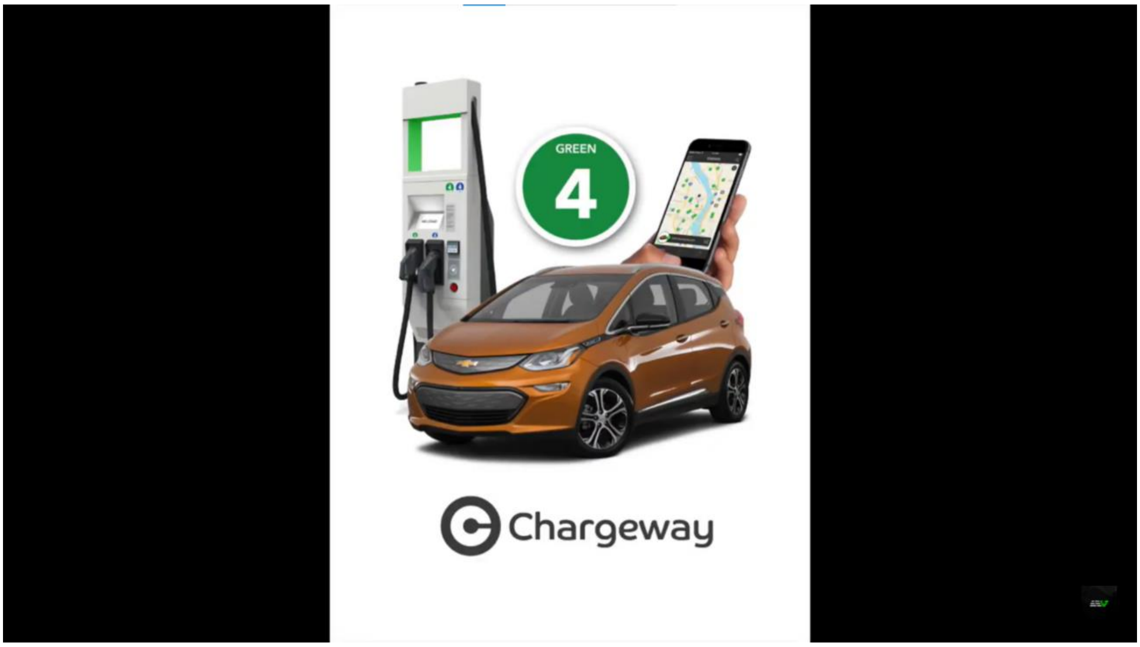

Figure 30. Chargeway app in page 28 [31]

The application in figure 27-30 was mainly used to discuss charging stations and charging station displays. However, since this was the last application, it was not discussed as much as the other applications.

4.3 Interpretation Sessions and Work Modelling

4.3.1 Interpretation Session

An interpretation session with several team members will not take place, because most of the work to create the GUI is done by only one person. However, data from the interviews is assembled and organised, so that other people can understand how certain design decisions were derived.

4.3.2 Work Models

There are five work models that are often used, that show different aspects of users' work. The first one is the flow model, that shows communication and coordination between different people or roles. The second is the cultural model, that highlights culture and policies. The third is the sequence model, that shows steps taken to achieve different tasks. The fourth is the physical model, that presents the physical space that supports the work. The fifth and last model is the artifact model that displays how artifacts are used in the work. [23]

Since all work models are not relevant, only some of them will be presented, namely the cultural model, the sequence model, and the artifact model. The cultural model will showcase different influences on drivers that affect their motivations and behaviour, hence contributing to the bigger picture. In addition, the sequence model will show tasks associated with charging and what triggers those tasks. Lastly, the article model will present tools and equipment that drivers currently operate when charging electric vehicles. The reason for not producing the flow model and the physical model is that this project is focused on only the driver and that the physical space is difficult to capture during a sitting interview.

4.4 Model Consolidation and Affinity Diagram Building

In this project, more focus is put on grouping different notes, instead of building the diagram. This is easily done, since there is only one person creating the notes in this project. The diagram is primarily built for visualising the thought process.

4.5 Personas

Personas will be used for representing some user groups and for communicating different user interests and needs. They will be based on data collected from three users, which could potentially lead to problems with covering all user needs. However, one assumption made is that it will be possible to combine the data to cover most of the must-have needs and some of the other needs, as illustrated by the Kano model in figure 3.

4.6 Visioning

Visioning is done by writing a vision statement. This vision statement will form after imagining the possibilities that comes to mind after interpreting all data.

4.7 Paper Prototypes and Mock-Up Interviews

4.7.1 Generating Prototypes

Making a paper prototype from scratch might seem like a dreadful task but starting out with the basic elements such as the app bar and application body simplifies the process. Most people use mobile phone applications daily and are familiar with the usual layouts that they provide, but app design recommendation changes frequently and it can be difficult staying up to date.

To aid in the process of designing the application, inspiration from already existing charging applications is assembled. Some guiding resources are used to understand what a good mobile phone application would look like, see appendix C. Pablo Perea and Pau Giner state that “[w]ell-designed products and services result in positive interactions.” [20] Well-designed does not necessarily mean an aesthetic product. In this context, a well-designed product is something that is good at solving problems.

4.7.2 Figma

For making paper prototypes, the interface design tool Figma was used. [32] Being new to Figma, watching and following tutorials on YouTube proved helpful. [33]

4.7.3 Mock-Up Interview

During the mock-up interview, there was a walk-through of the first prototype with two LP-drivers. The mock-up interview was held online through Teams. Every screen was discussed and comments that were made were written down in a notebook. These notes were considered when making the second prototype. The first prototype had one screen that was pretty much empty; it only contained a black frame and some text. The LP-drivers were asked to imagine what was missing and then tell. This was a way of testing the "let the user be a part of the design/developer team", by allowing the user to tell what should be done.

4.8 Implementation

4.8.1 Installing Software

Before implementing the application, all the required software must be installed on the computer. In order to know what software was needed for development, the introduction part of the book *Beginning App Development with Flutter* was read. [34] Furthermore, documentation on the system requirements was examined. [35] The standard requirement is to have access to an editor and git. Git is a version control system often used to coordinate development projects and is sometimes required to be able to install software. [36] It is possible to use editors, such as Android Studio, Intellij Community Edition or Visual Studio Code. Visual Studio Code has been chosen, because of pleasant experiences of using it in the past. [37] Apart from the standard software needed for development, software for developing mobile phone applications also need to be installed. To be able to run the application during development, a virtual device manager or a physical device is recommended. In Android Studio it is possible to create emulators that are also compatible with other editors, such as Visual Studio Code. [38]

Flutter was chosen as the framework for building the mobile phone application, because of the ability to create native cross-platform applications with one programming language and a single code base. [39] Flutter is installed as a plug-in in an editor. To be able to use the Flutter framework, a Flutter SDK must be downloaded from the Flutter web site. The Flutter SDK makes it possible to compile the code into native code, which makes the application work with either iOS or Android. [40] Flutter uses Dart as the main programming language, which can also be downloaded as a plug-in. Dart is an object-oriented language used primarily for user interface development. Both Flutter and Dart are developed by Google and are therefore highly compatible. [41]

There are other development frameworks such as React Native and Ionic. However, Flutter was considered the best option for this project, because of its good performance and high flexibility. Flutter compared to for instance React Native, offers more customizing capabilities. For instance, it is easier to adapt the visual appearance of an Android application. [42]

4.8.2 Learning Tools and Framework

After finishing setting up the development environment, focus was directed on learning these tools and framework. First, two codelabs introducing Flutter were conducted. [43], [44], [45] To understand Flutter well enough to develop applications independently, a YouTube tutorial was completed, that covered more than the basics offered in the codelabs. [42] Unlike the codelab, which primary focus was on getting acquainted with Flutter, the tutorial offered much more depth and understanding of the programming language Dart and the Flutter framework. Most of the tutorial was executed with ease, but since the tutorial was three years old, some of the content was outdated. This caused some errors when coding. Reading the comment section and searching for similar issues online proved helpful when solving these problems.

4.8.3 Flutter Widgets

In Flutter, everything you build is a widget. Therefore, the entire application user interface is a widget tree. There are different types of widgets, ones that are visible to the user and others that are invisible. The visible widgets are something that the user can see on screen, while the invisible widgets give structure and control how the visible widgets are seen. For example, a visible widget could be a button, while the invisible widget is the column influencing the positioning of that button. [42]

4.8.4 Connecting Back-End with Front-End

Before the first test session, some deliverables had to be completed, see appendix D. The first deliverable was to implement a data fetching example. [46] When data fetching worked with the example data, the URI in the code was changed to a URI that would connect the application with Xiaoying’s server. This can be seen in figure 31.

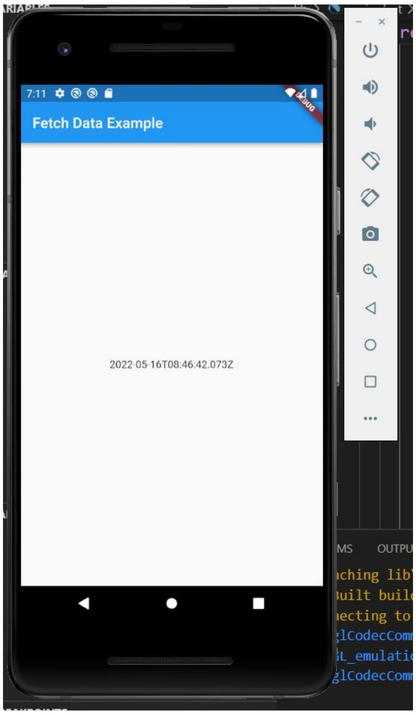

Figure 31. Testing of heartbeat URI

4.8.5 Minimum Viable Product

It was decided that a minimum viable product (MVP) should be made, which is a product with some features that can be tested and then built upon. This MVP would test some functionality that would have been discovered during the contextual design process. This MVP would be the result of testing of some feature with one vehicle and one charging station.

The charger screen was mainly used during the first test session to confirm that the URI was used, when restarting the application. Confirmation was done by printing the time stamp from the start or stop URI.

5. Results

This section shows the results from the design process that was supported by the contextual design method. Testing results from implementing some design solutions are also presented in this chapter. An essential part of the contextual design method is the contextual inquiry. The result from the contextual inquiry is better illustrated by the results derived from creating work models, building the affinity diagram, creating the vision, constructing personas, and building prototypes. The findings from the results generated from the contextual inquiry and the insights gained during the mock-up interview are combined in the form of user requirements. The purpose of these results is to show what needs have been discovered and then to interpret the needs from which design decisions can be brought about.

5.1 Interpretation and Work Models

The results from the interpretation session are presented here. Data from the interview and from getting acquainted with BEVs at Scania was used to construct the work models, which were constructed to show different aspects of drivers work.

5.1.1 Cultural Model

The cultural model highlights the work culture and policies that drivers live by. At large, the model generated shows that drivers need clear incentives for carrying out some of their duties. For instance, drivers' main work consists of transporting goods from point A to B, but to ensure flexibility, which is required by the manager, they might have to do tasks that are not part of their job description. The following sections outlines the drivers' motivations and behaviour in relation to other roles, namely the road haulage company, the customer, and the manager. Laws and such are not part of this model in figure 32, instead the model is focused on showing different influences, marked with arrows, and interpersonal friction, visualised in red.

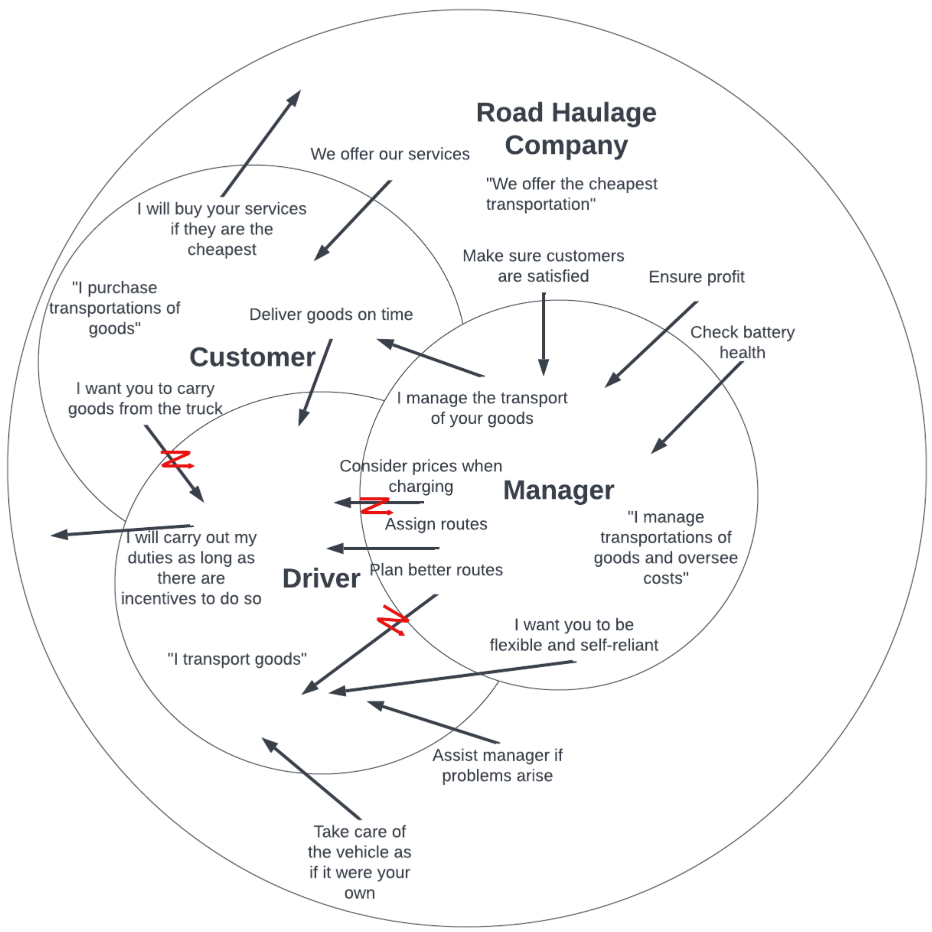

Figure 32. Cultural Model

Driver and Road Haulage Company

Many road haulage companies are family-owned businesses. The day before departure, drivers receive their schedule. Culturally, everything works just like a family. Drivers sometimes compensate on behalf of others to make sure that everything operates smoothly. For example, drivers might plan new routes or exchange routes, so that everyone gets home at a reasonable time. That is why the working hours sometimes are quite flexible. However, some working hours are tied to specific customers or specific routes. Note that there is usually some variety in the way that these companies operate.

The question of responsibility is quite central because there must be an incentive to refuel the truck for a lower cost, otherwise few drivers would be doing it. In most cases, it is the person responsible for the finances that is concerned with the costs. The driver is responsible for refuelling the car but is not responsible for the finances. Since the prevalence of BEV is quite new, it is possible that charging would also be the responsibility of the driver. Some drivers operate the vehicle as if it was their own because they always have the same truck. Other drivers operate different trucks, but this is less usual according to one of the interviewees. However, he mentions that drivers sometimes lend their truck to another driver, but it is often to someone that the driver trusts. Understanding different types of responsibilities at the road haulage company is necessary to identify relevant user requirements.

Different types of responsibilities are often transferred to the driver. The responsibility of objects, for example making sure that a chiller is still functioning during a longer resting period, is a natural part of the job. Otherwise, the company would have to manage the work in detail, which is not very cost effective. In many cases, drivers want to acquire interesting assignments and therefore must take on more responsibility as part of the work requirements, even if it interferes with leisure time.

Driver and Customer

The customer has a lot of power, and the road haulage company therefore has to offer some flexibility. However, the demand on flexibility is often handed over to the driver. For instance, drivers are not supposed to load goods at the destination, but are sometimes required to do so, because the customers ask them to.

Driver and Manager

One of the interviewees worked at a company with fifty vehicles. His role was to deliver goods or European pallets on largely fixed routes. He says that drivers at his firm specifically were not responsible for costs. He says that the Swedish mindset is: “as long as I do not have to pay”, so that is why drivers in his opinion cannot be responsible for fuel related costs. Furthermore, he argues that the directives to think about costs must come from the managers or the owners.

However, other drivers that have been interviewed do not quite agree. At their workplaces, drivers had to take some responsibility for costs, since they often travelled abroad. There could be large price differences between nations, so it would be considered wisely to purchase just enough fuel to get out of an expensive region. Therefore, the driver had to calculate how much fuel was needed. It seems that drivers usually avoid refuelling in expensive countries, such as Norway, Italy, and the Netherlands. This is not something that drivers always are told explicitly to do by their managers.

Customers that require transportation of their goods are connected to a dealer. Then, haulage companies make bids on transporting different goods. It is usually the haulage company offering the lowest price that wins. If the road haulage company has won several bids and if many of the routes seem to overlap, drivers usually make new route plans the day before departure. This responsibility is sometimes given to drivers indirectly or is an expected part of the job.

Working hours are to a large extent determined infrequently. Outside of Sweden, the working hours are said to be even more sporadic. The routes are often determined in short times notice. One driver said that you might be at home when the office calls and says, "you are going to Budapest". In addition, it is not unusual for last minute changes, meaning that you might have to switch routes with another driver. Bad planning is often a factor causing stress among drivers. They are only allowed to drive for a certain amount of time, otherwise there will be a penalty.

5.1.2 Sequence Model

The first sequence model shows steps taken by the driver to charge for a lower cost. With the current technology, drivers believe that they would not be able to consider costs when charging. Today, if drivers would consider costs, they would have to physically start the charging process in the middle of the night, when they should be sleeping.

One interviewee believes that without a charging application for mobile phones, the driver would have to call the electricity company to know when prices are low. This driver is referred to as U01 in figure 33. The answer from the electricity company is believed to be somewhere between 1 and 4 o'clock at night. The sequence model in figure 33 illustrates this charging problem.

The second sequence model in figure 34 shows the steps taken to start and stop charging processes using the charging stations at Scania. This is how charging currently operates when using the MVP that will be shown later in the results.

U01
Title: Charge truck for a lower cost

Sequence #1

Intent: Charge truck so that it is fully charged at time of departure
Trigger: At the end of the workday, the manager has reported high charging expenses by phone and tells the driver to consider costs when charging

↓

BD: Cannot think of a way of knowing electricity prices without calling an unspecified electricity company

↓

Searches online to find a phone number to the electricity company

↓

Calls electricity company and receives information about the low-priced hours

↓

Intent: Charge vehicle when the costs are low
BD: Interference with driver's leisure time

↓

Wakes up in the middle of the night and walks to the vehicle and connects it to the charger

↓

Intent: Make sure that charging has been completed

↓

Puts an alarm on the phone that rings when charging should be completed

↓

Walks outside to check on the vehicle

Figure 33. Sequence model

This sequence model is not based on an actual task that drivers are required to do but shows how some drivers think they would do if they were asked to charge for a lower cost. The intents show why the driver take certain steps to carry out their tasks. [23, p.

130] If the resulting design support these intents, the other steps in the sequence can be removed. The breakdowns, in red, show when the driver have trouble in carrying out the steps. The trigger is what initiates the entire sequence. [23, p. 130]

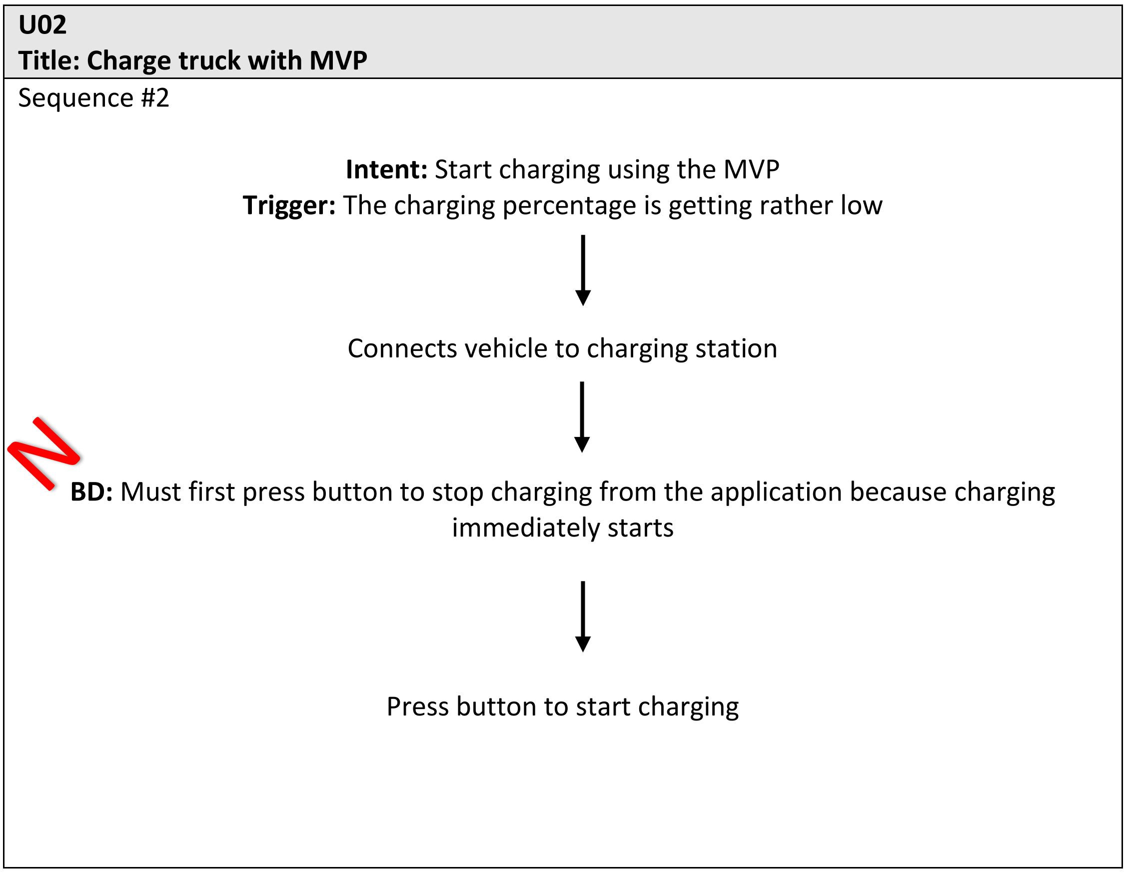

Figure 34. Sequence model

5.1.3 Artifact Model

The artifact model presents the tools that truck drivers at Scania use when charging their BEVs. The purpose of the artifact model is to describe how the artifacts are used by drivers when they are carrying out charging related tasks. Here, the artifact model only shows one type of charging station, including the display, and one type of BEV. These are the ones that are used in this project.

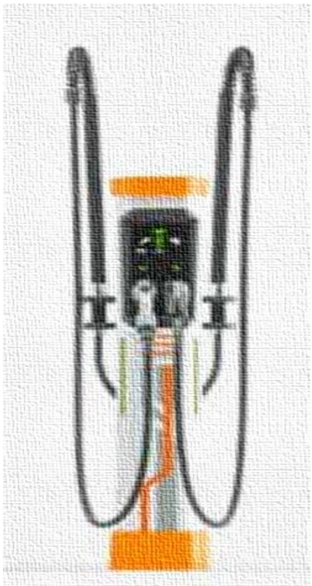

Figure 35. Charging station

The charging station in figure 35 is used to supply BEVs with electrical power with the intent of allowing BEV operators to start, stop and oversee charging sessions. To use the charging station, the operator connects it with the vehicle by using the connector. Charging should start immediately. If charging does not start immediately, some error might have occurred.

Figure 36. Charging station display

The charging station display in figure 36 is used to visualise data from the current charging process with the intent of enabling easy access to valuable information for BEV operators. This charging station display is mounted on the charging station in figure 35. It only shows data when a vehicle is connected to it. It displays information such as the charging percentage, kWh, kW, and other information related to the charging status. It is possible to scan a QR code on the display to follow the charging process via a mobile phone.

Figure 37. Battery Electric Truck

The Scania battery electric truck in figure 37 is used for transporting goods with the intent of enabling emission free transports.

5.2 Affinity Diagram

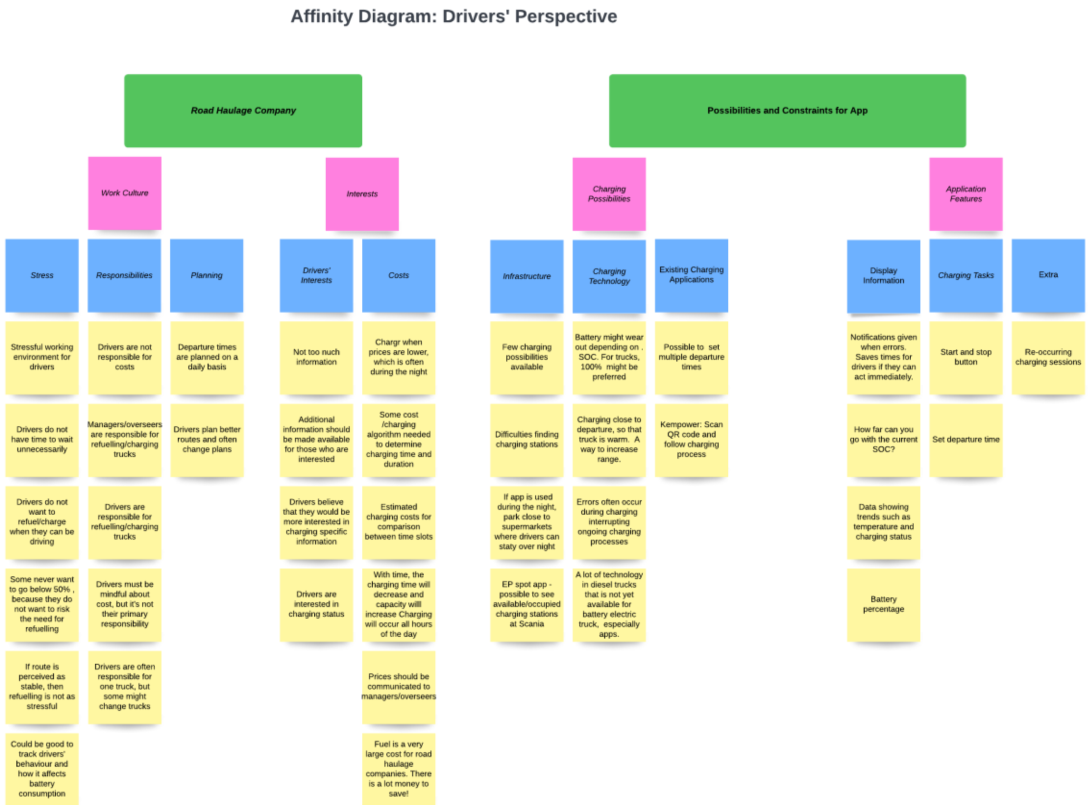

Figure 38. Affinity Diagram

The affinity diagram in figure 38 is mainly for visualising the organisation of thoughts during the design process. The green cards are labelled “Road Haulage Company” and

"Possibilities and Constraints for App" respectively. These two categories were the last two categories to emerge after discovering connections between notes from the interview sessions. The other categories include the pink categories consisting of "Work Culture", "Interests", "Charging Possibilities", and " Application Features", as well as the blue categories. The two green categories that were identified in the affinity diagram building session show the drivers' relation to charging technology and the road haulage companies.

5.3 Vision

The following section summarises the vision statement that was derived after creating the work models and finishing the affinity diagram.

5.3.1 Vision Statement

For customers operating Scania's battery electric vehicles, the smart charging manager is a mobile phone application that will allow road haulage firms to lower their charging expenses. Unlike any similar applications that already exist on the market, the smart charging manager will with the help of day-ahead-prices determine what time frame is the cheapest. Our product will also allow users to gain more control over their vehicles by not only monitoring charging session, but also by being able to schedule charging sessions, start sessions immediately if needed or terminate ongoing session with the use of a smart phone application.

5.4 Personas

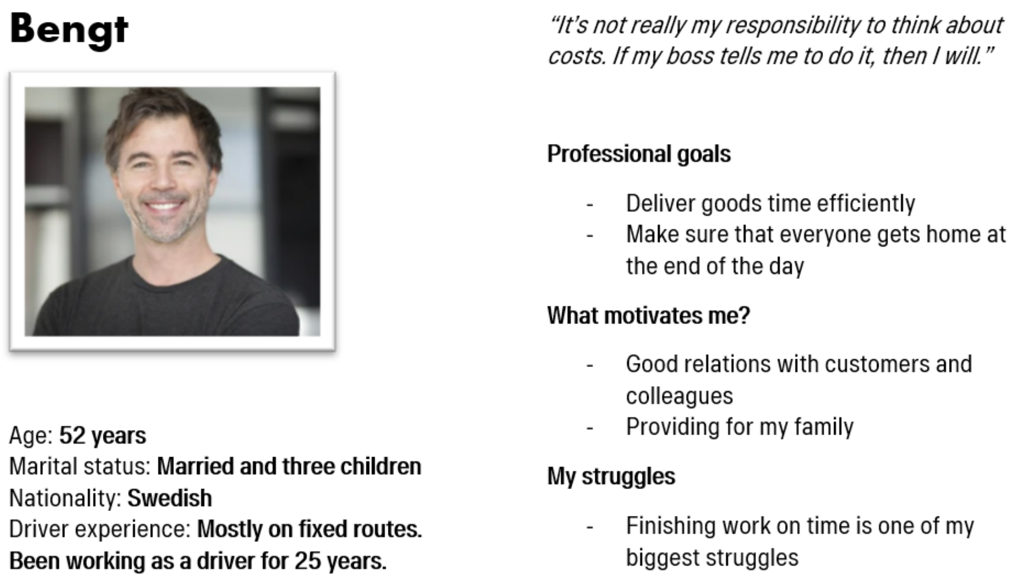

Figure 39. First persona

Figure 40. Second persona

The personas in figure 39 and figure 40 illustrate two different types of user groups: drivers operating on mostly fixed routes and drivers operating on more flexible routes. Their motivations, professional goals and struggles give hints about interests and needs within these user groups. In this case, the struggles are perhaps the most interesting part. Bengt has problems with being time efficient, while Johannes struggles with managing friction on the workplace. Friction is in the case of Johannes, problems with planning routes, calculating costs for fuels etc. Bengt does not see these things listed here as a problem, because he does not feel that those things are his responsibility.

5.5 Prototypes

This section shows the two paper prototypes that were created. The first paper prototype mentioned in 5.5.1 was used to test initial ideas with users. The mock-up interviews using the first paper prototype resulted in the second paper prototype described in 5.5.2.

5.5.1 First version of prototype

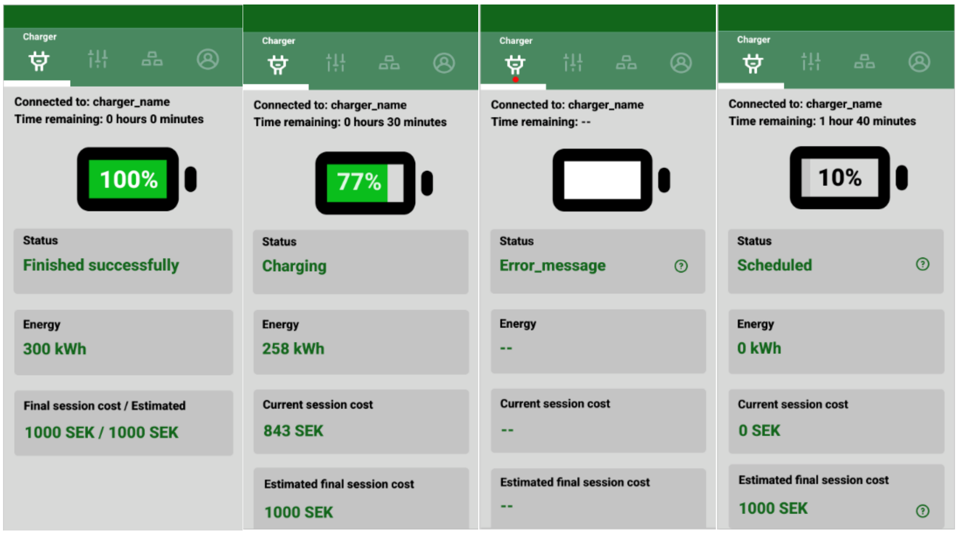

Figure 41. Charging status screen

Figure 41 shows the first prototype version of the charging status screen. From left to right: charging has finished successfully, charging is ongoing, an error has occurred during charging, and lastly a charging session is scheduled.

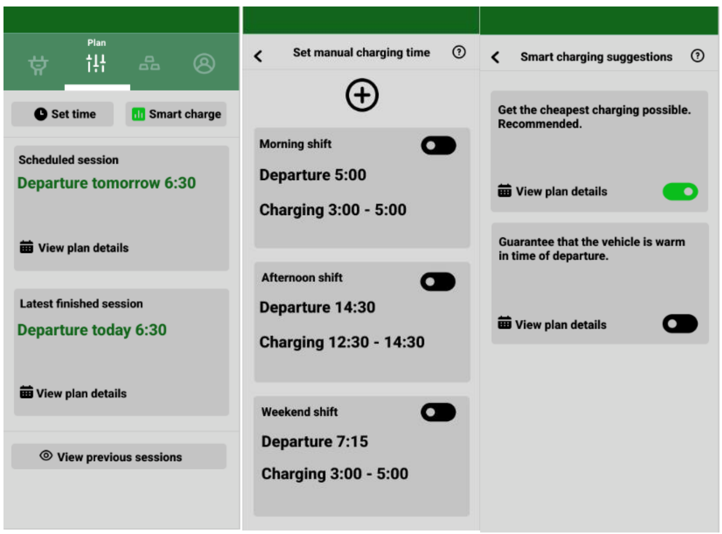

Figure 42. Planning screen

Figure 42 shows the first prototype version of the planning screen. From left to right: a user can plan charging sessions or view scheduled sessions, a user can set manual charging time, and lastly a user can choose a smart charging solution.

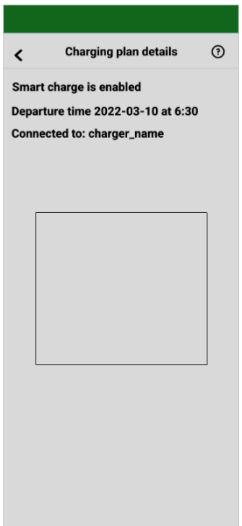

Figure 43. Charging plan details screen

Figure 43 shows the first prototype version of the charging plan details screen. This screen is empty with the intent of allowing interviewees express what they are missing.

5.5.2 Second version of prototype

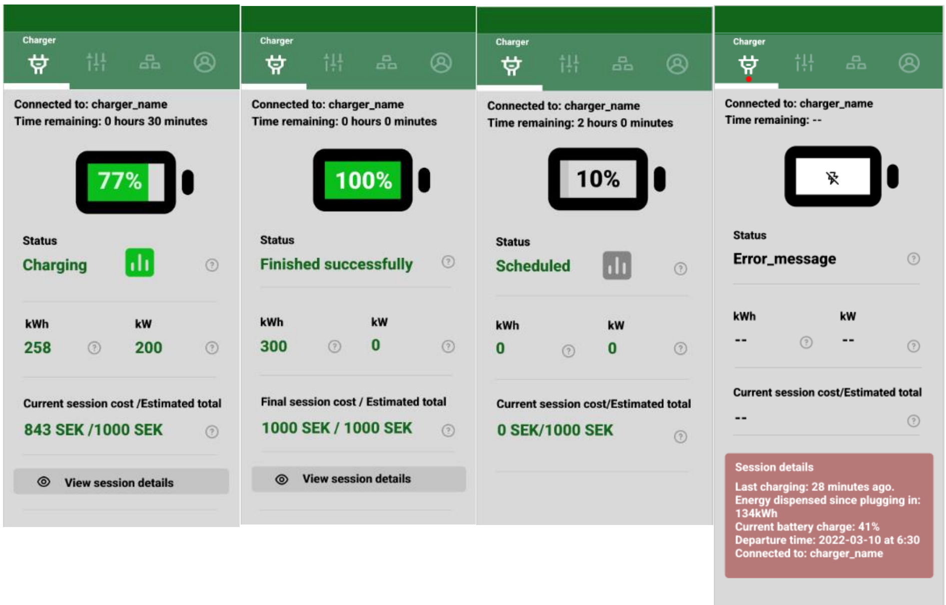

Figure 44. Charging status screen after mock-up interview

Figure 44 shows the charging status screen after the mock-up interview. The most notable change is perhaps the cleaner layout. Also, red colour has been added to increase the message that an error has occurred.

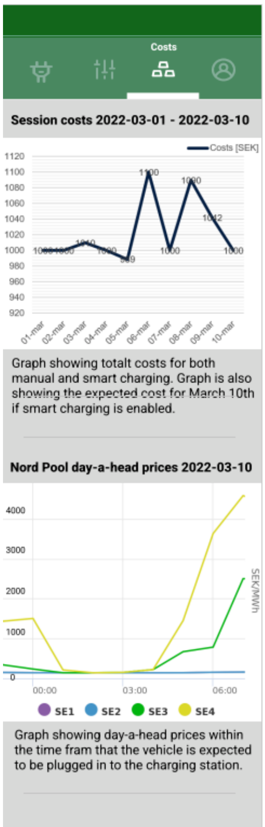

Figure 45. Costs screen

Figure 45 shows the cost screen. The first graph shows the total charging cost, no matter if charging has been done with manual charging or with smart charging. The second graph shows day-ahead-prices.

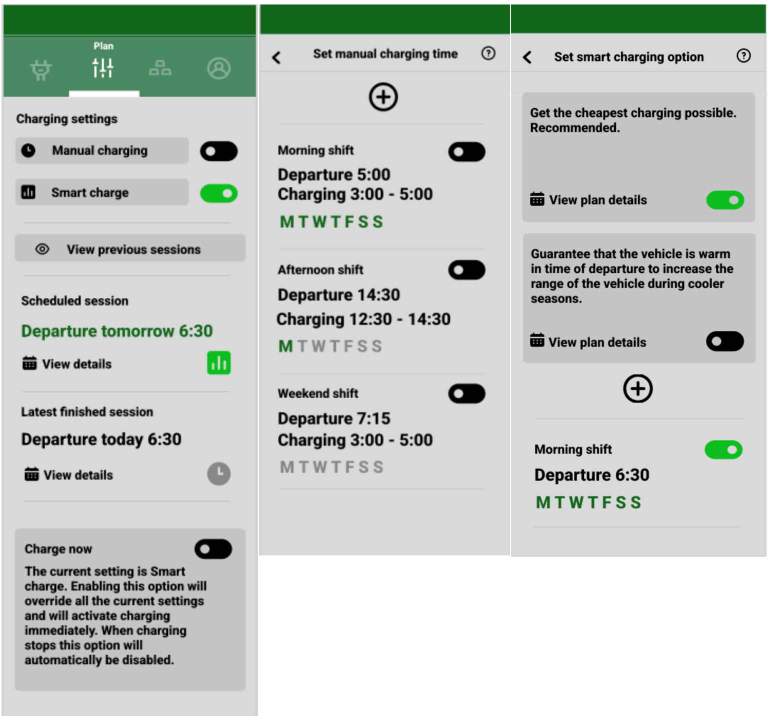

Figure 46. Planning screens

Figure 46 shows the planning screens after the mock-up interviews. There have been some adjustments in the layout. The most important difference is likely the added “charge now” functionality.

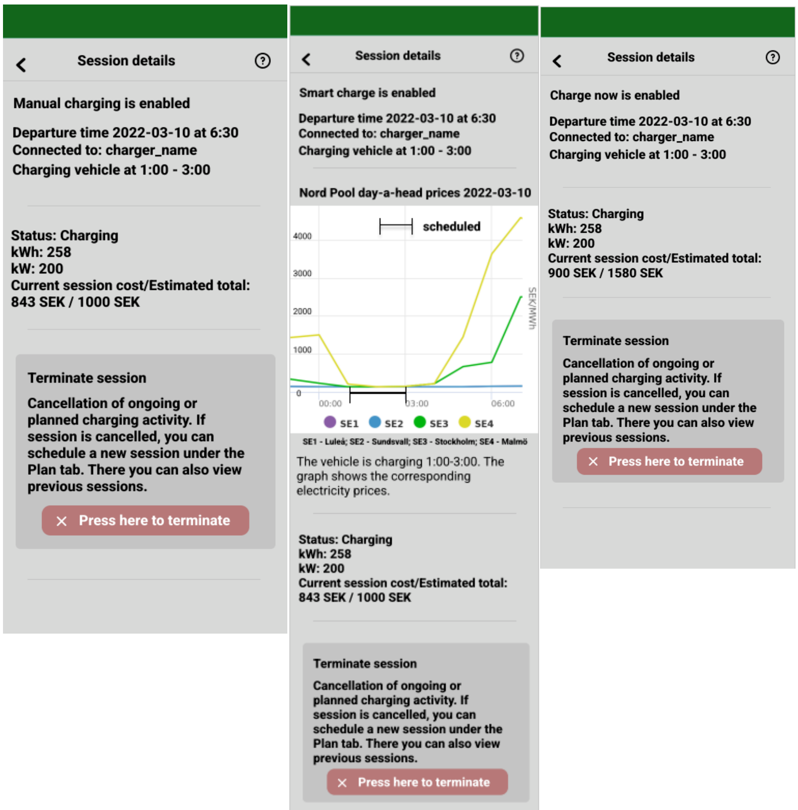

Figure 47. Session details screens

Figure 47 shows the sessions details screens after the mock-up interview. This is the plan details screen in the first prototype version. In this screen, the user can see the charging plan and terminate the planned session if it is required.

5.6 User Requirements

This section includes a summary of the user requirements that have been recorded. The requirements relate to the user needs that were identified during and after the contextual inquiry. See appendix E to view the detailed user requirements. Three groups of requirements have been identified: viewing charging state, taking action, and consider costs.

5.6.1 Viewing Charging State

The driver needs access to information related to charging, which enables the driver to take specific actions. This is information such as whether the vehicle is fully charged, the current charge percentage, time left until the vehicle is fully charged, the current charging solution operating, what charger the vehicle is connected to, the general state (e.g., error, scheduled session, charging), as well as the SOC at different times. The actions related to the state are mostly about ensuring that the charging process is operating according to plan and being able to decide when it is possible to stop charging or continue the journey.

5.6.2 Taking Action

The driver needs to be able to take certain actions to feel in control of the charging process. These are actions such as starting charging immediately from the mobile phone application overriding current settings, terminating ongoing charging session, setting manual charging time, planning charging sessions and managing errors. These actions that the driver is allowed to take should be supported by sufficient information that guide the driver through the process.

5.6.3 Consider Costs

The driver needs to be able to view charging costs to have an easier time planning a charging session. By viewing charging costs the day before, the driver will most likely find it easier to choose a charging solution that is the most optimal in the given situation. Also, by viewing costs the day before, the driver will be able to confirm that the expected total price is reasonable.

5.7 Minimum Viable Product (MVP)

This section shows the results from testing the implemented GUI with the server. Testing was done in two different sessions.

5.7.1 The First Test Session

During the first test session, the start and stop functionality was tested. This functioned properly when using the URIs for start and for stop in the get URI section of the code. However, the application had to be restarted when changing the URI between start and stop. A limitation in the code was discovered that only allowed the URI to run during application reload. It was seen as a successful start when the charging station display confirmed that charging had started. Also, it was seen as a successful stop when charging stopped after changing the URI and confirming that the application reload was finished. Hence, this test session brought satisfying results. The next step was to implement buttons for the start and stop functionality.

5.7.2 The Second Test Session

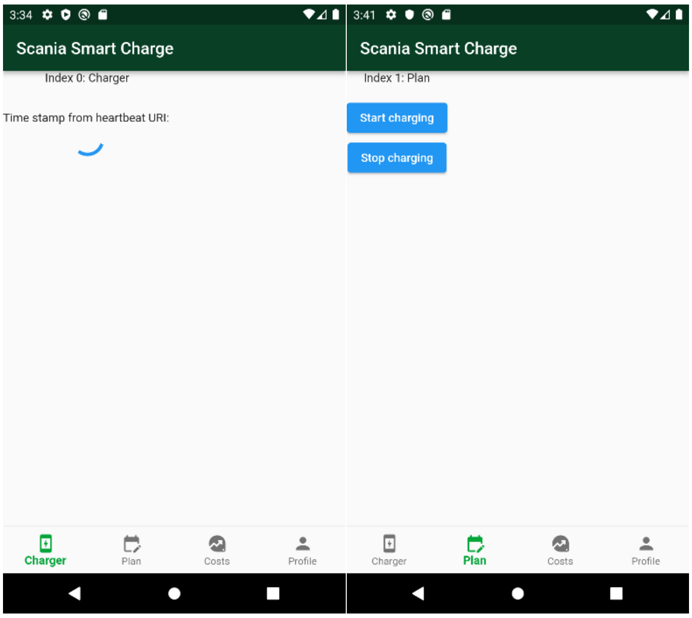

Figure 48. Screenshot showing the charger screen and the planning screen

Figure 48 shows the screens that were used in the first and the second test sessions. The only difference is that the URIs for start, and stop were used, instead of the heartbeat. Figure 48 shows how the charger screen looked during the second test session specifically. The planning screen shows the buttons that were used for starting and stopping a charging process. In the code, see appendix F, the URIs were exchanged for the real start URI and stop URI during test sessions.

The second test session was considered less successful than the first. The problem was noticed after successfully using the start button. After a few seconds of charging, charging would suddenly stop. At first, it was difficult to decide whether the problem was with the vehicle, the application, the server, or the charging station. To rule out the charging station, the start and stop functionality was tested using another charging station nearby. However, the same problem happened there. To rule out the mobile phone application, all the connection between the application and the server were shut down. In addition, the start and stop functionality was tested using Xiaoying's implementation. However, the same error happened again. It was noted that the implementation of the server only kept track of the latest connected BEV. The problem could have been due to disturbances from other ongoing charging activity. Xiaoying was asked to investigate the problem further.

6. Discussion

This chapter outlines the implications of the results achieved in the project and how they are relevant for the HCI area as well as Scania.

6.1 Driver's Responsibility

According to the theory of *a meaning processing approach*, the consequences and the values that lead to positive outcomes should be maximised. Also, the consequences and the values that lead to negative outcomes should be reduced. The results from the work models show that there are some frictions within the work culture at some road haulage firms. Friction at road haulage firms as it seems tend to occur due to shifting responsibilities. Drivers are required to be flexible and take responsibility for their truck. Therefore, some drivers believe that they have responsibility to be mindful about costs whereas others do not consider costs at all.

Recall that *operators that are in control of their actions have high correspondence between their interpretation of the situation and the meaning of the situation*. In many cases, drivers are responsible for charging their truck. Then, a charging monitoring solution that makes drivers feel in control of the charging process should give drivers the responsibility that they expect. This includes showing relevant charging status information, for example the information displayed in figure 44.

The solution should also be mindful about what cost related information is shown to the driver. For example, drivers are in most cases required to keep track of costs in different regions. However, they should for instance not be able to keep track of costs of other vehicles at the same road haulage firm, because they would usually not expect that information. Adding that information without an extra thought would result in clutter. It is likely better to allow drivers to access all information that is available, but the designer should consider adjusting the prominence level of all features, so that important information is highlighted, and less relevant information is filtered or reduced.

The same thing can be said about data visualisations, showing charging costs statistics. In this project, drivers have been shown many examples of EV applications with a lot of data and statistics. Most of their reactions seem to be that the manager of the road haulage firm would be interested in that kind of data and that it does not concern them. Adding costs graphs like the ones in figure 45 could potentially increase the negative experience of the application, because drivers would not be certain whether the information concerns them. A possible solution to this would be to address that specific driver in that interaction or interface when referring to costs, to help the driver understand that the information is relevant or to allow the driver to hide this information.

6.2 Implementation

The charging solution should consider what a *natural* interaction is in terms of charging. Right now, the MVP requires the user to press the stop button, see figure 34, after connecting the vehicle to the charging station. When charging a mobile phone, the expectation is that charging starts immediately when connecting the charger. The same thing happens when using the charging station in this project; charging starts immediately.

6.3 HCI

In section 3.2 it was stated that a successful action taken by the user would likely have a high correspondence between meaning and interpretation. The way I see it is that the contextual design methods mainly focus on the interpretation part of a given situation. Understanding users is half the problem and that can be achieved with some of the available user-centered agile methods. To understand more about the work domain, it is possible to conduct tests and try out real life examples, which was done in this project. What one also could do is to do online research on a topic and gather data and information from relevant sources. If it is possible to map the space of possibilities and outline the consequences and values, it is sufficient to understand what meaning in that work domain is.

6.4 Needs

The *Noriaki Kano model* distinguished between three different types of needs: must-have, linear and latent. It can be said that all the must-have needs are required for BEV operators to feel in control of the charging process. In this project, almost all the "must-haves" can be found in the charging status screen in figure 44. This is the information that BEV operators expect to find, and it is also what most competitor EV applications include as well. There are also some linear needs that can be supported by the ideas generated in this project. When supporting BEV operators' linear needs, they should generate some value from it. In this case, the planning screens, and the functionality in them would save time for the BEV operator. In the most optimal situation, BEV operators would be able to save time from thinking about costs when being abroad, because the mobile phone application would take care of it. However, the scope of this thesis project is limited to one charging station at Scania. Enabling a smart charging solution, like the one in figure 46, would in many cases support needs (latent) that BEV operators did not know that they had. All these features mentioned are possible and valuable for Scania to implement, because they are linked to user needs that increases efficiency and user satisfaction. They also save time and money for the haulage firms.

6.5 Implications of the Results

So far, this thesis project has led to the discovery of needs from which design solutions can be brought about. Some current technology has also been tested and resulted in the implementation of an MVP.

The focus was to design and implement solutions intended to make a person responsible for charging feel in control of the process. The results show that there are some things that can be taken into consideration when designing the interface and the interactions. Things to consider are for instance all the needs that should be captured and the ones that could be captured to generate more value to the BEV operator (or the target user). Perhaps the most important insights are what solutions make the target user feel in control of charging. It seems to be solutions that are perceived as *natural* and have a high correspondence between what the user believes to be their task and what they can do with the current charging technology. For instance, a solution should consider what is natural in the context of charging a BEV with the help of a mobile phone. It is natural for charging to start immediately when a charger is connected to device, or in this case, a truck, see figure 34. However, to charge during hours when electricity prices are low, charging must be stopped when the BEV is connected at the end of the workday. Who or what should stop the charging process after connecting the vehicle: the mobile phone app, the driver or something else? What would be the next natural step? This is something that should be considered when continuing development of this functionality.

There have of course been some limitations in this project. If there was more time, more effort would have been put into conducting extensive user-research and producing many more design solutions. This project has generated two prototypes, but that is far from what is required to build good interfaces and interactions. Moreover, with a larger team it would have been possible to interview more drivers apart from those working at Scania. Right now, the results in this thesis project depend to a large extent on the interview data that was generated from talking to three drivers.

For Scania, I believe it would be possible and valuable to implement a charging monitoring solution that has the driver’s or the BEV operator’s perspective in mind. BEV operators tend to carry the weight of many responsibilities and therefore, solutions that can alleviate some of these responsibilities could potentially generate value for the BEV operators and the road haulage firms. Apart from saving time for the BEV operators, road haulage firms could at the same time lower their expenses. Offering a charging monitoring system could also be an incentive for road haulage firms to purchase BEVs in the future, because the responsibility of charging, for instance environmentally friendly and cost-effectively, would not necessarily be transferred to the driver.

6.6 Future Thesis Work

Some suggestions for future work include continue building on the implementation in this project, implementing and evaluating an algorithm for calculating costs or do more in-depth research into current charging monitoring solutions. I believe that the most interesting work would be to implement some cost algorithm and then test how much it costs. An algorithm I thought of using myself but did not have the time to implement was the Kadane's algorithm that can be used for finding the maximum or minimum value of a sequence. In this case, the algorithm could perhaps be used to generate the lowest charging price. I know that Xiaoying already implemented some smart charging solution, but I do not have further insight into that part of her work.

7. Conclusion

Solutions that are perceived as relevant by drivers in the given context of use make BEV operators feel in control of the charging process. What is perceived as relevant is what the driver would expect to have access to, because of different driver needs. Thus, a charging monitoring solution that make BEV operators feel in control should have interfaces and interactions that feel *natural* due to *prominence levels* being adjusted according to drivers' responsibilities. The design should be able to explain why and what information is relevant in a *natural* way by allowing the operator to explore the solution.

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Appendix A

This appendix shows the interview questions from the contextual interview. Since the interviews were semi-structured, it is likely to have been some variations in the questions asked.

Background information (notes):

Xiaoying is making a server from which my mobile phone application will be able to access information. One of the goals with this project is to discover something that will make the user feel in control of the charging process. A central part of this project is to find out more about the users – you. You know a lot about drivers and the road haulage and distribution industry and during this hour I would like to know more about your experiences.

Interview Questions:

1) What is your background (driver)?
2) Where did you work?
3) How was it working at [company]?
4) How was a regular working day?
5) What roles were there?
6) What role did you have?
7) Who was responsible for what?
8) Who was responsible for costs?
9) Who was responsible for refuelling vehicles?
10) Do you operate an electric vehicle privately?
11) Have you used any charging monitoring applications before?

Appendix B

This appendix includes a summary of the notes taken during the interviews. Please note that the summary was done in Swedish.

När? 2022-02-17 ca 10:10 – 11.45

Var? Scania, by 106, piazzan (lunch/fikarum)

Vem? M (endast för egen referens)

Sammanställning av intervju

- Har tidigare arbetat med timmertransport för ett åkeri
- Jobbat som testförare i 3 år, även en kortare period 2002-2003
- Upplever arbetet på Scania som lugnare, ingen stress
- Stress som "riktig" förare är kopplad till arbetstiderna.
- En mindre del av stressen är kopplad till de digitala förarkorten, även om det ska sägas att de till stor del gjort arbetsvillkoren bättre för föraren. Ex. att de inte kan eller ska köra mer än de timmar som är lagliga. Här räknas all tid, varje sekund räknas. Får inte köra för mycket för då blir det höga böter, ca 4500 kr.
- Mycket kontrollerad bransch. Körkort till hög kostnad. Olika tillstånd. Samt böter för olika regel/lagbrott.
- Kunden behöver hantera höga priser, ex. ökande bränslepriser och andra ökade omkostnader. Ex. sägs priset på takpannor inte ha ökat sedan -81, kostnaden tas någon annanstans ifrån. Dvs. transport av enbart takpannor är inte lönsamt.
- Appen har olika ingångar: en för fordonsköparen och en för föraren. Fordonsköparen/chefen är den som har det huvudsakliga ansvaret för kostnader. Den svenska inställningen sägs vara något i stil med: "så länge jag inte behöver betala…" Därför kan inte förarna ansvara för att ladda billigt, utan direktiven behöver komma från chefen/fordonsägaren.
- Behöver på något sätt kommunicera till föraren varför billigare laddning är viktigt. Ex. Att föraren har större chans till jobb nästa månad också.
- Skogsbolag. Har skärmar som extramonteras m. appar osv som laddas ner. Skulle vara bra att ha detta färdigt istället för att köpa till.
- **Ansvaret:** Åkarens/Chefens ansvar att se till s.a. det är el i bilen, men chauffören ska också kunna se detta → Ska kunna se detta för att 1) Planera nästkommande arbetsdag 2) Hantera oförutsedda händelser genom att kontakta chefen (inte ett krav, men de som bryr sig mycket om detta ska ha möjligheten)
- Arbetstider: Dagen innan får chaufförerna schemat. Rent kulturellt funkar företaget som en familj – alla ska ha det bra, alla vill komma hem i slutändan. Chaufförerna kompenserar för varandra för att få det att funka. Därför är arbetstiderna ganska flexibla. Vissa arbetstider är bundna till specifika kunder som behöver varorna vid specifika tider varje dag (fasta tider). Alltså, chauffören bestämmer tiden.
- Föraren: Har mest nytta av appen när det kommer till att veta hur laddat fordonet är. Föraren kan dock inte ha ansvar över priserna.
- Roller: chef (pratar m. kunder), förman (underlättar för chefen, ex. problem som dyker upp), åkeriägare, anställda/chaufförer (kan ibland ta rollen som förman)

- Ekonomi: Hur göra laddningen ekonomisk utan app?
  - Ringa elbolaget och fråga när det är billigast. Ladda någon gång mellan 1-4 på natten för att det är billigare. Dock inte praktiskt! Med en app skulle föraren ställa in att ladda mellan 1-4 på natten.
  - En app m. sådan funktion skulle förmodligen kosta pengar, men fordonsägaren skulle tjäna på det i längden för att laddningskostnaderna skulle minska. Det finns ett värde i att ha appen.
- Priserna: Ska kommuniceras till chefen/fordonsägaren
- Laddningen: Ska kommuniceras till föraren och chefen
- Måste finnas någon form av motivation till att köra bränslesnålt förutom att det är billigare för företaget. T.ex tävling mellan förarna i att tanka billigt/ställa in laddning baserat efter pris osv.
- Notiser:
  Färdig laddning
  Avbruten laddning eller ändrad plan.
  Fel som uppstår. För att kunna kontakta chefen och för att veta vad som hänt och vad som behöver göras.
  Inga notiser om planen följs.
- Befintliga appar:
  Kempower, skanna, ta med och kolla hur laddningen går
- Provförare: Intresserad av laddtid, kwh, beräknad laddtid (när färdig)
- Chaufför: Intresserad av att bilen är laddad, ju mer ampere, ju mer styrka.
- Värdefull information om laddning, % innan fullt (chaufför), batterihälsa (chefen/ägaren)
- Om service behövs, när service? (felet, verkstadens ansvar)
- Chefen, se alla bilar (regnr, chassi)
- Chaufför, byt bil i appen –> se regnr → Välja från lista
- Annat förslag: Karta
- Filtrera för Preem
- Vilka laddplatser lediga? Var finns dem? (om 3km…)
- Gör så att föraren kan planera körningen så att det inte blir stopp. Kan bli stoppolyckor. Kan med gott samvete ta paus och starta med fulladdad bild.

När? 2022-02-17 ca 15:05 – 16.30

Var? Scania, by 106, piazzan (lunch/fikarum)

Vem? J (endast för egen referens)

Sammanställning av intervju

- Civilingenjör i maskinteknik
- Beräkningsingenjör, exjobb 2001, hållfastberäknare, utmattning på växellådor
- På Scania: Varit objektledare, produkutvecklare, motorutvecklare, provingenjör
- SAAB, GM, utvecklingsingenjör. Gick i konkurs, uppköpt.
- Tillbaka på Scania 2014
- Provning av motorer
- Alltid intresserad av fordon och lastbilar, körerfarenhet för att bli bättre ingenjör
- LP-gruppen, heltidsanställda

- 2017 som LP-förare, dröm om att jobba som lastbilsförare professionellt
- Förarutbildning, Scania Sverige –> Var inte riktigt som tänkt -> tillbaka på Scania som provförare
- Kör delar som inte är produktionssatt -> Alla produkter
- 16 förare, 8 på varje skift
- Helbilsprovning
- Livslängsprover mm. Rapporterar in avvikelser osv.
- Varje bil rullar 1 år
- Ungefär liknande uppgifter som andra förare.
- Många grupper som kommer får hjälp av LP-gruppen
- Kör elbil/personbil privat
- Kört i 2 år, liten ceat (ren elbil)
- Installerad laddbox hemma
- Får ladda på jobbet
- Underlätta för laddning
- Utan förarkortet fungerar inte Fleet Manager
- Abonnemangskostnad
- Kostnad: alla kunder använder inte
- Används inte av kostnadsskäl, inte nytta av all funktionalitet
- Servicesystem, data på servern
- Laddning hemma:
- abonnemang, debitering per timme
- Samma pris ändå
- Kan ställa in när åka på morgonen, värma upp kupén
- El lastbilarna: nyttja när lastbilen är ansluten redan
- Batteriet:
- Bäst att ta bilen när den är färdigladdad, speciellt på vintern
- Sämre verkningsgrad/räckvidd på vintern
- Ladda fortare när varmt
- Lastbil, saknar: Programmera avfärdstid, avbruten laddning under paus
- Varm innan urkoppling
- Vill kunna se när den är fulladdad!
- Få laddningsföretag visar laddsessionen
- Bättre att ha i bilen på något vis -> Lastbild, ladda på många olika ställen
  QR-kod, som gör det smidigt att Ldda
- I bilen : programmera: klimatreglering, räckvidd, laddstatus, batteristatus
- E kund vill köra lastbilen så mycket som möjligt
- Arbetsledaren vill se när den är fulladdad -> ex. om en kollega ska ta över lastbilen
- Hur långt laddningen kommer att ta → workarounds för att själva beräkna hur lång tid laddningen kommer att ta
- Körtid och sträcka från senaste laddning vore bra, samt batteriprocent och medelförbrukning
- Aggressiv körstil: förbrukar mer, vore bra att se i appen
- -SEAT connect- (tillverkarens app)
- Olika ivägkörningstider, förinställda
- Slitage på batteriet, ställa in max. laddningsnivå, kunna ändra

- Lasbilar vill man nog ha 100%
- Kort räckvidd, vill ha fullt varje gång man åker hemifrån
- Tesla 80% ex. SOC
- Inte ?? ladda ner bil 10-20%
- Lågprisströmsfunktion, ställer in när den ska laddas ex. om man vet mellan 2-4 på natten
- Helst klimatreglering när bilen är ansluten, värmer kommer ganska fort i elbil
- Sätesvärme, rattvärme, kupévärme, defrost
- Batteriet sjunker fortare än om man tar den när den är helt varm
- Nu: Bilen kall! (batteriet sjunker fortare) Dieselbilar kan programmera startid, men inte ellastbilarna → saknar detta
- Viss räckvidd i bra förhållanden, begränsat i sämre förhållanden –> skulle vara bra att kunna programmera detta! (när bilen ska starta och värmas upp)
- Snittförbrukning, räckvidd, kört hur långt, kördata (senaste färd)
- När och varför kunna se data om körtider och körsträcka
- ex. vid provtillfällen
- Inte den viktigaste infon
- Medelförbrukningen mer intressant kan se trender ex. data som visar medeltemp. den dagen
- Laddstatus, när färdigladdad
  Det huvudsakliga
- Ska helst inte ladda när man kan köra, ladda till tillräcklig räckvidd
- Kör och vilotider, 45 min rast efter 4 h. Körning → kan vara bra att följa status på nuvarande laddning i relatid
- Med QR-koden, se laddarens status → n. kempower kan ej se körsträcka osv. temp o tid
- Avbruten laddning pga strul:
- Problem just nu
- Hög effekt på lastbilarna
- Kan bero på att det är för varmt och kulning eller andra problem, problem med laddare
- Vill inte upptäcka detta efter en rast!
- 1a steg: laddstatus, batteriprocent, räckvidd just nu…
- Styra uppvärmning
  → tider, ex. 3 inställda
- Bränslekostnader en jättestor del för ett åkeri/företag
- Mycket att spara!
- (Jämföra olika förare på el-lastbil också)
- (- Fleet Manager även för el lastbilar -)
- Mycket för dieselbilarna har inte funnits i el-lastbilarna
- Vill följa laddningen under dagen också
- Snittförbrukning hur påverka räckvidd?
- - ex- på senaste laddning
- - EP spot app –
- Kan se laddarna på Scania.

När? 2022-02-17 ca 8:35 – 10:05

Var? Scania, by 106, piazzan (lunch/fikarum)

Vem? P (endast för egen referens)

Sammanställning av intervju

- Dröm om att resa omkring i främmande länder
- Arbetat som förare i 20 år
- Arbetade som förare för ett åkeri i 10 år mellan 21 – 31år ålder, men tröttnade då han kände att han stannade i utvecklingen.
- Han kände sig färdig med körandet, men hade sett att det fanns de som körde provbilar när han var ute på vägarna. Förstod att detta var provbilar i och med att de var anonyma och saknade företagens logga.
- Svårt att ta sig in på attraktiva positioner på Scania om man kommer utifrån. Sökte en tjänst som LP-förare, kallades på intervju, men fick den inte. Insåg att han skulle få tjänsten han sökte lättare om han redan var anställd på Scania.
- Började plugga när han inte kom in på Scania och av en händelse såg han då att Scania sökte hundratals montörer. Han fick jobb direkt.
- Jobbade på ett familjeföretag med ca 50 lastbilar. Körde styckegods (Europapall, kartonger och livsmedel)
- 9 timmars skift (totalt arbetsdag på ca 12 h)
- Vissa skift mer regelbundna och alltid på samma klockslag. Dock inte alltid det vanligaste.
- Utomlands är det lite mer ”vilda västern” när det kommer till arbetstider.
- Han körde i hela Europa.
- Vilka kör vilka sträckor? Det är ofta bråttom. Sträckorna kan bestämmas med kort varsel. Kan vara så att man befinner sig hemma när kontoret ringer och säger ”du ska till Budapest”. Det är väldigt spontant, snabba puckar, saker kan även ändras i sista minuten.
- Dålig planering! Inte helt ovanligt.
- Ansvar hos föraren: Föraren sköter tankningen/laddningen.
  Kan vara annat om det är bussgarage. Där har inte föraren samma typ av ansvar.
- Hur skulle du göra för att ladda lastbilen ekonomiskt: ladda på natten.
- Ofta obemannat på åkeri. Företaget han jobbade på var ett familjeföretag, så de hade hus på gården. Dock hände det att åkaren ringde andra och bad dem ordna saker.
- Jobb och fritid: sköter bilen som att man äger den. De flesta har samma lastbil hela tiden. Det händer att man byter eller lånar ut lastbil, men det är alltid till någon man litar på.
- Jobbet flyter ihop med fritiden. Kunde hända att man oroade sig för något kylaggregat skulle ha slutat fungera, så då åkte man dit och kontrollerade. De hade hänt att kylaggregat gått sönder. Åkeriet har ansvaret över varorna. Åkeriet vill dock ha självgående förare som är ”kapten” över sin bil. Ansvar lämnas ofta över på föraren, vilket kan leda till konflikter.
- (Åkaren = Ägaren)
- Ansvaret över ex. kylvaror är en del av jobbet, det kommer naturligt. Det som skulle hända om det inte var så är att åkaren skulle säga: ”den här killen håller inte måttet”.

Det skulle leda till att man blev mer styrd, vilket inte är önskvärt hos den här typen av förare. De vill ha mer intressanta uppdrag.

- Förarna kan ibland lösa/organisera bättre transporter än distributören. Det här ansvaret förs ofta över på förarna (indirekt). Företag som vill ha varor transporterade är kopplade till en distributör. Åkerier budar på transporter, ex. ”vi kan frakta för…”. Åkerierna konkurrerar främst på pris, det är oftast billigast som vinner.
- Samordning kan ske olika tider under dagen. Ibland sker det dagen innan. Samordning sker om åkeriet har flera vunna transporter och flera transporter ser ut att korsa varandra (nord- och sydgående riktning).
- Kunden har mycket makt. Åkeriet har ansvar att vara flexibla, men kravet på flexibilitet förs ofta över på föraren.
- Destruktivt med lastning efter transport, men föraren rättar sig efter de olika situationer som dyker upp, där man kan bli ombedd att lasta även fast det egentligen inte ingår i det huvudsakliga uppdraget.
- Tiden då man väntar på att få lasta av händer inte mycket. Använder tiden till att läsa osv, men det är stressigt att vänta. Det kan hända att man tankar under tiden.
- Idag finns knappt några laddningsmöjligheter. Det optimala vore att ha laddaren där man befinner sig. De näst bästa vore att hitta ett ställe där man kan ladda och parkera för natten, ex. vid en stormarknad.
- Undviker att tanka i dyra länder. Dyra länder är ex. Norge, Italien och Holland. Oftast tankar man innan man åker in i landet. Detta styr mestadels var och när föraren behöver tanka, när det kommer till utlandsresor. Om man ex. befinner sig i Italien så tankar man så att man klarar att ta sig ut.
- Beräkning av kostnader och sträckor (för att ta sig ut ur ett land) är något som föraren gör själv. Föraren förväntas göra detta. Kontoret pratar inte mycket med föraren. De märker dock hur stor ”sopparäkningen”, servicekostnader osv blir.
- Priset och föraren: Handlar mycket om arbetsmoral (psykologiskt). Det känns onödigt att betala mer. Att tanka billigt visar på att man är rätt person för jobbet.
- Åkaren har bra koll på förarna och bränslekostnader.
- Svårigheten med att ladda billigare är att man inte kan koppla i/ur, för det är oftast på natten när man sover som priserna är lägre.
- Kör och vilotider: Under natten sker inga spontana ryck, mycket ovanligt. Det är en bra tid att ha en laddningslösning som ser till att ladda billigt.
- Med tiden kommer laddtiden att sjunka och kapaciteten att öka, vilket gör att elpriskurvan förmodligen kommer att plattas ut. (Folk kommer bl. a. att ladda sina prylar osv. alla tider på dygnet).
- -Diskussion om GUI –
- Ha ”estimated” och ”current” bredvid varandra, som på en riktig tankstation (note: kolla hur detta ser ut…)
- Mest intressant att se hur lång tid det är kvar av laddningen.
- Om laddningen visar 91% och det är 30 min kvar kommer föraren att tänka: ”Jag har massa annat att göra, jag har ju inte tid att stå här”
- ”Stå 30 minuter för 9 procent… Ute på riktigt hade man blivit hispig”
- Reflektion: Minimum SOC är nog en säkerhetsgrej! Kan ske soppatork på grund av att det uppstår vågor i tanken. Pumpen dit man kommer kan också vara trasig, då är det bra att ha extra bränsle.

- En del kör aldrig under 50% (diesel). De vill undvika att det dyker upp tankningsbehov när man behöver köra.
- Om det är en planerad körning som uppfattas som stabil så behövs inte 50%.
- Bra med streck som separerar olika delar, jobbigt med mycket information där man inte vet vad som tillhör vad.
- Statistik: jobbigt att titta på. Upplevelsen är: ”nu måste jag tänka”. Också jobbigt med omvända datum (amerikanskt), jobbigt att ställa om och se vilket datum som är vilket. Grafen visar laddning men inte enhet vid grafen. Enheten är någon annanstans.
- Det som påverkar hur mycket bränsle som går åt/krävs är hur mycket last som finns, topografi och egen körning.
- Jobbigt med mycket grejer i en app. Det är säkert någon nördig som blir lycklig, men den skulle nog också störa sig på att det är fel på enheterna.
- Hur långt man kan åka är mer intressant.

Appendix C

This appendix shows inspirational photos of screens that were used during the interviews with LP-drivers and during the design process. The app screens were distributed on 28 different pages in a printed document.

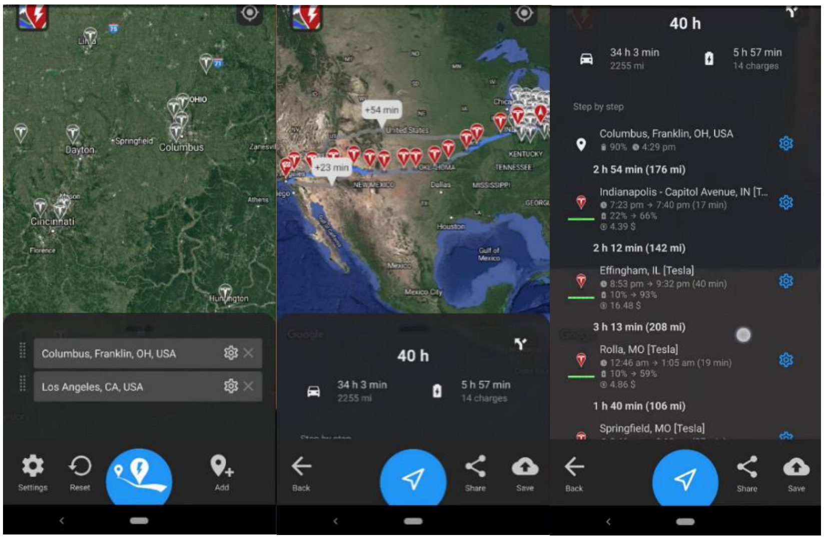

Figure C1. A better Routeplanner app in page 1

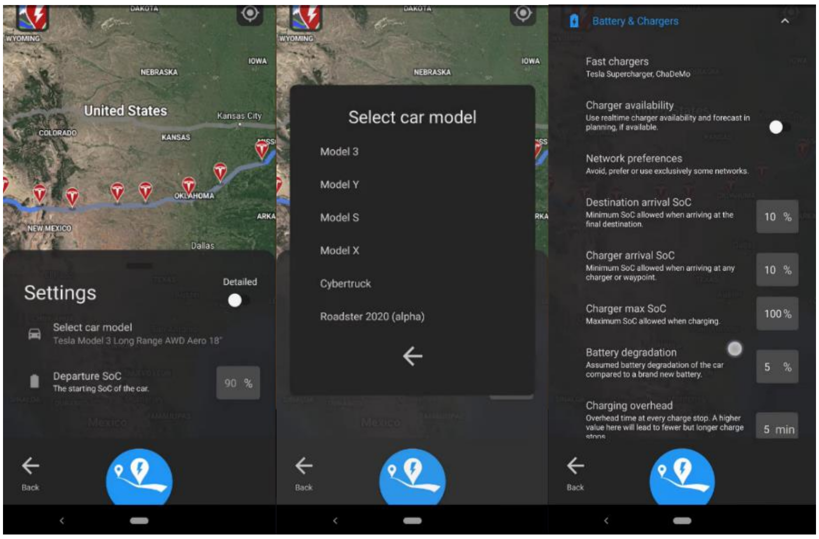

Figure C2. A better Routeplanner app in page 2

Figure C3. Tesla's Stats app in page 3

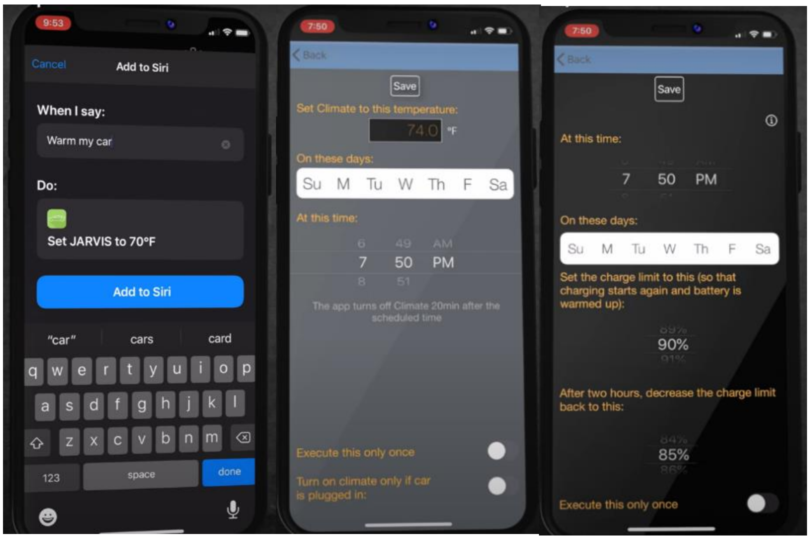

Figure C4. Tesla's Stats app in page 4

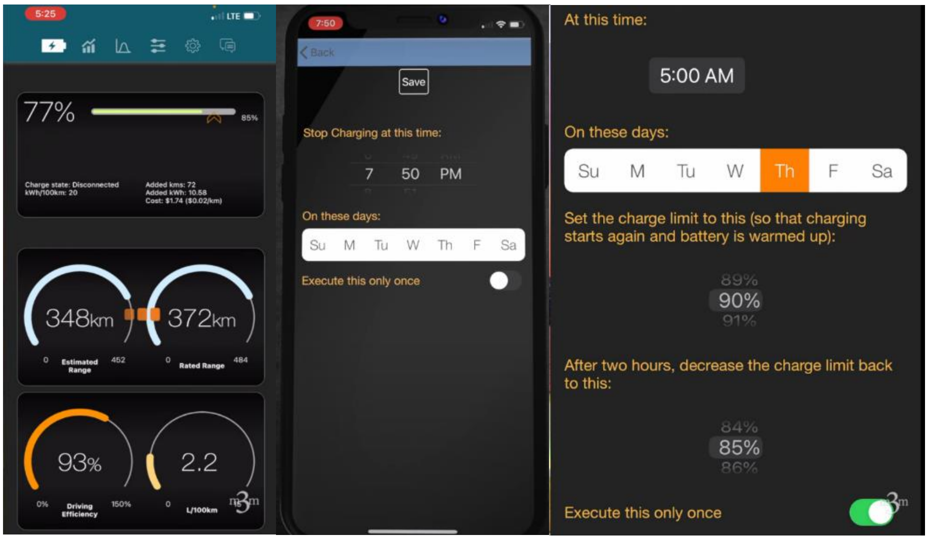

Figure C5. Tesla's Stats app in page 5

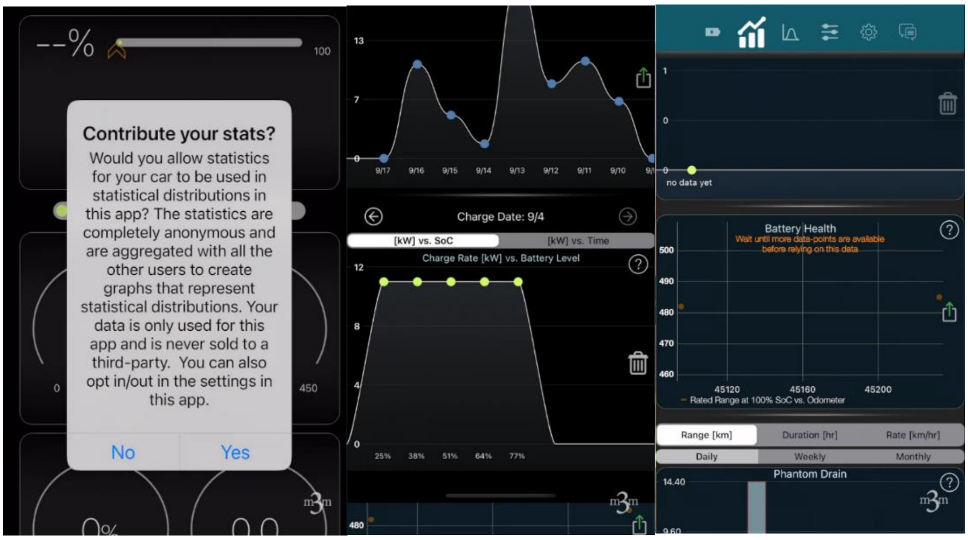

Figure C6. Tesla's Stats app in page 6

Figure C7. Tesla app in page 7

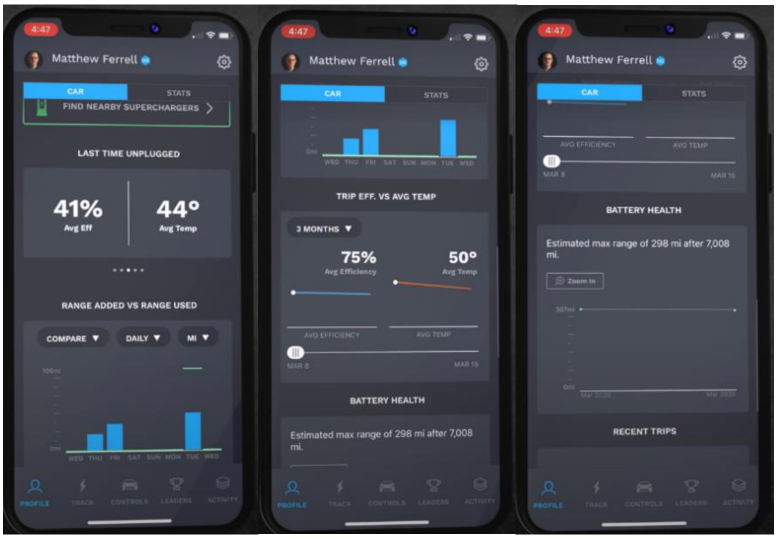

Figure C8. Tesla app in page 8

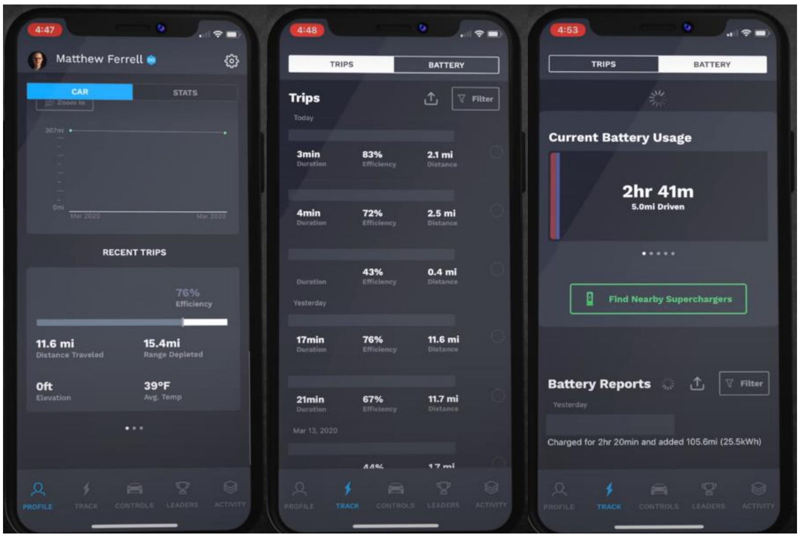

Figure C9. Tesla app in page 9

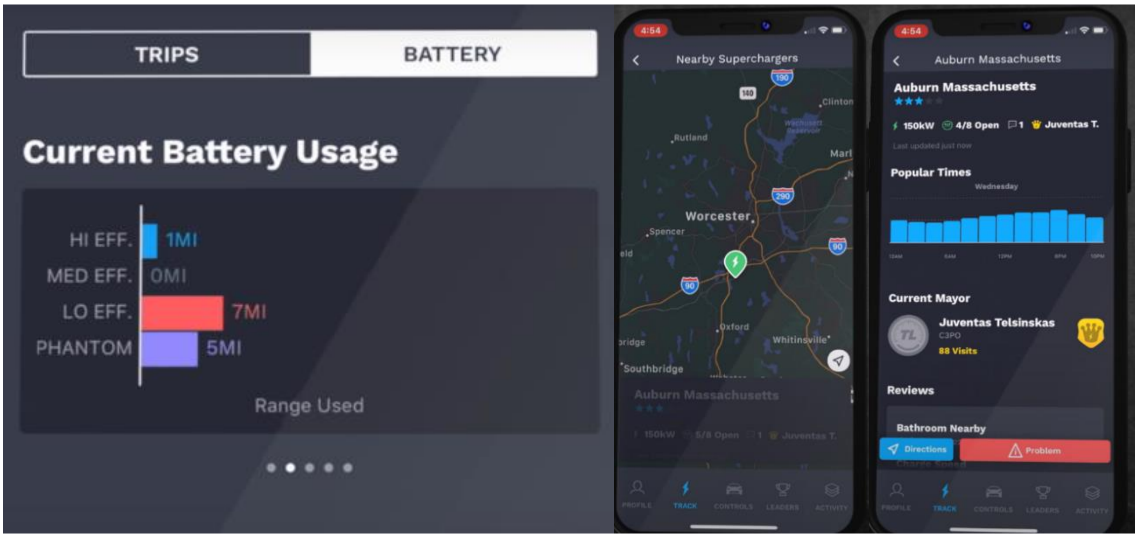

Figure C10. Tesla app in page 10

Figure C11. Tesla app in page 11

Figure C12. Tesla app in page 12

ä

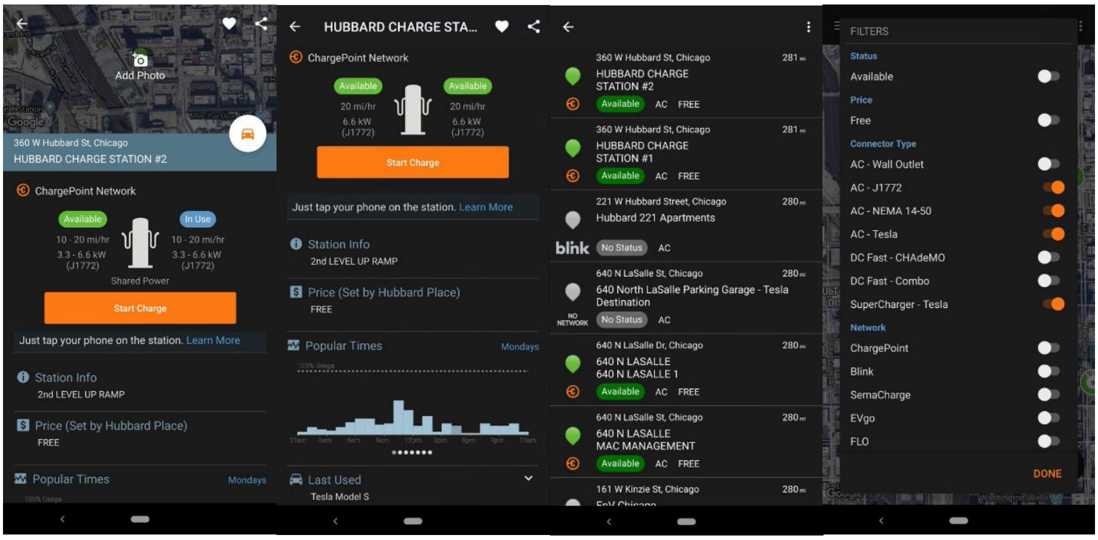

Figure C13. Chargepoint app in page 13 and 14

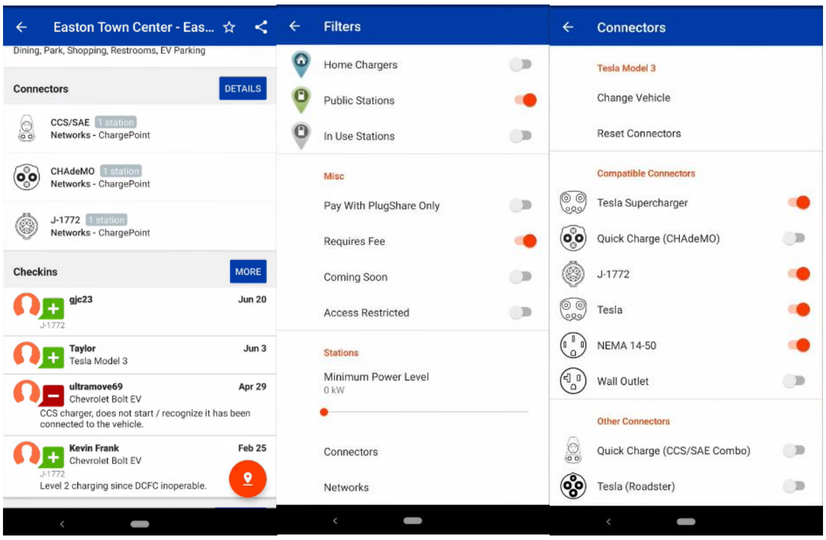

Figure C14. PlugShare app in page 15

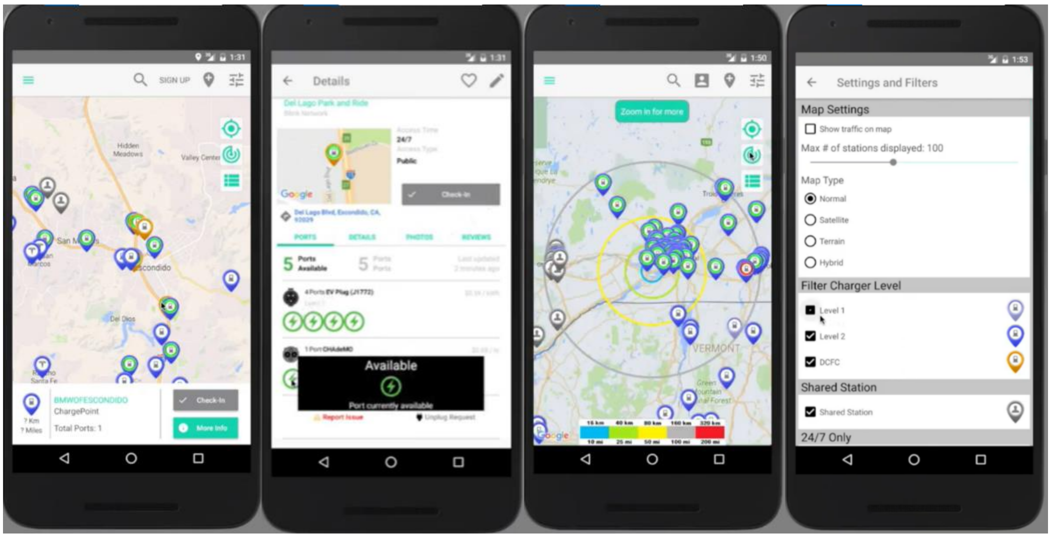

Figure C15. ChargeHub app in page 16

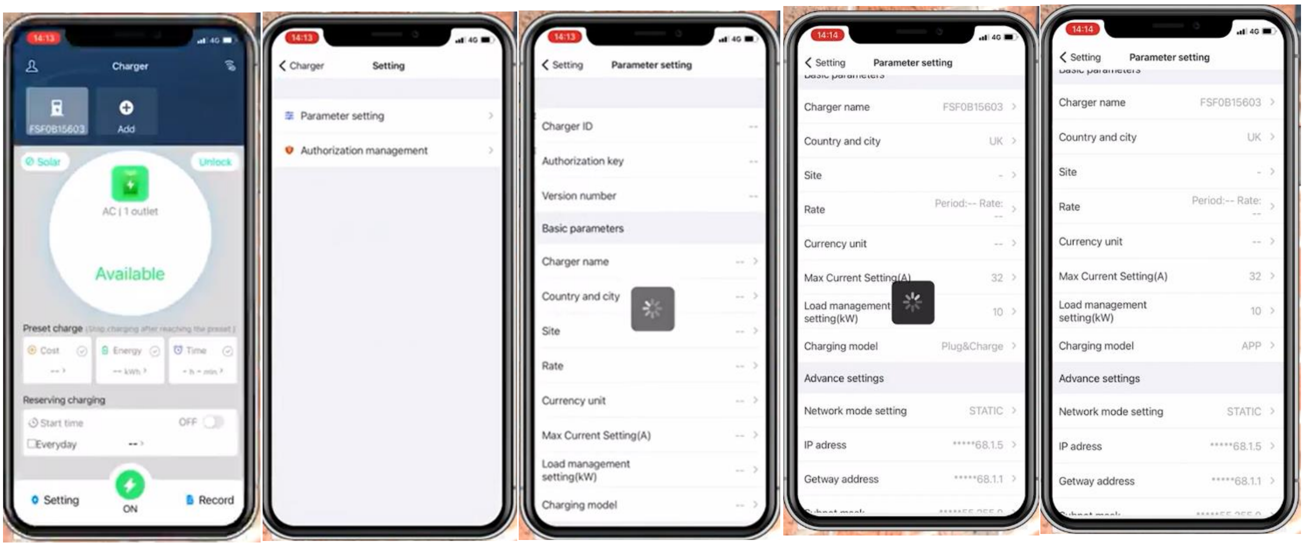

Figure C16. Project EV Free app in page 17 and 18

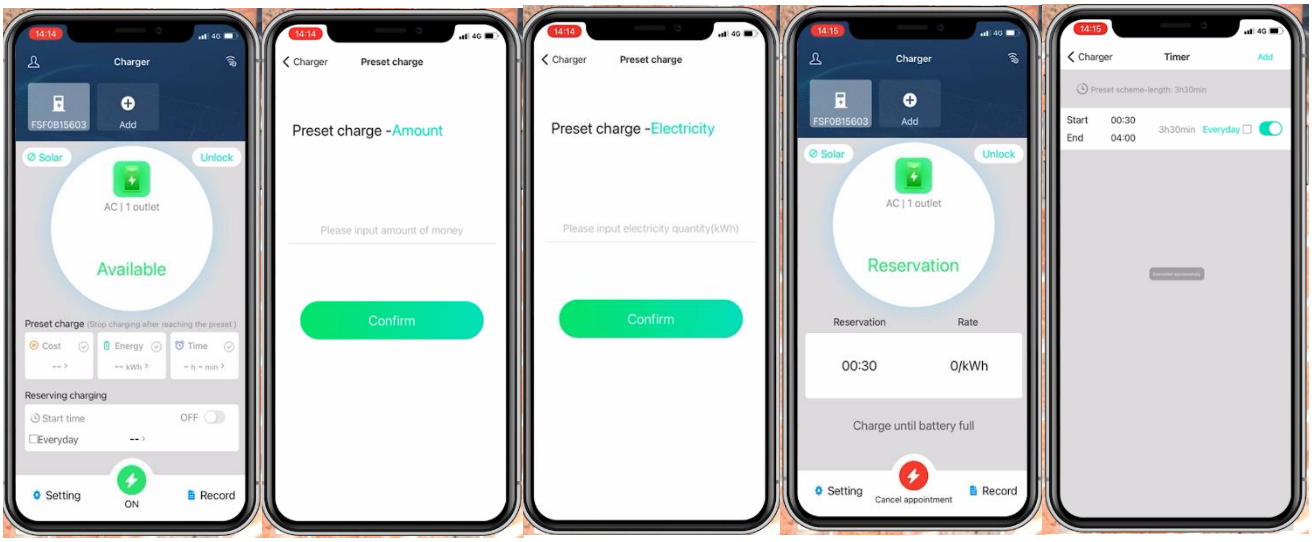

Figure C17. Project EV Free app in page 18 and 19

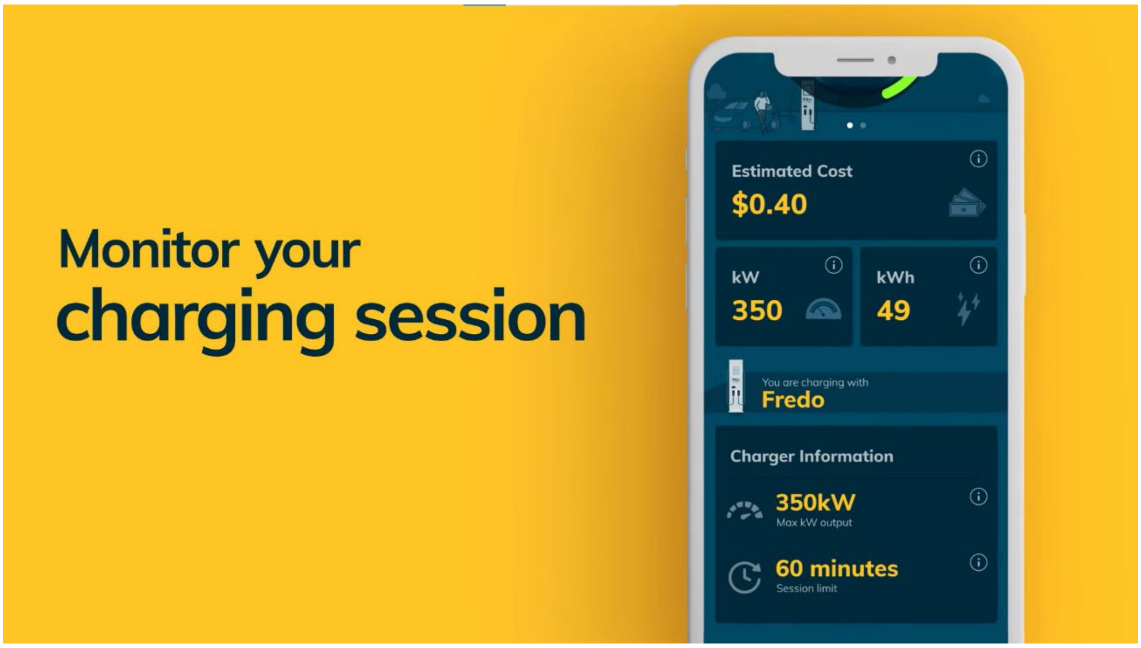

Figure C18. EVgo app in page 20

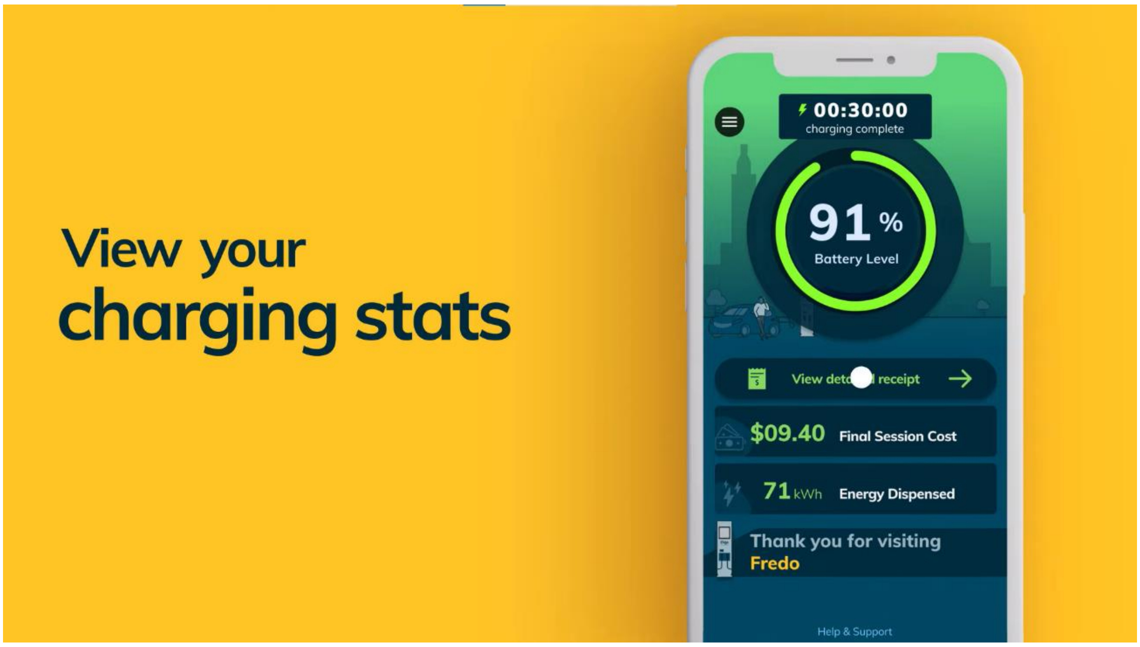

Figure C19. EVgo app in page 21

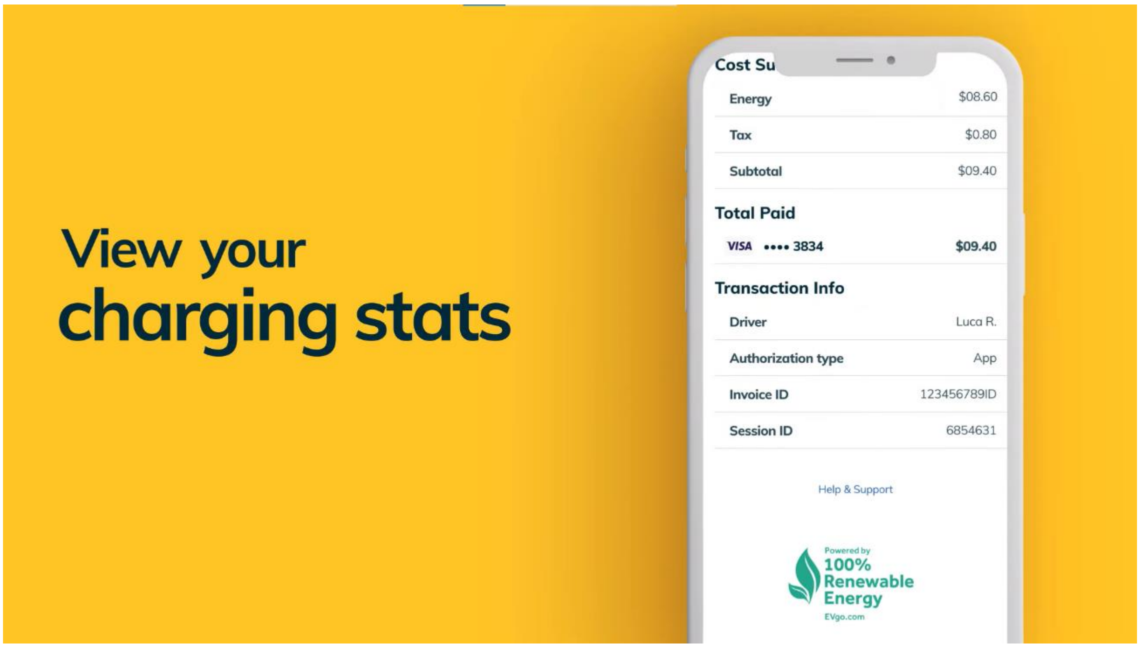

Figure C20. EVgo app in page 22

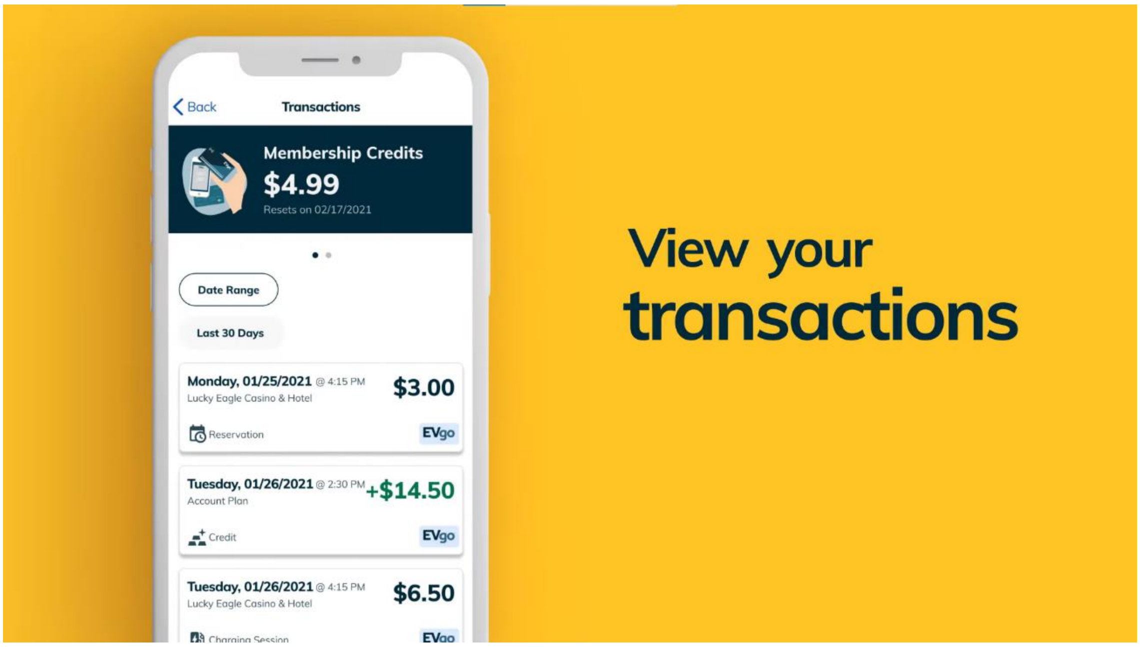

Figure C21. EVgo app in page 23

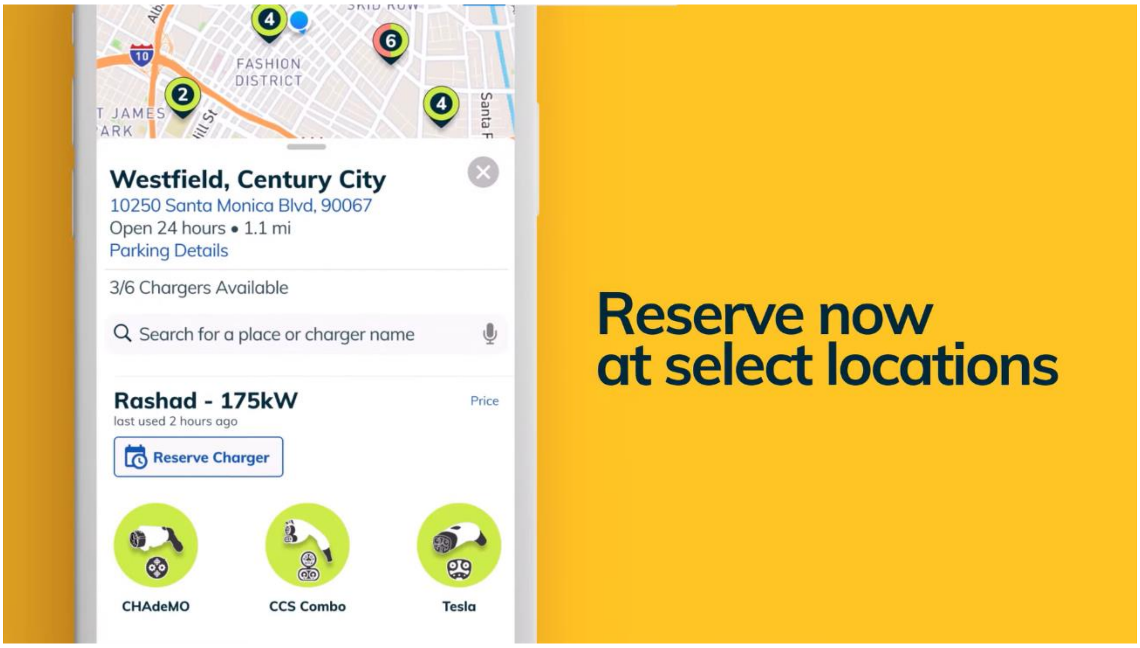

Figure C22. EVgo app in page 24

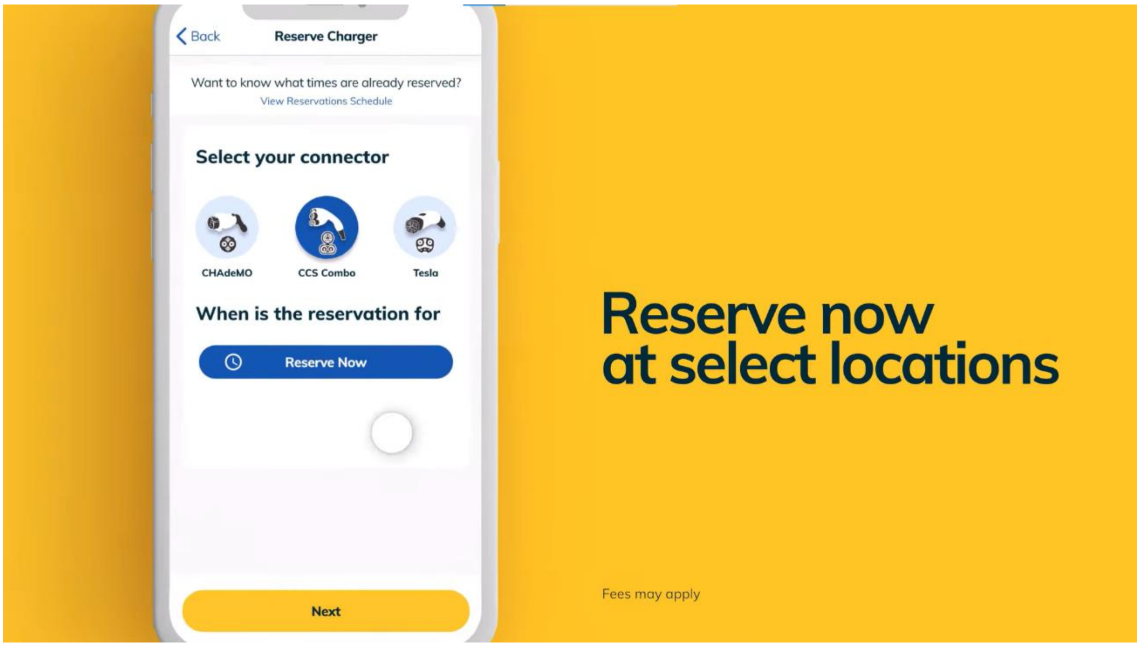

Figure C23. EVgo app in page 25

Figure C24. Chargeway app in page 26

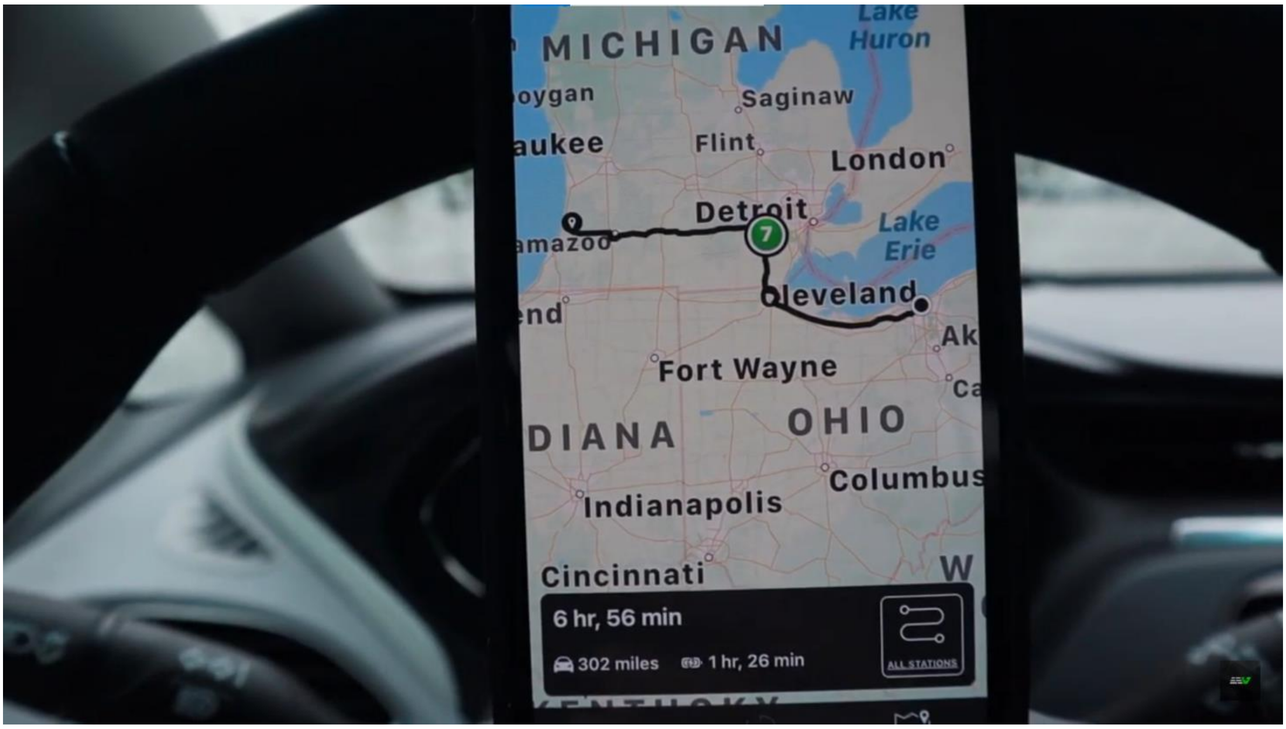

Figure C25. Chargeway app in page 26

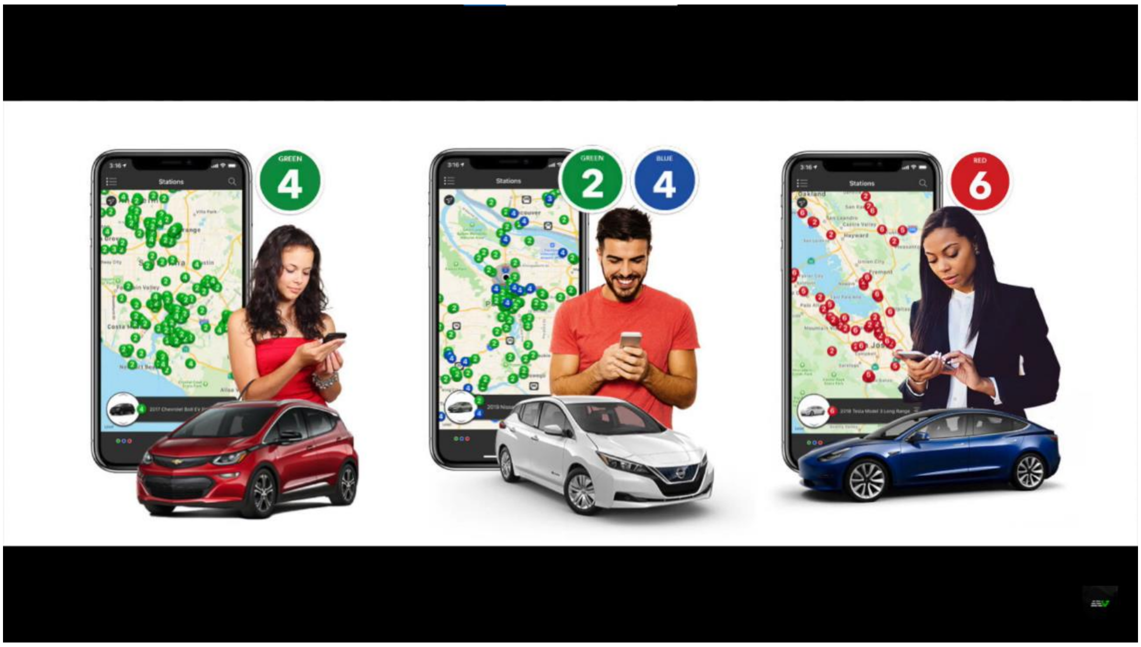

Figure C26. Chargeway app in page 27

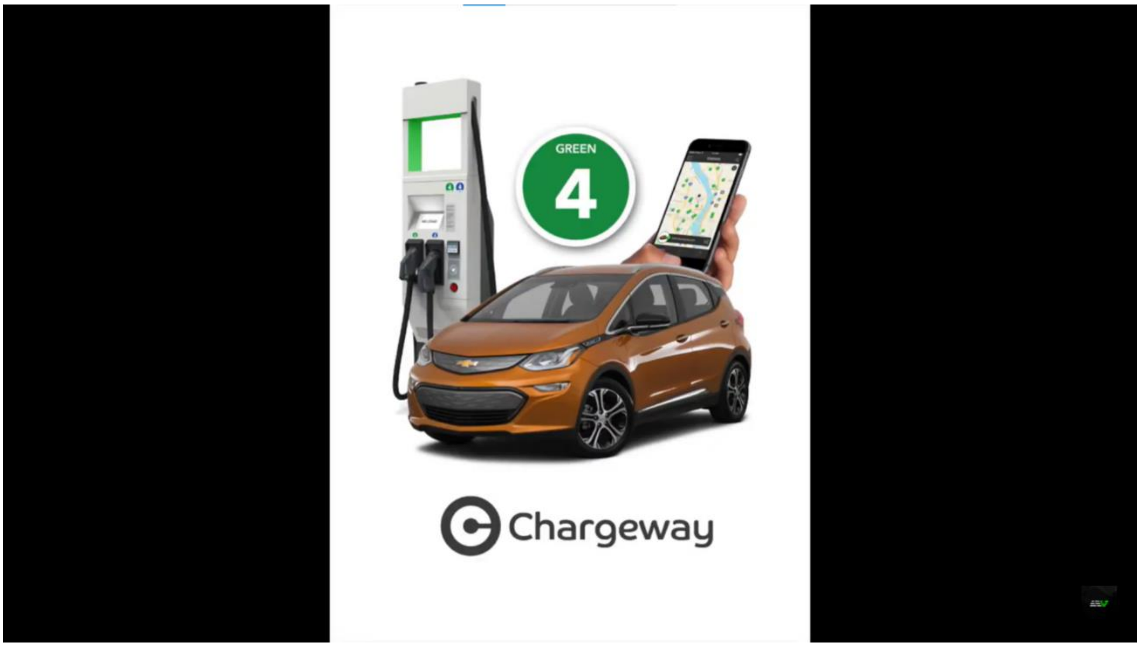

Figure C27. Chargeway app in page 28

Appendix D

This appendix consists of the deliverables for the integration part of the thesis. These deliverables are the same for both this thesis project and Xiaoying Sun's thesis project.

Deliverables

D1: Try out URI example and implement in project

May 13th , Christine: Implement tutorial and prepare for URI from Xiao

Xiao: Fix Reservation form submit problem on the back-end(Response 500 right now)

D2: Connect flutter application to server or get API

May 16th at the office, Xiao: Submit URI (Very Simple one, just test)

, Christine: Get the response (successful or non-successful connection, 200 or not)

D3: Test response body (Do we get a JSON file?

May 17th online , Xiao: Submit formal document on URI path + response body (Start + Stop + Heartbeat)

, Christine: figure out how to read response body (JSON), how to use it in flutter

D4: Test app with mobile phone

May 19th, Christine: Try with mobile phone (android)

D5: Test D3

Xiao and Christine: Test start, stop and heart beat. Open access to real charging stations (Before the server won't do anything when receive the Start/Stop request).

D6: Plan testing (physical)

Xiao and Christine: Write test plan with vehicle.

D5: First test with truck

May 24th , Xiao and Christine: Book one truck (the 24th of May) with low SOC, from 13:00-16:00

D6: Second test with truck

May 26th , Xiao: Give a pre-presentation to KTH supervisor and examiner. Book one truck (the 26th of May) with low SOC, from 13:00-16:00 (again)

Final deliverable: Something functional to continue building

Appendix E

This appendix shows the user requirements that were introduced after conducting user research. The requirements are not in any specific order, but may be referred to using their number in this list.

User Requirements

1. As a driver I need to be able to see when the vehicle is fully charged (100%), so that I know that I am finished charging and that the vehicle is ready.
2. As a driver I need to be able to see the current charge percentage, so that I know whether I have enough charge to continue my journey or so that I can plan a reasonable time of departure.
3. As a driver I need to be able to see how much time there is left before the vehicle is fully charged, so that I know when the vehicle will be ready for departure.
4. As a driver I need to be able to start charging the vehicle immediately, overriding scheduled plans, so that I can adapt to changing plans.
5. As a driver I need to be able to terminate the ongoing charging session, so that I can adapt to changing plans.
6. As a driver I need to be able to set a manual time for charging, so that the vehicle is charging according to my preferences.
7. As a driver I need to be able to view costs from previous sessions, so that I can see the expenses over time.
8. As a driver I need to be able to view the estimated and total cost of charging, so that I am sure that the price is reasonable.
9. As a driver I need to be able to charge cheaper without already knowing anything about the costs, so that I am not fully responsible for the charging expenses.
10. As a driver I need to be able to see how many kW, so that I can get some indication of the state of the charging session.
11. As a driver I need to be able to see how many kWh, so that I know how much energy has been dispensed.
12. As a driver I need to be able to see scheduled charging sessions, so that I can plan charging activities.

13. As a driver I need to know what the current charging solution is, so that I know that I have chosen the right one.

14. As a driver I need a notification when an error occur, so that I can address the issue immediately.

15. As a driver I need information about what error has occurred, so that I know what action to take.

16. As a driver I need information about the latest charging session if an error has occurred, so that I can determine whether the battery will last.

17. As a driver I need to be able to set reoccurring charging sessions, so that I do not have to set charging manually every day.

18. As a driver I need to be able to view the current state of charging process, so that I know if everything is going according to plan.

19. As a driver I need to be able to view which charger I am connected to, so that I know that I am connected to a charger.

20. As a driver I need to be able to charge my vehicle close to departure, so that the vehicle is warm in case it is cold outside.

21. As a driver I need to be able to view the prices for the following day, so that I can easily confirm that the scheduled charging session is reasonable or set my own charging session manually.

22. As a driver I need to be able to see the SOC at different times, so that I can decide when I have enough battery to continue my journey.

Appendix F

This appendix shows some of the source code. The URIs used in this project have been hidden with ***.

F1: Plan screen

```
import 'dart:async';

import 'dart:convert';


import 'package:flutter/material.dart';

import 'package:http/http.dart' as http;


class Plan extends StatefulWidget {

  const Plan({Key? key}) : super(key: key);


  @override

  _PlanState createState() => _PlanState();

}


class _PlanState extends State<Plan> {


  Future<void> getDataStart() async {

    var res = await http.get(Uri.parse('http://***/dayPrice'));

    //For testing with vehicle:

    // var res = await http.get(Uri.parse('http://***/api/start'));

    print("start");

   // print(res.body);
```

```
}

Future<void> getDataStop() async {
  var res = await http.get(Uri.parse('http://***/api/heartbeat/1'));
  //For testing with vehicle:
  //var res = await http.get(Uri.parse('http://***/api/stop'));
  print("stop");
  //print(res.body);
}

get optionStyle => null;

@override
Widget build(BuildContext context) {
  return Column(
    children: [
      Text(
        'Index 1: Plan',
        style: optionStyle,
      ),

      Text(
        ' ',
        style: optionStyle,
      ),
```

```
        ElevatedButton(
            onPressed: getDataStart,
            child: const Text('Start charging')),
        ElevatedButton(
            onPressed: getDataStop,
            child: const Text('Stop charging')),
      ],
    );
  }
}
```

F2: Charger screen

```
import 'dart:async';
import 'dart:convert';

import 'package:flutter/material.dart';
import 'package:http/http.dart' as http;

Future<Album> fetchAlbum() async {
  final response =
      await http.get(Uri.parse('http://***/api/heartbeat/0'));

  if (response.statusCode == 200) {
    // If the server did return a 200 OK response,
    // then parse the JSON.
    return Album.fromJson(jsonDecode(response.body));
  } else {
    // If the server did not return a 200 OK response,
    // then throw an exception.
    throw Exception('Failed to load album');
```

```
  }
}

class Album {

  final int id;
  final int? connectorid;
  final String timeStamp;
  final String status;
  final String errorCode;

  const Album({
    required this.id,
    required this.connectorid,
    required this.timeStamp,
    required this.status,
    required this.errorCode,
  });

  factory Album.fromJson(Map<String, dynamic> json) {
    return Album(
      id: json['id'],
      connectorid: json['connectorid'],
      timeStamp: json['timeStamp'],
      status: json['status'],
      errorCode: json['errorCode'],
    );
  }
}
```

```
class Charger extends StatefulWidget {
 const Charger({Key? key}) : super(key: key);

 @override
 _ChargerState createState() => _ChargerState();
}

class _ChargerState extends State<Charger> {
 Future<Album>? futureAlbum; //added from main.dart

 get optionStyle => null;

 @override
 void initState() {
  super.initState();
  futureAlbum = fetchAlbum();

 //Add above for Album2
 }

 @override
 Widget build(BuildContext context) {
  return Column(
   children: [
    Text(
     'Index 0: Charger',
     style: optionStyle,
    ),
    Text( ' ', style: optionStyle,),
    Text( ' ', style: optionStyle,),
    Text( 'Time stamp from heartbeat URI: ', style: optionStyle,),
```

```
        FutureBuilder<Album>(
            //add if-statement about selectedindex...
            future: futureAlbum,
            builder: (context, snapshot) {
              if (snapshot.hasData) {
                return Text(snapshot.data!.timeStamp);
              } else if (snapshot.hasError) {
                return Text('${snapshot.error}');
              }
              // By default, show a loading spinner.
              return const CircularProgressIndicator();
            },
          ),
      ],
    );
  }
}
```

F3: Main

```
import 'package:flutter/material.dart';

import 'charger.dart';
import 'plan.dart';
import 'costs.dart';

void main() => runApp(const MyApp());

class MyApp extends StatefulWidget {
  const MyApp({Key? key}) : super(key: key);

  @override
  _MyAppState createState() => _MyAppState();
```

```
}

class _MyAppState extends State<MyApp> {
 // late Future<Album> futureAlbum;
  //Added by me below
  int _selectedIndex = 0;
  static const TextStyle optionStyle =
      TextStyle(fontSize: 30, fontWeight: FontWeight.bold);
  static const List<Widget> _pages = <Widget>[
    Charger(),
    Plan(),
    Text('Cost screen'),
    Text(
      'Index 3: Profile',
      style: optionStyle,
    ),
  ];

  void _onItemTapped(int index) {
    setState(() {
      _selectedIndex = index;
    });
  }

  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      // Hide the debug banner
      debugShowCheckedModeBanner: false,
      title: 'Fetch Data Example',
      theme: ThemeData(
```

```
  primarySwatch: Colors.blue,
),
home: Scaffold(
  appBar: AppBar(
    backgroundColor: const Color.fromARGB(255, 8, 63, 37),
    title: const Text('Scania Smart Charge'),
  ),
  body: Column(
    //Center(
    children: [
      IndexedStack(
        index: _selectedIndex,
        children: _pages,
      ),
    ],
  ),
  bottomNavigationBar: BottomNavigationBar(
  type: BottomNavigationBarType.fixed,
  selectedLabelStyle: const TextStyle(
      fontWeight: FontWeight.bold), //to allow more than 3 items
  items: const <BottomNavigationBarItem>[
    BottomNavigationBarItem(
      icon: Icon(Icons.charging_station),
      label: 'Charger',
    ),
    BottomNavigationBarItem(
      icon: Icon(Icons.edit_calendar),
      label: 'Plan',
    ),
    BottomNavigationBarItem(
      icon: Icon(Icons.data_exploration),
```

```
          label: 'Costs',
        ),
        BottomNavigationBarItem(
          icon: Icon(Icons.person),
          label: 'Profile',
        ),
      ],
      currentIndex: _selectedIndex,
      selectedItemColor: const Color.fromARGB(255, 3, 165, 57),
      onTap: _onItemTapped,
    ),
    ),
   );
  }
}
```