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Synergy Unleashed - Creating an integrated electric vehicle charging service for drivers' seamless customer experience

An Optimized EV Charging Experience

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Looking ahead, I am eager to continue contributing to the interaction design field, undertaking more inspiring research and design endeavors.

Chiapei Lai

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Abbreviations

EV
Electric Vehicle

EMSP
E-Mobility Service Provider

CPO / CSO
Charging Point Operator / Charging Station Operator

OEM
Original Equipment Manufacturer

BEV
Battery Electric Vehicle

PHEV
Plug-in Hybrid Electric Vehicle

FCEV
Fuel Cell Electric Vehicle

AC
Alternating Current

DC
Direct Current

CX
Customer Experience

LOS
Level of Service

HMI
Human-machine Interaction

SoC
State of Charge

SoH
State of Health

Executive Summary

Project Objectives

This project aims to improve the EV charging experience in the Netherlands due to the growing European EV market and rising Battery Electric Vehicle (BEV) driver expectations of their charging experience. Despite standardization efforts, fragmented charging services developed in siloed business lead to user inconvenience. It is imperative to identify the reasons behind drivers' less-than-ideal customer experiences and address them to support the transition to electric cars. Thus, this study represents a collaboration between VanBerlo, TU Delft, and KAIST to address the initial question:

> ***"What are the primary challenges and limitations experienced by Dutch BEV drivers that impede a seamless customer experience when using public charging infrastructure?"***

Research Gap and Design Goal

To address this, a literature review is first conducted. Two research gaps arise. First, empirical research concerning the entire user charging journey and service integration is lacking. Additionally, more influential factors should be identified while predicting user preference of charging decision. To bridge the gaps, semi-structured interviews is carried out to examine the journey from charging intent to completion and explore factors influencing driver decisions. User pain points are clustered into a journey map, revealing three main challenges hindering the seamless charging experience. The research suggests that addressing these challenges during planning phase can streamline the overall journey. Thus, the design goal is:

> ***"How might we design an effortless planning phase that adapts to user needs and contextual factors, ensuring a seamless public charging experience for BEV drivers."***

The concept and the Value Proposition

Based on literature and qualitative research, a route and charger suggestion service is proposed to enhance the overall charging experience. The mechanism behind the scenes is first outlined. Subsequently, five design guidelines are developed to inspire the creation of this new service, providing application strategies for potential service developers such as vehicle manufacturers and E-Mobility service providers (EMSPs). Moreover, interactive prototypes are created as a tool to validate the concept. At its core, this concept integrates factors from the vehicle, charging network, user behavior and preferences, as well as road and environmental conditions to deliver personalized and optimal charger suggestions in real-time. This minimizes cognitive effort, enabling informed and efficient charging decisions while driving, and ensuring compatibility between chargers, BEVs, and user preferences.

Validation and Future Recommendation

After creating the concept and prototypes, validation was conducted in person with several previous BEV drivers participating in the interview section, along with some experts. Feedback was collected through concept demonstrations, focusing on whether it aligns with the design goal and how BEV drivers perceive the new planning experience. The audience responded positively. Compared to the current fragmented planning experience, a more effortless route planning and charger selection process was validated, and users appreciated the context-aware service that made their charging experience relevant. However, further research is essential to gauge real-world feasibility by consulting stakeholders in the EV charging ecosystem. Additionally, exploring what other influential factors out there and how developers weighted them differently based on user preferences and situations is recommended.

Introduction

Project Background

The widespread adoption of Electric Vehicles (EVs) is pivotal in government efforts to reduce greenhouse gas emissions and meet climate goals (LaMonaca & Ryan, 2022). Recent legislation, exemplified by the 'Fit for 55' package from the Council of the European Union, has spurred governments and manufacturers to implement policies fostering EV sales growth across Europe. This legislation introduces stricter CO2 emission standards, aiming to eliminate CO2 emissions from new cars and vans by 2035, bolstering the European EV market. In 2022, European countries boasted 4.4 million BEVs and 3.4 million plug-in hybrid electric vehicles (PHEVs) on their roads, marking a 40% increase in EV sales compared to 2021 (Abo-Khalil et al., 2022; IEA, 2023b)

Conforming to this legislation, the Dutch government claimed a 35% share of the new electric car sales market in Europe in 2022. Publicly accessible EV chargers are pivotal for facilitating wider EV adoption and ensuring convenience comparable to refueling conventional vehicles (IEA, 2023a). The Netherlands boasts the highest number of EV charging infrastructure in the EU, with 128,581 slow chargers and 5,207 fast chargers as of April 2023 (Incentives and legislation, 2023). However, despite the high density of charging infrastructure, users' simple goal of having fully charged EVs ready for use faces challenges due to the complex nature of the evolving charging market (Eider et al., 2017). Decentralization of charging providers and an unregulated charging system hinder drivers' ability to easily locate and access chargers, impacting user convenience and customer experience (CX) (Eider et al., 2017; Figenbaum et al., 2022). Even in a mature Norwegian market, users must interact with numerous apps and navigate through multiple payment systems to access chargers. Different connector types, power levels, and charger interfaces further complicate the experience for drivers (Figenbaum et al., 2022).

Despite efforts by governments and organizations to address this issue, empirical research on consumer experiences and charging service interoperability is scarce (Hardman et al., 2018). Existing research often focuses on strategies of infrastructure allocation, quantitative research of charging behavior data among EV users, or investigations of stakeholder interests and conflicts within the charging ecosystem. Some studies also research user acceptance of smart charging technologies (Talantsev, 2017; Wolbertus et al., 2020; Brey et al., 2021; Figenbaum et al., 2022). However, these studies often overlook user-centric factors and the need for holistic integration throughout the charging journey. This research gap emphasizes the necessity for a comprehensive approach that considers the holistic user experience and ensures seamless integration at every stage of the charging process.

Therefore, this thesis examines seamlessness from the initial intention to charge until the completion of the charging event. The target audience is BEV drivers, as they rely more on public charging infrastructure. As end users increasingly expect convenience, ease of use, and autonomy with EVs, understanding factors causing friction in the customer experience is crucial to support the transition to electric cars. The initial research question for this project is:

"What are the primary challenges and limitations experienced by Dutch BEV drivers that impede a seamless customer experience when using public charging infrastructure?"

Project Structure & Chapter overview

There are four main steps of this project: Discover (Chapter 1), Define (Chapter 2 & 3), Develop & Refine (Chapter 4 & 5), and Finalize (Chapter 6 & 7), which is illustrated in Figure 1. The original project brief can be found in Appendix A.

During the "Discover" phase, a contextualization of the EV industry is carried out to gain deeper understanding of the wicked problem of EV adoption, which in turn helps narrow the project's focus to the public charging experience of BEV drivers. Then, in the “Define” phase, the literature review is conducted to support the user needs of a seamless charging experience, figure out the mismatch between current services and user expectations, and mentioned relevant strategies, which is potentially able to enhance the charging experience, proposed by previous studies. A research gap is emerged within this section: almost no previous empirical studies have taken a macro perspective to examine the reasons behind a non-seamless charging journey. Among the limited studies that aim to enhance seamlessness, there is a lack of consideration for the real-world context that end-users consider when making decisions. Thus, qualitative research is conducted to fill this gap.

After formulating the User Journey Map to organize the user pain points and needs, three bottlenecks of a seamless public charging experience and the influential factors within the charging event context emerge. The research suggests that addressing these challenges during route planning and charger selection can streamline the overall journey. Thus, the project enters the “Develop & Refine” phase with the following design goal:

“How might we design an effortless planning phase that adapts to user needs and contextual factors, ensuring a seamless public charging experience for BEV drivers?”

In this phase, a ***Context-Aware Service Model Streamlining the Planning Phase of an EV Charging Journey*** is proposed to enhance the overall charging experience. Following that, five design guidelines are established to inspire the development of this innovative service, offering practical strategies for potential service developers like vehicle manufacturers, charging point operators (CPOs), and E-Mobility service providers (EMSPs). Additionally, interactive prototypes are crafted to verify the concept's viability. This concept incorporates elements from the vehicle, charging network, user behavior and preferences, as well as road and environmental conditions, to provide personalized and real-time charger recommendations. This simplifies decision-making, allowing informed and efficient charging choices while driving, and ensuring charger compatibility with both BEVs and user preferences.

In the “Finalize” section, the concept is validated with several previous participants of the interview session and experts. By gathering their feedback, the study aims to provide valuable guidance for potential service providers and policymakers to develop similar solutions in the future. The recommendations are also elucidated in the final chapter, offering future research directions for further implementation of this concept in real-world scenarios.

Introduction

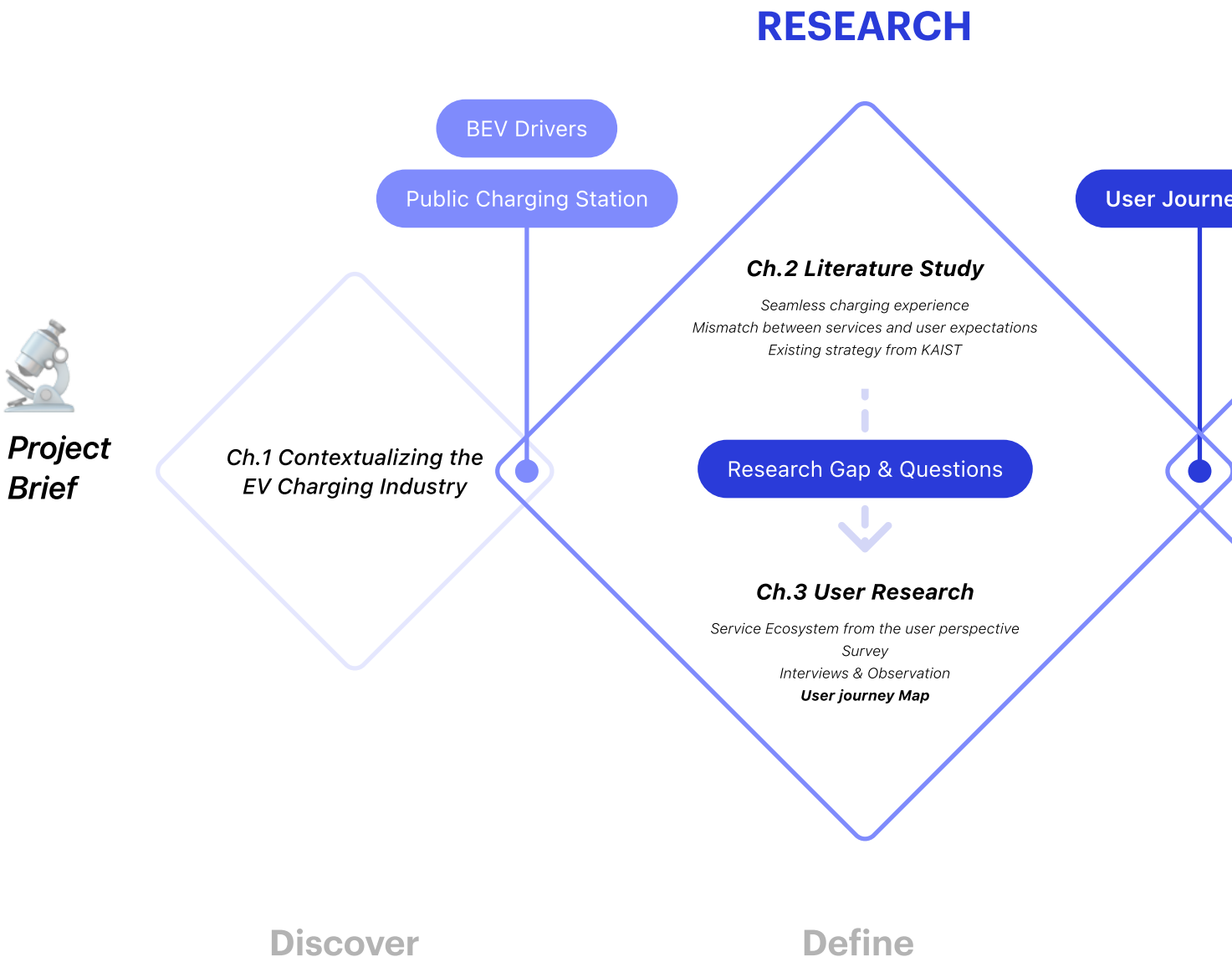

Figure 1. The project structure.

DESIGN

ey Map

Design Guideline &
The Concept

Ch.4 Design Focus

Design Goal
Design Guidelines

Ch.5 Strategies to apply the guidelines

Selected scenarios
Concepts & Strategies
Prototypes for validating the strategies

Ch.6 Validation
Ch. 7 Conclusion &
Recommendation



Graduation !

Develop & Refine

Finalize

Project Overview

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Appendix

Contextualizing the EV Charging Industry

Intro

This chapter delves into Battery Electric Vehicle (BEV) ownership and charging infrastructure deployment, with a primary focus on the European market, particularly the Netherlands. It starts by examining the policy landscape contributing to the rapid BEV market expansion. Subsequently, the chapter presents statistical insights into BEV adoption and ownership, providing an overview of the current market status. Recognizing the crucial role of charging infrastructure in driving BEV adoption, the chapter also explores charging behavior data from EV drivers. The chapter concludes by emphasizing the need to optimize the public charging station experience, setting a clear research direction for **improving BEV drivers' public charging experience.**

Chapter Overview

1.1 The policy incentives
1.2 BEV ownership
1.3 The Charging Infrastructure
1.4 Conclusion



Discover

01

1.1 The Policy Incentives

The necessity of transitioning the transport sector towards greener alternatives has become increasingly apparent. Since passenger cars and light commercial vehicles alone accounts for 15% of total EU emissions of CO2 (refer to Figure 2), the Council of the European Union toughen the regulation of CO2 emission standards for cars and vans (Fit For 55, 2023). The targets set by the new regulation in 2023 include a 55% reduction in CO2 emissions for new cars and a 50% reduction for new vans between 2030 and 2034 compared to 2021 levels. Furthermore, from 2035 onwards, both new cars and vans are expected to achieve a complete elimination of CO2 emissions. From 2025 through the end of 2029, a regulatory incentive program will be in place to encourage the adoption of zero- and low-emission vehicles (ZLEV). Under this program, manufacturers can qualify for more lenient CO2 emission targets if they meet specific sales targets for eco-friendly vehicles ('Fit for 55': Council Adopts Regulation on CO2 Emissions for New Cars and Vans, 2023). Therefore, whether it is government's complying with the EU Fit for 55 package (Fit For 55, 2023) or car manufacturers themselves, this policy compels and motivates them to increase the sales of electric vehicles in their respective countries and markets.

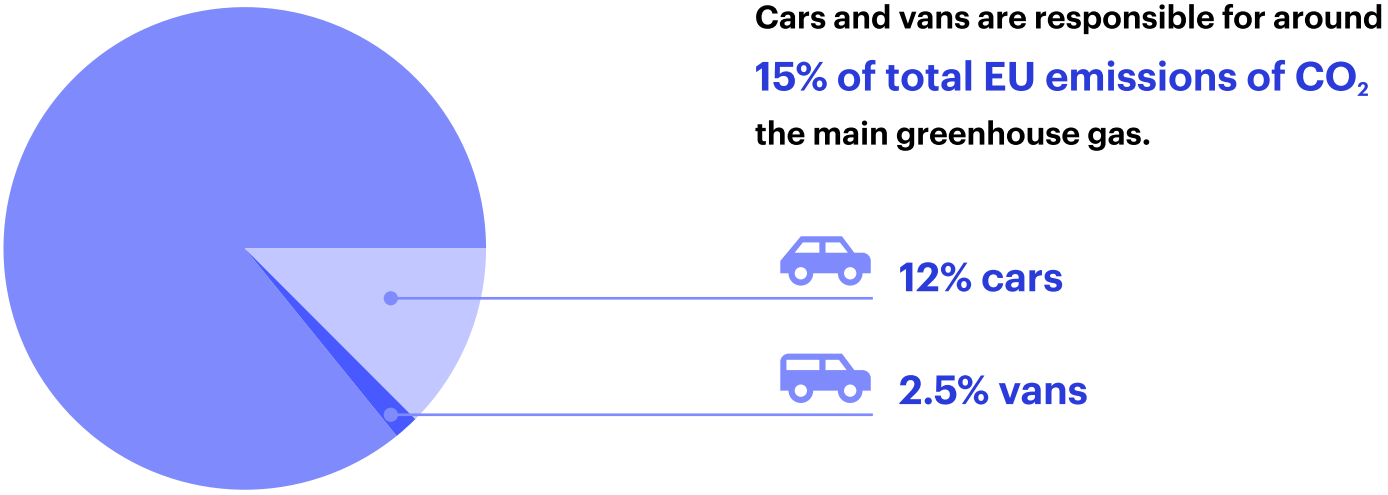


Figure 2. Passenger cars and light commercial vehicles alone accounts for 15% of total EU emissions of CO2 (Revised from Fit For 55, 2023).

1.2 BEV Ownership

1.2.1 EV market in Europe

It is evident that the European EV market is steadily growing. According to the IEA's Global EV Outlook for 2023, **Europe had a total of 4.4 million BEVs** and 3.4 million PHEVs on the roads in 2022, marking a 40% increase in the total EV stock compared to 2021. (See figure 3) Europe maintained its position as the world's second-largest electric car market after China, accounting for 25% of global sales and 30% of the total electric car stock. Leading European countries in EV sales included Norway (88%), Sweden (54%), the Netherlands (35%), Germany (31%), the United Kingdom (23%), and France (21%) in 2022.

1.2.2 Dutch ambition and realization of EV adoption

Despite the Netherlands being one of the leading European countries in EV sales, there is a need for additional efforts from the Dutch government to meet the objectives outlined in the environmental agreement. The first objective aims for '50% of all new passenger cars sold to have an electric powertrain and plug'. The second goal is for 'at least 30% of these vehicles (equivalent to 15% of the total) to be zero-emission (BEV or FCEV) (Green Deal on Electric Transport 2016-2020 (Green Deal 198) – Policies - IEA, n.d.). However, the current statistics indicate that the overall sales of electric vehicles (including BEV, PHEV, and FCEV) only account for 40.3% of total passenger car sales. Moreover, the percentage of zero-emission vehicles (BEV or FCEV) is only 26.51% (Electric Vehicles Statistics in the Netherlands, 2023). These data indicate that **reaching the 2030 target of 100% zero-emission vehicles for all new passenger car sales still remains challenging.** It is evident that further measures and initiatives are necessary to accelerate the adoption of electric vehicles and achieve the ambitious goal set for a greener transportation sector in the Netherlands.

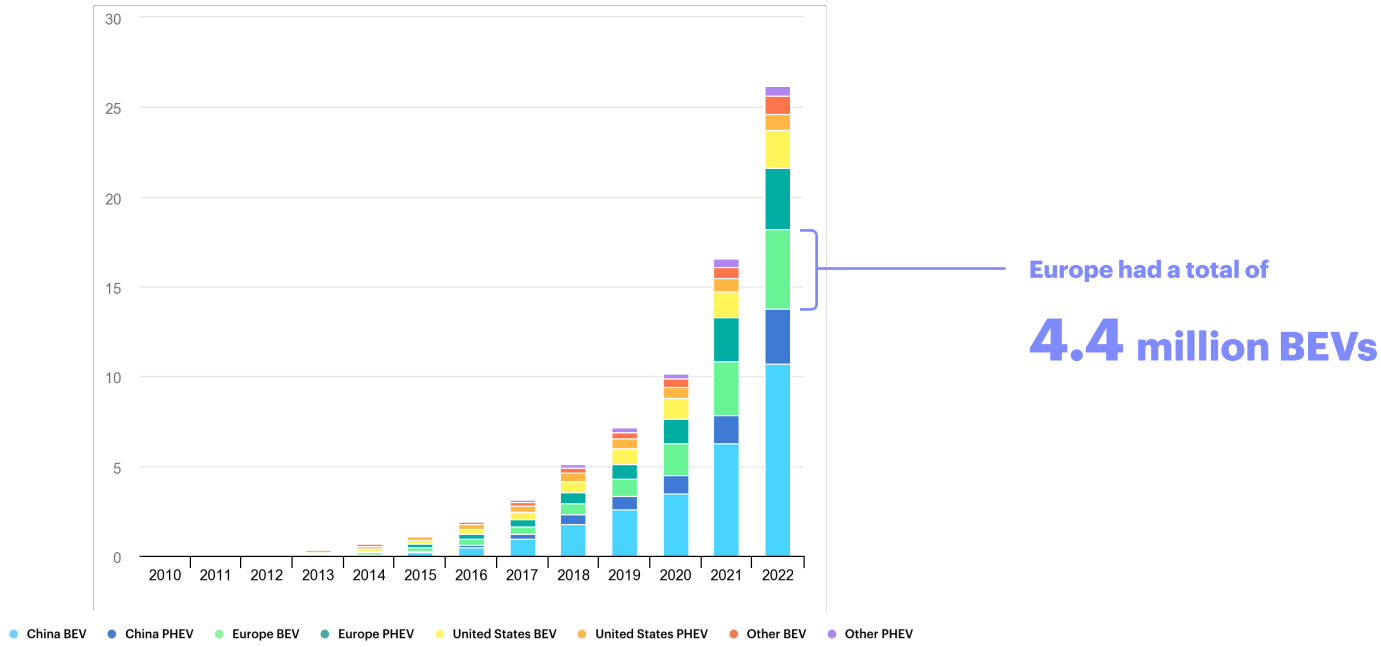


Figure 3. Global electric car stock, 2010-2022 (Global EV Outlook 2023 – Analysis - IEA, n.d.) .
**In "Europe", European Union countries, Norway, and the United Kingdom account for over 95% of the EV stock in 2022; the total also includes Iceland, Israel, Switzerland, and Turkey.*

1.2.3 The EV adoption and driver's ownership in the Netherlands

Within the total sales of alternative cars, **BEV accounted for the largest portion in the market** (Figure 4). According to the April 2023 report from the Netherlands Enterprise Agency, the number of BEV passenger cars in the country's fleet saw an increase to 362,739. In terms of new sales, there were 8,257 BEV passenger cars sold, accounting for a monthly market share of 28.6%. Compared to other types of EV (e.g. PHEV or FCEV), BEV maintains its dominance in the Dutch market.

The fifties group is the most common age group (28%) (Statista, 2023). These findings align with global consumer data on BEV owners in terms of demographics. The EV drivers can be classified into six distinct categories based on their ownership patterns: **Private buyer, Private leaser, Business buyer, Business lease as a self-employed person or DGA (direct major shareholder), Business lease as an employee, and Shared car driver.** In the 2022 National Survey, the majority of participating drivers are still 'Business lease as an employee'. In terms of charging costs, most EV drivers bear the expenses themselves, either as individuals, self-employed individuals, or sometimes as employees. Only 36% of cases involve employers covering all charging costs. Which means, even the business lease driver sometimes also needs to put effort into considering different prices and locations to charge their car.

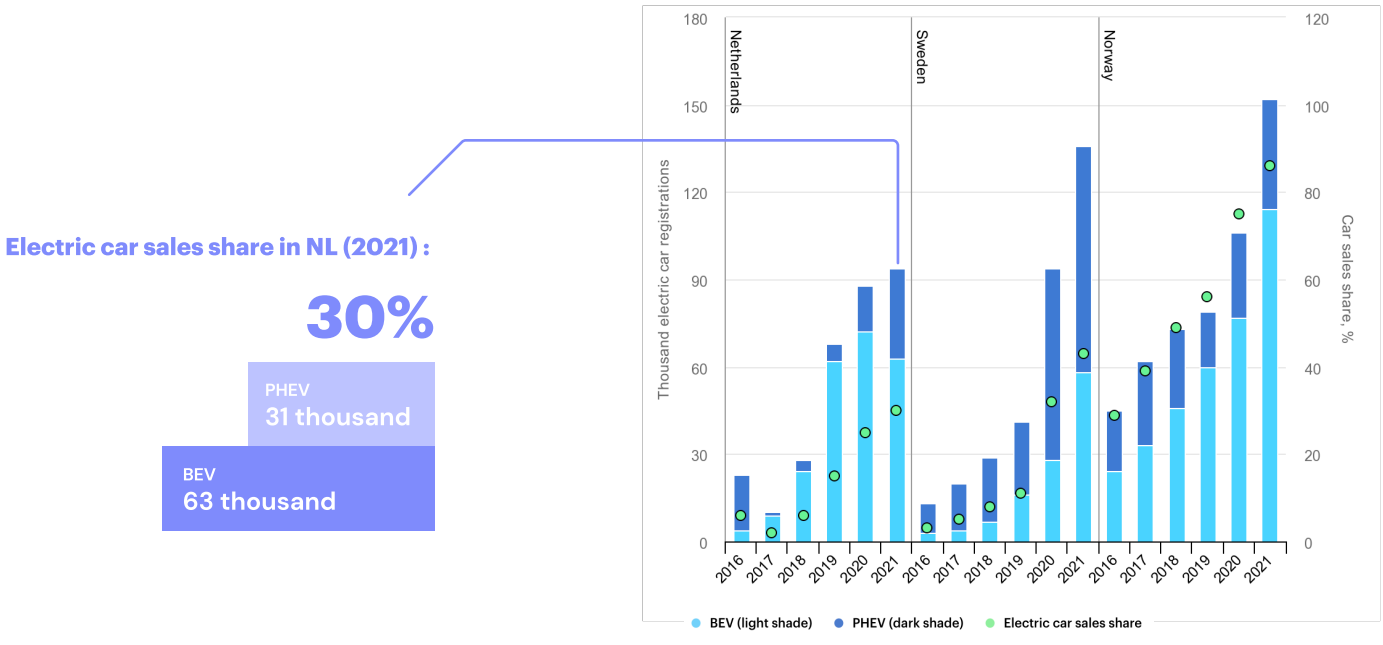


Figure 4. Electric car registrations and sales share in North-Western European regions, 2016-2021 (IEA, 2022).

1.3 The Charging Infrastructure

The expansion of commercial and residential charging infrastructure is the prerequisite for the adoption of EVs (Baresch & Moser, 2019; Falchetta & Noussan, 2021). This section begins by elucidating the technical terminology and different types of charging stations to foster effective communication among stakeholders in this project.

1.3.1 Alternative Current (AC) / Direct Current (DC) Charging

The power grid supplies alternating current (AC), EV batteries require direct current (DC). The conversion from AC to DC can occur either within the vehicle itself or at the charging point. For AC charging, the conversion from AC to DC takes place within the vehicle. The capacity of the AC-DC converter in the car determines how much of the available charging capacity from the charging station can be utilized. AC charging is typically slower, although AC fast charging (> 22 kW) is also possible.

On the other hand, DC charging involves converting AC to DC outside the vehicle, specifically at the charging point. Direct current (DC) allows the charging point to provide high-power charging (> 22 kW). The charging point establishes direct contact with the car battery, enabling efficient charging (Falchetta & Noussan, 2021).

1.3.1.1 Charging modes

Categorizing charging modes involves grouping various charging techniques based on factors such as capacity, communication, and safety (Visser, 2019). As illustrated in Table 1, there are four modes of EV charging. Mode 1 and 2 use domestic plugs for charging at power levels of 1.5-3 kW, while mode 3 improves communication between the grid and the car, allowing for optimal scheduling and additional services. Mode 4 enables fast charging using DC and specific connectors like CHAdeMO or Combined Charging System (CCS) (Hardman et al., 2018). Here is a breakdown of the four charging modes and their respective details.

Modes 1, 2, and 3 involve charging through the vehicle's converter, where AC from the charging station is converted to DC for the vehicle battery. The converter's capacity determines the amount of available charging capacity from the station that can be utilized.

Mode 4, on the other hand, is DC-charging, where the conversion from AC to DC happens at the charging station itself. The charging cable is integrated into the charging point, and the delivered capacity typically ranges from 50 kW to 175 kW.

Mode [IEC 61851]	Power [kW]	Typical location	Socket system [Outlet I Inlet]	Time to charge 100 miles
Mode 1 (Level 1)	1-3	Home	Domestic plug I Type 1/2	> 10 h
Mode 2 (Level 2)	1-7	Home, Work	Domestic plug I Type 1/2	2-12 h
Mode 3 (Level 2)	Up to 43.5	Work, Public	both Type 1/2	0.5-1.5 h
Mode 4 (Level 3)	Currently 50-150 (< 400)	Corridor	CCS (CHAdeMO)	<15 min

Table 1. Different modes of charging (and the associated levels in North America) and their detailed information. (Revised from Hardman et al., 2018).

1.3.2 Types of charging stations

According to LaMonaca and Ryan (2022), the Electric vehicle supply equipment (EVSE) can be classified into **1) Home charging, 2) Public charging station, 3) Workplace charging, and 4) Fast charging.** Here is a detailed explanation of the four charging stations:

1. Home charging

Home charging is widely considered **the primary and convenient approach** for recharging EVs (Franke & Krems, 2013), usually utilizing level 1 or level 2 chargers. Various countries provide incentives to EV buyers to encourage the installation of level 2 chargers at their residences. However, the feasibility of home charging relies on having access to an exclusive, off-street parking area, such as a driveway or garage. On a global scale, home charging remains the prevailing method, accounting for approximately 50-80% of EV charging (Chakraborty et al., 2019). Home location charging encompasses both private charging points and public charging infrastructure situated in residential areas (Hardman et al., 2018).

EV drivers heavily rely on private charging, particularly due to the limited availability of public charging infrastructure. Surveys and behavioral studies in the Netherlands (Nationaal Laadonderzoek 2022, 2022) also shows that home charging dominates over other locations. However, as EV ownership expands beyond urban or densely populated areas, public charging infrastructure becomes more important, especially for those living in apartment-style housing without access to off-street parking.

2. Public charging station

Public charging stations, which include level 2 chargers and DC fast chargers, are crucial in providing charging options for EV drivers. Level 2 charging stations are commonly found in locations where vehicles are parked for longer periods, such as shopping centers, airports, hotels, and government offices. On the other hand, fast chargers are more frequently located along highway corridors to cater to drivers undertaking longer journeys (LaMonaca & Ryan, 2022).

In Europe, the Alternative Fuels Infrastructure Directive (AFID) mandated EU members to set deployment targets for publicly accessible chargers (Homepage | European Alternative Fuels Observatory, 2023). **However, the implementation of charging infrastructure has been inconsistent across the EU.** Efforts are being made to ensure that each battery electric vehicle registered in a member state has access to a certain power output through publicly accessible charging stations.

Public charging infrastructure has been found to be important for increasing EV uptake (Kester et al., 2018). Surveys conducted in Norway (Erik Figenbaum, 2016) revealed that while most EV owners charged at home or work using slow chargers, a significant portion also utilized public level 2 charging and fast charging. **As more EV owners without access to dedicated private parking purchase EVs, the importance of public charging will continue to grow.**

1.3

3. Workplace charging

Workplace charging offers a critical opportunity for EV drivers who lack easy access to home charging. Level 2 stations are commonly installed in workplaces. Workplace charging initiatives, such as funding incentives for employers offering free charging, have been implemented in various countries to promote EV adoption. Workplace charging not only facilitates EV uptake but also has the potential to contribute to increased renewable energy utilization, especially in regions with surplus clean power generation during daytime hours (Coignard et al., 2018; Fang et al., 2018).

4. Fast charging

Fast charging plays a vital role in addressing the charging needs of drivers undertaking longer journeys (LaMonaca & Ryan, 2022). It closely replicates the refueling experience of conventional vehicles and can help ease the transition to EVs (Neaimeh et al., 2017). However, the economics of fast-charging provision can be challenging due to low utilization rates, which can hinder profitability for charging station operators (Wirges, 2016). Concerns regarding battery degradation with fast charging is mentioned as well (Hoke et al., 2011). Lithium-ion batteries generally lose capacity as the battery is repeatedly charged and discharged over time, depending on factors like state of charge and temperature.

In conclusion, while home charging remains the most common approach for EV recharging, **the availability of public and workplace charging infrastructure is crucial for widespread EV adoption.** Public charging stations, including level 2 chargers and fast chargers, play significant roles in providing charging options for EV drivers, especially for those without access to home charging. Workplace charging initiatives and the development of fast charging networks further enhance the convenience and feasibility of owning an electric vehicle, making long-distance travel more viable and replicating the refueling experience of traditional gasoline-powered vehicles.

1.3.3 Experience with “Public Chargers” Requires Attention

The Netherlands is widely recognized for its highly developed charging infrastructure, boasting the highest density of electric vehicle charging points among European countries. As of April 2023, the country has a staggering total of 128,581 regular charging points, along with 5,207 fast charging points (Cijfers Elektrisch Vervoer, n.d.).

EV charging behavior among drivers in the Netherlands varies based on their charging preferences and availability of charging infrastructure. In The National Charging Survey 2022, **home charging is the predominant method**, with 42% of miles charged at private charging stations and 8% using home outlets. Public charging stations near home account for 21% of charging, while 13% occur at charging stations at work. Fast chargers and public charging stations elsewhere contribute 8% and 7% respectively, while charging at outlets elsewhere represents 1% of total charging.

However, around 75% of households in the Netherlands lack a personal driveway where they can conveniently charge their vehicles (Brey et al., 2021). The ability to charge at home, either with a private driveway or charging facilities, emerges as a significant factor influencing the decision to switch to an electric car, especially for newer EV drivers. This finding indicates that **if the experience with public charging stations is not deemed trustworthy, potential drivers may feel that relying solely on public infrastructure is insufficient for their security and convenience charging needs.** This preference for home charging is more prevalent among private drivers, while business drivers rely more on workplace charging. Interestingly, the use of fast chargers does not significantly differ between business and private drivers.

The National Charging Survey (2022) also mentions that, regarding public charging, 37% of EV drivers occasionally charge at a public charging station near their homes, while a larger proportion, 52%, use public charging stations located elsewhere. It is worth noting that **71% of the respondents occasionally face bottlenecks when charging at public stations** [N=1636]. As for fast chargers, EV drivers generally express a positive attitude towards fast charging, rating it an average of 7.9 out of 10. However, 43% of them occasionally experience bottlenecks with fast charging, **highlighting the need for improvements in this area.** When selecting a fast charger, location is a crucial consideration for EV drivers. However, factors such as charging speed and operator also play a role in their decision-making process.

1.4 Conclusion

To sum, the European EV market has experienced significant growth, with Europe ranking as the second-largest market globally. However, further efforts are needed in the Netherlands to meet the environmental agreement objectives and accelerate the adoption of electric vehicles. **The dominance of BEVs in the Dutch market highlights the importance of focusing on this vehicle type.** The availability of public and workplace charging infrastructure is crucial for widespread EV adoption, as it provides options for drivers without access to home charging. Factors such as housing stock, vehicle mix, driving patterns, and policy choices influence the quantity and type of recharging infrastructure required in European countries. In the Netherlands, home charging remains the most common approach, **but the experience with public charging stations needs improvement to ensure security and convenience.** Addressing bottlenecks and enhancing the fast-charging network will also contribute to a more optimal public charging experience. Ultimately, the combination of effective infrastructure deployment and improved public charging will support the growth and acceptance of electric vehicles in Europe. **Therefore, the upcoming chapter of the thesis will primarily focus on elucidating the challenges encountered by BEV drivers when charging their vehicles at public charging stations (See Figure 5).**

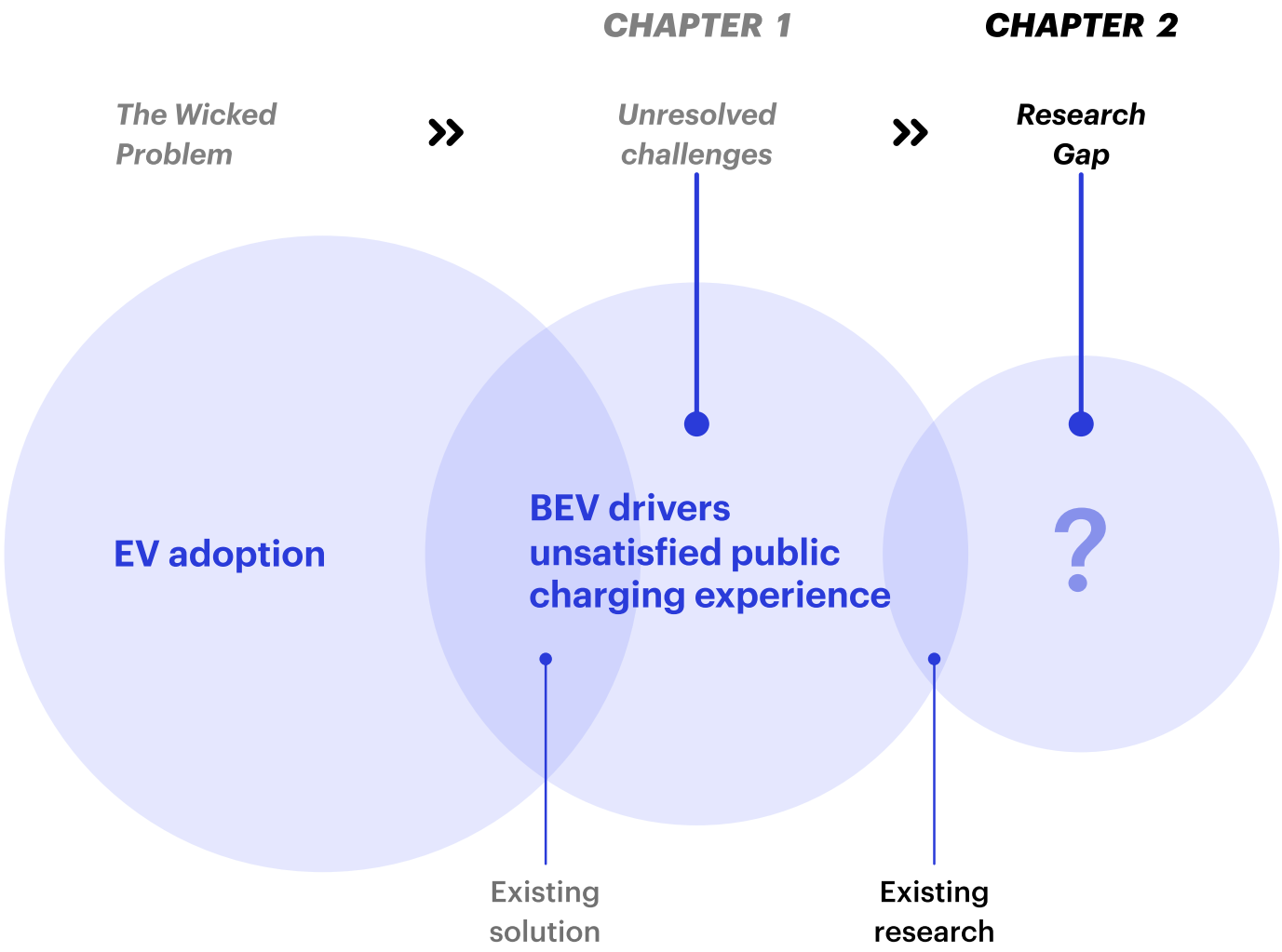


Figure 5. This diagram illustrates how the project's scope is narrowed down to identify a research direction in the literature.

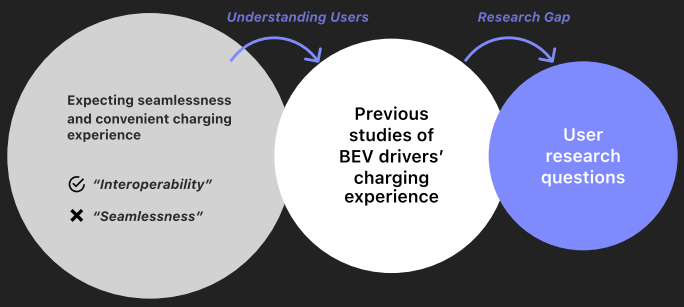
Literature Review

Intro

This chapter conducts an analysis of the existing literature concerning **the interaction of BEV drivers with public charging infrastructure** in Europe. The expanding electric vehicle market has introduced several challenges within the BEV charging sector. As per the literature, a notable issue revolves around the **fragmented user experience** when engaging with various charging providers. This fragmentation leads to negative experiences due to a lack of standardization and information integration. Consequently, this chapter introduces the term "seamlessness" to identify research gaps in prior studies, aligning with the core concept of seamless service design.

Chapter Overview

2. 1 Seamless Charging Experience
2.2 The complex market needs a Seamless Mindset
2.3 Mismatch between services and user expectations
2.4 Takeaways



2.1
Seamless Charging Experience

2.1.1 The Seamless Experience

To contribute to a more optimal public charging experience, **it is essential to establish an understanding of the ideal user experience.** By identifying the gaps between users' desired journey and the current friction they encounter, designers can effectively improve the charging experience.

This thesis draws upon the concept of "seamlessness" from Omnichannel User Experience. The definition of ***"Seamlessness"*** is mentioned in the Salazar (2017) article published on NN group–

> ***"Seamlessness is a quality of any cross-channel customer journey where the transitions (or handoffs) from one channel to the next involve zero or minimal overhead for the users. Basically, if you can pick up where you left off, the user experience will be seamless. But if users have to re-establish their contexts and/or redo work when switching to a new channel, then the experience will feel bumpy."***

The concept of "seamlessness" from the field of mobile computing also elucidates the contrasting experience of a fragmented charging journey –

> ***"Seamlessness refers to a smooth transition that involves a potential state change without causing significant disruption or distraction to the user (Satyanarayanan et al., 2005). "***

This mindset highlights the importance of providing users with a cohesive and smooth interaction across various channels. In the context of Charging Experience, users engage with charging ecosystem through multiple channels, such as EMSP's Services, CPO's services, in-car HMI, Physical chargers, and more. Any user experience failures within one channel can negatively impact the overall perception of the journey.

The key idea is to design for the entire user journey rather than focusing on single touchpoint or interactions. Users often switch channels for reasons like external interruptions, the suitability of a different channel, or the nature of the task itself (Salazar, 2017). Understanding why and when users transition between channels can help design efficient and streamlined channel transitions, creating a seamless journey for users. Thus, instead of considering only a small subset of the whole journey, **the holistic view for bridging the gap in between is needed to make the charging experience consistent and streamlined for drivers.**

2.2 The complex market needs a Seamless Mindset

2.2.1 Increasing complexity of the BEV charging industry

The natural variations in human behavior can form unique patterns, particularly when observed over an extended period (Korda et al., 2015). Madina et al. (2016) delves into the intricacies of charging events. The paper employs morphological box analysis (Kley et al., 2011) to illustrate numerous considerations individuals face when dealing with EV charging (refer to Figure 6). This mapping of variables offers insights into the intricate nature of an individual's charging habits, presenting a multitude of potential charging routes.

Beyond the act of charging itself, market stakeholders and newcomers further complicate the process for BEV drivers seeking the most advantageous charging options (i.e., the “best deal”). Madina et al. (2016) identifies two pivotal roles in their research. The first is the **Electro-Mobility Service Provider (EMSP)**, a key figure emerging during the study's timeframe. EMSPs offer service agreements to end-users and furnish the user interface for accessing and utilizing charging infrastructure. Their services encompass a range of functionalities, including route planning, authentication, charging, and other integrated services. Prominent examples in the Netherlands include ABRP, Bonnet, ChargeMap, PlugSurfing, etc.

The second role highlighted in Madina et al. (2016) research is the **Charging Points Operator (CPO),** referred to as CSO in their work. These entities bear responsibility for the oversight, maintenance, and operation of the charging stations, encompassing both technical and administrative facets. The CPO's role can be categorized into two distinct areas:

1. Administrative Operation CPO: This involves tasks such as access management, roaming agreements, and billing to MSP (Mobility Service Providers).

2. Technical Maintenance CPO: Typically, technical maintenance is carried out by the manufacturer.

CPOs undertake several crucial responsibilities, including identifying suitable hosts, handling legal and real estate aspects, coordinating with energy providers for wiring, overseeing station construction, and managing customer transactions, maintenance, and support. Importantly, it's worth noting that a single stakeholder can assume multiple roles, simultaneously acting as both the CPO and EMSP. Examples of such entities in the Netherlands include EVBox, FastNet, IONITY, Shell, etc.R

Numerous additional stakeholders are involved in the realm of EV charging (refer to Appendix B), including car manufacturers, regional grid operators, energy firms, and governmental bodies. What was once an unregulated charging system has evolved into a complex web, with diverse actors establishing their charging networks guided by individual business or organization strategies. Predictably, As anticipated, this fragmented approach has led to considerable user confusion when navigating across disparate platforms, lacking cohesion, as observed in (Figenbaum et al., 2022) study.

2.2.2 The lack of interoperability

The study by Figenbaum et al. (2022), conducted primarily in Norway, sheds light on the cumbersome experience of EV charging. Many of the challenges encountered by BEV users stem from the diversity of service providers in the fast charging market. The paper states that users in Norway grapple with the task of engaging with numerous applications, ranging from 20 to 30, and navigating around approximately 13 distinct payment systems to gain access to available chargers. This intricate landscape is further complicated by the multitude of plug types, power levels, charger interfaces, and the various alternative routes illustrated in Figure 6. An interviewee's comment from their research explicitly underscores the lack of seamlessness in these services:

"Having all these all apps these is confusing, apps is confusing, because if I'm because planning if a I'm trip, I planning can't just a trip, use I Google can't just use planning a trip, I can't just use Maps Google and "Having Maps find all and all the these find different all apps the charger is different confusing, services charger there. because My services if experience I'm there. is My that I'm experience unable to is that I'm get Google a full overview, Maps and and find that all I'm the forced different to use charger each app services individually there. My experience is that I'm to locate charging stations, and get information about the terms and so forth, and then I'm not even sure if I have the right app".

Similarly, Visaria et al. (2022) highlighted that "customers have an affinity for the convenience of interoperability across charging providers." Also, W. Fichtner (2016) indicates that "consumer respond positively to interoperability" in one of their trail in Germany. However, most EV drivers encounter difficulties in obtaining comprehensive information regarding charging options in their vicinity (Joey Dabell, 2022). The lack of interoperability between countries or even within a nation further complicates the situation. Despite ongoing efforts to enhance charging infrastructures' deployment, standardization of charging infrastructure, and lower barrier for authentication and payment methods (Burnham et al., 2017; Hardman et al., 2018; Mart van der Kam, 2020), **EV drivers still spend significant time and effort gathering essential details about the charging infrastructure, such as location, availability, accessibility, charging speed, and pricing, to meet their specific charging requirements** (Brey et al., 2021; Figenbaum et al., 2022; Joey Dabell, 2022).

Nevertheless, **the current studies' suggestions of achieving "interoperability" predominantly revolve around technical usability, standardization of public charging stations** (Figenbaum et al., 2022), **a back-end connection for customer authorizations and B2B settlements, and the ability of customers to make payments** (Joey Dabell, 2022). The method for seamlessly integrating the aforementioned information and streamlining drivers charging experience remains uncertain.

To sum up, the previous two sections, the charging network is likely to become even more intricate and less unified as more players enter the scene (Figenbaum et al., 2022). BEV drivers are expecting seamless and convenient charging experience (Visaria et al., 2022). However, unless measures such as consolidation, regulation, or the involvement of independent network orchestrators are introduced to unify information and services, the seamlessness of EV charging experience is expected to remain challenging.

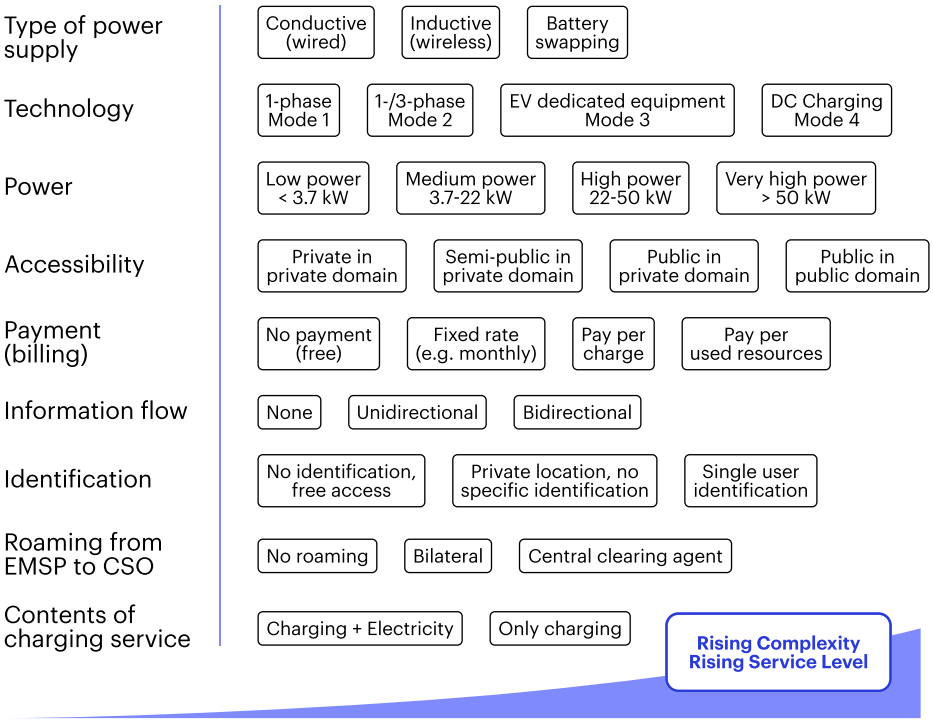


Figure 6. Revised from Madina et al., (2016)'s morphological box analysis for EV charging event.

2.3 Mismatch between services and user expectations

2.3.1 User preference of charging decisions

The study conducted by Visaria et al. (2022) investigated user preferences in BEV charging through interviews, pinpointing **key factors such as detour time, costs, charging speed, and charger availability.** These insights were then used to construct stated-choice (SC) experiments to simulate the decision-making process that EV users undergo when selecting a charger for long journeys (ChoiceMetrics, 2018). The primary aim of these experiments was to uncover the influential factors in charging decisions and to what extent they impact user choices.

The attributes, derived from the four factors mentioned above, employed in the experiments included ***Detour time (in minutes), Chargers Available (the number of chargers at the location), Charging Speed (measured in km per 10 minutes), Cost (DKK/kWh), and Additional Facilities.*** A total of 558 BEV respondents participated in the study, and the data collected were analyzed using mixed logit (ML) models to identify the significant aspects of the charging process and their effects on user decisions.

The results of the study revealed several noteworthy findings. On average, available chargers were valued at 7.87 min of detour, while occupied chargers were valued at only 0.53 min of detour. Additionally, respondents were willing to detour for approximately 5.59 min to save 1 DKK/kWh. Charging speeds were valued at 0.28 min of detour for each additional km of range obtained per minute of charging.

These findings indicate that **users are willing to take detours for stations with more available chargers, cost savings, and nearby amenities.** This reveals the complexity of the decision-making process of selecting a charger. Users must consider a multitude of factors from their current context before planning the trip, adding users' cognitive load particularly during long-distance drives. The research highlights the intricate nature of users' decision -

> ***"The charging behavior was a mix of contextual and subjective triggers"*** *- Visaria et al. (2022)*

Given the complexity of real-world conditions, **there are still numerous attributes in reality that require exploration to better mimic real-world outcomes** in similar experiments, offering policymakers and charging operators insights to set up regulation or develop their business with a user-centric approach.

2.3.2 Issues for separated subset

Currently, Dutch BEV drivers face less range anxiety, but they frequently express dissatisfaction with other aspects of the charging process.Brey et al. (2021) conducted a broad survey which more than 1800 Dutch BEV drivers participated. They state that within the 78% of BEV drivers charging their vehicles at public charging stations, several challenges are encountered. People perceived shortage of charging points in the area (72% of respondents), insufficient clarity regarding charging expenses (over 60% of respondents), uncertain or slower than expected charging speeds (55% of respondents), difficulty in finding charging stations (38% of respondents), and inaccurate location information in charging apps.

1. Malfunctioning Charger

Brey et al. (2021) references a survey conducted by Plugin America concerning public charging infrastructure. **It unveiled that the prevailing issue reported was the non-operational public chargers.** Figenbaum et al. (2022) also mentioned the same user feedback found in their research. This negative experience resulting from malfunctioning charging stations could potentially impact the electric vehicle market. Brey et al. (2021) states later on that the recharging points data, when available, should "include information on real-time accessibility as well as historical and real-time charging information" according to the Deployment of Alternative Fuels Infrastructure (AFID) regulation to make the EV ecosystem developed successfully.

2. Lack Transparency in Price

In addition, the Brey et al. (2021)'s survey raises concerns about **the lack of transparency in charging costs. Respondents, on average, scored 2.31 out of 5, indicating disagreement or neutrality regarding knowing charging costs in advance,** suggesting that costs are frequently uncertain for them. This aligns with EVA England's research, emphasizing the importance of not just having clear pricing information but also transparency regarding the various costs linked to using a public charger. Additionally, it emphasizes the necessity of distinguishing the transparent pricing for charging a vehicle from other expenses like parking fees and connection fees. This sentiment is supported by Kurani et al. (2016) and Figenbaum et al. (2022), highlighting potential barriers due to unclear payment information. Figenbaum et al. (2022) noted that BEV users often received price details for public fast chargers only after charging had concluded.

3. Uncertain Charging Speed

The uncertain charging speed is mentioned in Brey et al. (2021) research as well. Charging speed is measured in kilowatts (kW) and is influenced by various factors. Firstly, each car model and brand has its own maximum charging speed. Secondly, the charging point itself sets the maximum power output, which can vary depending on the type of charger and whether multiple vehicles are charging at the same time. Lastly, the connection between the charging station and the electrical grid has its own maximum capacity. As a result, the actual charging speed is constrained by these factors. The literature highlights the undesirability of EV drivers finding themselves with insufficient charge to reach their next destination or charging location. To address this concern, one potential solution involves allowing users to specify their desired charge level and departure time. Such user input can be factored into the operation of a smart algorithm or system to optimize charging schedules and ensure adequate charge for upcoming trips.

2.3

There are other barriers in a charging context such as the **congestion at charging station, network roaming is not available for every charging network, lack of charging etiquette, an insufficient amenities** (Figenbaum et al., 2022; Visaria et al., 2022). Indeed, when services diverge from user needs and desires, they can jeopardize the long-term viability of charging infrastructure and hinder BEV adoption (Figenbaum et al., 2022). However, these pain points belong to only subsets of the overall charging journey, which typically **focuses on isolated aspects instead of a holistic perspective.** In essence, resolving these issues individually may enhance the user-friendliness of specific touchpoints within the charging system, but **it falls short of improving the seamlessness of the entire BEV charging experience.** For instance, swiftly updating data about non-functional charging stations helps users avoid arriving at unusable stations. However, users may still struggle finding charging stations compatible with their specific charging cards even when many functional stations are available, rendering their charging journey non-seamless. The next chapter will elaborate strategies proposed by several studies for overcoming current BEV drivers' challenges.

2.3.3 Strategy to improve the chargers' Level of Service

To tackle emerging user challenges, current empirical research primarily delves into the roles and relationships of stakeholders within the EV ecosystem (Talantsev, 2017; Wolbertus et al., 2020). It also explores how these stakeholders' interests influence the expansion of the EV market. Some studies do shed light on the issue of fragmented services but mainly propose future trends in business model development or highlight emerging technical trends, such as smart charging systems (Brey et al., 2021; Figenbaum et al., 2022). On the other hand, a significant portion of research concentrates on optimizing the allocation of charging stations (Ghamami et al., 2020; He et al., 2022; Xi et al., 2013). However, there is a notable gap in developing actionable strategies to enhance users' Level of Service (LOS) when both the displacement and capacity of charging infrastructure are already established.

To address this constraint, the Korea Advanced Institute of Science and Technology (KAIST) conducted a study aimed at offering actionable recommendations for enhancing LOS at established stations (Yichan An, 2023). They propose three immediately applicable policies aimed at improving the efficiency and effectiveness of EV charging services, with a focus on reducing user waiting and detour times. These policies include:

Policy 1. Adjusting the number of chargers per station while keeping the total number of chargers constant in a specified region, which is useful for planning new charging station deployments.

Policy 2. Real-time assignment of the optimal charging station for each charging event with key information.

Policy 3. Evenly distributing daily charging demands.

The last two of these combinable policies are suitable for EV infrastructure operators to execute for improving the BEV drivers' charging experience. To assess their impact, Monte Carlo simulations are employed in their research, introducing a novel metric called "reliability-based macroscopic capacity." (Yichan An, 2023)

This metric quantifies the LOS of a public charging system within a designated area, in terms of weighted delay. Weighted delay is defined as “the weighted sum of waiting time and detour time, measured in Equivalent Waiting Time Only (EWTO) [hr/veh].” In essence, when the macroscopic capacity increases, it means operators can accommodate more EVs while maintaining the same LOS for the system (See figure 7).

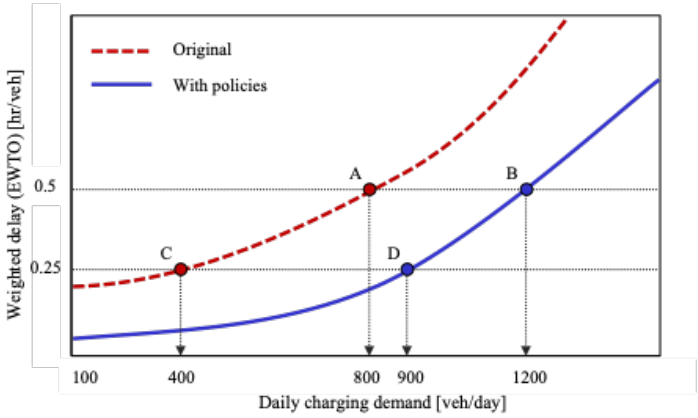


Figure 7. A conceptual example of applying reliable-based macroscopic capacity strategy. The points A, B, C, and D show the system's capacity for handling electric vehicles based on different maximum allowable wait times. (0.5 and 0.25 hours, respectively).

This chapter will specifically delve into Policy 2 as it closely relates to end-user interaction and experience. Instead of selecting a charger solely based on its location and detour time, Policy 2 focuses on providing users with real-time data encompassing expected waiting times and precise detour times, **aiming to minimize total travel time and prevent users from waiting unnecessarily at charging stations.** As a result, the team can assume that each EV can be efficiently directed to optimal charging station, considering both minimal waiting and detour times. The research also **recommends incorporating real-time factors like the number of EVs currently charging at each station, the State of Charge (SoC) of vehicles, and the expected arrival times of incoming EVs into the system.**

This practical approach can be seamlessly integrated into smartphone apps and modern navigation systems (Kavianipour et al., 2021a).

This research holds value in reducing the overall travel and charging time for drivers. **It can prevent situations where drivers arrive at a location only to find long queues and need additional detours, thereby enhancing the seamlessness of their entire journey.** However, as discussed in Chapter 2.2.1, charging decisions should encompass more than just a single factor. Also, it is important to reflect on human variability to improve the design and management of charging infrastructure (Khaleghikarahrodi & Macht, 2023; Kim et al., 2016). **To achieve a truly seamless journey, factors beyond time should be considered when optimizing the entire charging experience.** To be more specific, while this policy can certainly save users time by reducing waiting times, it may still direct them to a charger that's incompatible with their charging pass, more expensive than expected, or lacks the necessary amenities, revealing gaps of a seamless journey. Therefore, further research is essential to understand the broader context of driving and ensure the effectiveness of the policy presented above.

2.4 Conclusion

As the adoption of BEVs continues to expand, there is **a growing demand for a seamless charging experience at public stations**. A seamless experience not only requires increased standardization in charging infrastructure and payment methods, but also an optimal and streamlined journey for users to plan and charge their car in a second without thinking too much. The literature review has taken a close look at the growing intricacies within the BEV charging sector, notably the conspicuous lack of interoperability among key charging stakeholders like EMSPs and CPOs. It has illuminated the challenges stemming from fragmented user experiences, primarily arising from the lack of consistency and the absence of incorporation of information and interaction strategies within the charging domain. However, existing research and regulatory efforts pertaining to EV charging interoperability have largely concentrated on establishing standardization for public charging stations or enabling roaming for back-end data exchange (Jnr., 2020). **The aspect of designing a seamless service experience for end-users has often been neglected.**

To address these challenges, researchers are moving towards a direction focused on gaining a better understanding of our drivers. However, **certain studies concentrate on predicting user-preferred routes based on limited factors**, which may not accurately represent real-world situations. On the other hand, some empirical studies aim to **uncover individual pain points experienced by users, while the broader issues hindering a truly streamlined journey remain undiscovered**. An actionable strategy is introduced to enhance users' Level of Service (LOS) by reducing waiting and detour times. Nevertheless, **it's crucial to recognize that achieving seamlessness in the BEV charging experience requires considering factors beyond time**, such as compatibility, cost, and amenities. Therefore, further research is needed to explore the context of driving and ensure the effectiveness of proposed policies. Figure 8 below presents the summary of the literature review.

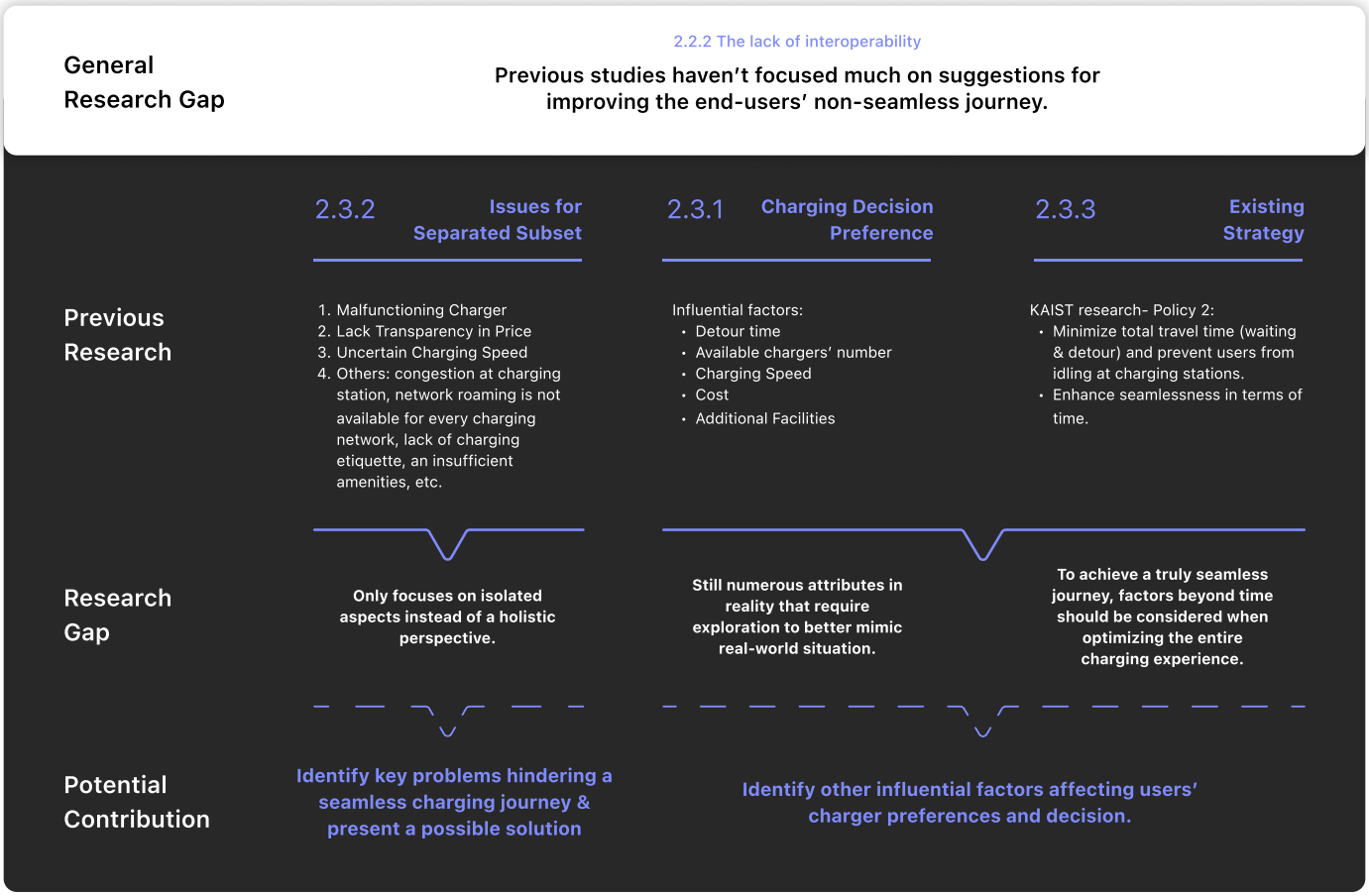


Figure 8. The research gap identified in the boxes with purple background.

To sum, there is a scarcity of empirical research examining the seamless experience throughout the whole consumer's charging journey and the integration of charging services. This research gap is supported by Hardman et al. (2018)), who contend that there is a paucity of empirical data exploring consumers and interoperability. More attributes from the driving context and situation at the moment should be identified and considered to help conceptual strategy implement in the real world. Hence, **this thesis places its emphasis on examining the seamlessness of the entire process,** commencing with the recognition of the necessity for charging, progressing through the arrival of at public charging stations, and till the act of authenticating and plugging the vehicle. Moreover, the influential factors of drivers' charging decision will be investigated.

Therefore, the primary research question for the qualitative research is formulated as follows:

"How can the BEV charging experience be optimized to provide seamlessness by considering a holistic view of the user journey, *in terms of selecting, navigating to, authenticating at, and using public charging infrastructure, to address the challenges posed by the complex and fragmented charging sector?"*

The second research question is:

"What influential factors should be considered while predicting user preference of charging decision?"

The next chapter will dive into the execution, analysis, and present the insights of BEV driver's qualitative research.

User Research

Intro

First, a "service ecosystem" is performed to place the seamless customer needs at the center and gain an overview of previous two chapters' notion of the BEV drivers' possible journey of charging at a public charging station. This mapping process encompasses the discovery of charging needs and extends to the completion of the charging session. It serves as a facilitator for subsequent interview questions with BEV drivers. Second, a survey is conducted to filter the target user- which are the novice driver having 1-3 years' experience of driving an EV. Third, eight interviews and three observations are conducted to understand the latent user needs to optimize the system and offer a seamless charging journey.

Chapter Overview

3 .1 EV Charging Service Ecosystem from the User Perspective
3.2 Survey
3.3 Interviews and Observation
3.4 Results
3.5 Discussion and Insights
3.6 Takeaway

3.1 EV Charging Service Ecosystem from the User Perspective

3.1.1 Purpose of using the framework

A "service ecosystems" is defined as a “relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange” (Vargo, 2011). To elaborate, a "service ecosystem" is a dynamic network of actors, like businesses, organizations, and individuals, who collaborate to provide and receive services. They integrate resources and assets, follow shared rules, and create value through service exchange. Additionally, it is constantly evolving, responding to changes in customer demands, technological advancements, and market conditions. By comprehending the complex and dynamic nature of this multi-actor network, designers can gain clearer insights into how to effectively implement their concepts in real-world contexts.

3.1.2 The “Service Ecosystem” framework

3.1.2.1 Definition

In the initial stages of a service design project, the "service ecosystem" can be identified and visualized well in advance, even prior to conducting more detailed activities such as customer journey mapping and service blueprinting (*SDN | Using a Service Ecosystem to Quickly Grasp Complexity*, 2021). This framework is beneficial during the fuzzy front-end phase of developing a new service, as it helps avoid costly and unnecessary discussions and interpretations concerning intricate details of granular activities.

Figure 9 depicted the circular visualization of a service ecosystem proposed by Grime (2018) in the *Touchpoint Vol. 10 No. 2 - Designing the Future Journal*. Similar to customer journey maps and service blueprints, a service ecosystem provides a chronological overview of a service experience. However, unlike the precise sequencing of detailed events in customer journey maps and service blueprints, a service ecosystem focuses on broader phases of the experience. Within each phase, the user's needs are identified, along with the service interactions and touchpoints that facilitate them (*SDN | Using a Service Ecosystem to Quickly Grasp Complexity*, 2021).

The utilization of this macro-perspective overview framework serves three purposes:

1. Firstly, it facilitates a shared understanding of the project scope among the team members.

2. Secondly, it facilitates the identification of key stakeholders engaged in crucial touchpoints where users interact with the services, which has been discussed in Chapter 2.2.1. Rather than mapping stakeholders in the ecosystem without any specific focal services or products, the team can utilize this framework as a foundation to structure the roles of stakeholders, highlighting the interplay between the key players and the services they provide.

3. Furthermore, this visualization tool can **serve as a facilitator for the following semi-structured interviews’ questions.** After the interviews, the central user needs can be validated or adjusted to be more accurate. In addition, the team can then choose which touchpoints occur the most fragmented experience and have a focus to deal with the issue.

3.1

3.1.2.2 Implement

This project focuses on the ecosystem of charging services for BEV drivers at public charging stations, encompassing the entire process from the discovery of charging needs to the completion of the charging session. The whole journey is divided into four steps in this framework, clockwise **1) Discovering the charging need 2) Navigation & Routing 3) Authentication and Payment and 4) charging the EV.** (Refer to Figure 10)

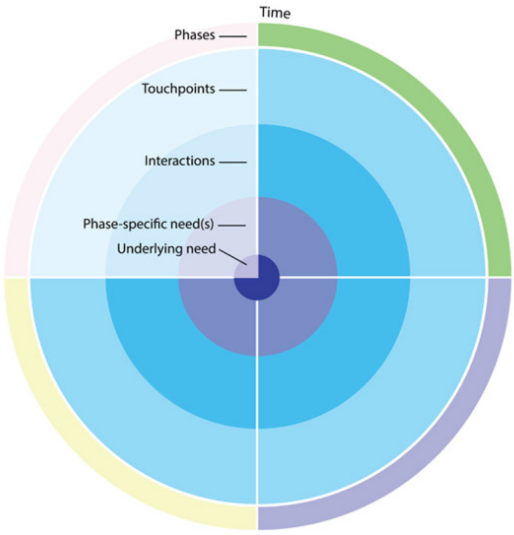


Figure 9 The template of "Service Ecosystem Framework" (SDN | Using a Service Ecosystem to Quickly Grasp Complexity, 2021).

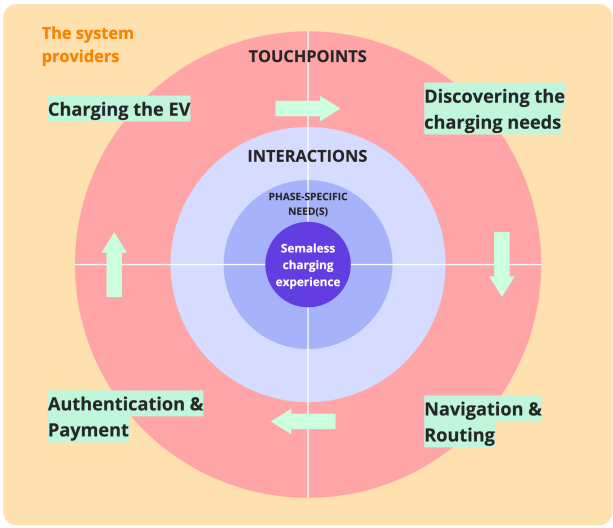


Figure 10 Adjust the template of "Service Ecosystem Framework" to fit the need of this project.

The selection of these four sections is based on the following two journey maps:

The first one is the "Customer Journey: Charging without any surprises" program, led by The Netherlands Knowledge Platform for Charging Infrastructure (NKL Nederland, 2022), aims to make public EV charging a seamless and reliable process by 2025. Their focus is on studying the specific journey of "I'm on my way to charge at a (semi) public charging station." The target group for this program is EV drivers in the Netherlands who rely on public charging due to not having their own driveway and are responsible for their charging fee. The journey includes seven steps, as shown in Figure 11. **The second reference** (See Figure 12) is from the consultancy report by Arthur D. Little (Pischalnikov, 2022). The article highlights the importance of building a "frictionless journey" for end-users and identifies the inconsistent customer experience in public EV charging. It also notes that EV charging in the US can vary in terms of plug type, location type, payment availability, and membership requirements. Although these two journeys are not from a scientific literature, the common charging process is still worth referenced for building the service ecosystem framework.

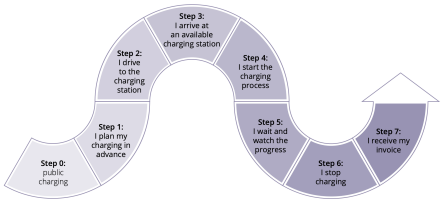
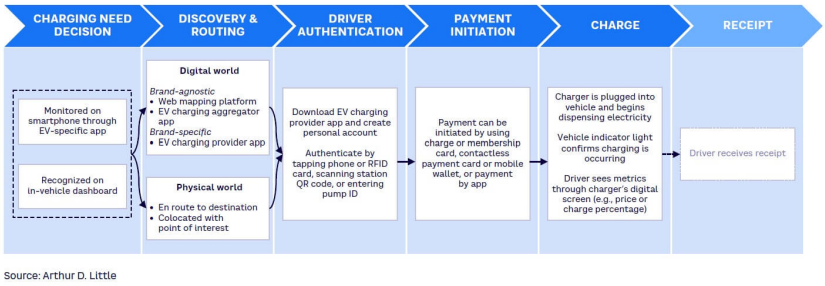


Figure 11 The first referred journey (The Netherlands Knowledge Platform for Charging Infrastructure - NKL Nederland, 2022).



Source: Arthur D. Little

Figure 12 The journey of charging at the public station in US by Arthur D. Little (Pischalnikov, 2022).

Taking inspiration from the two aforementioned journeys and the user needs interpreted from the findings of Chapter 2, the initial version of this project's service ecosystem map is presented below (Refer to Figure 13). The map puts the seamless charging experience as a main user need in the center, lists out the phase-specific needs for each step, incorporates the interaction and touchpoints between the user and the system, and provides an overview of stakeholders involved in this ecosystem. **Building upon this service ecosystem map, the semi-structure interview questions have been formed, aiming at validating some assumption of the user needs in this framework, discovering the bottlenecks hindering a seamless charging experience, and identify the influential factors of drivers' charging decisions.**

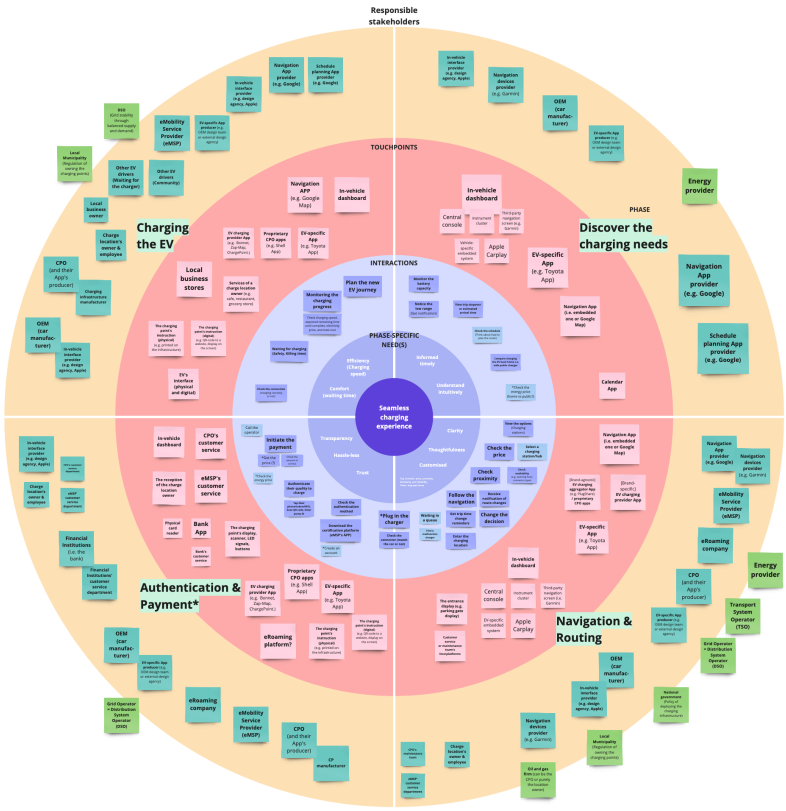


Figure 13 The service ecosystem map created for EV charging experience.

3.2 Survey

3.2.1 Method

An online survey was carried out in May and June 2023. The purpose of it is to filter the interview participants that fits the projects' target group criteria. This thesis aims to find the novice drivers with less than 3 years of experience driving a BEV, since they normally encounter more issues than the experienced drivers. Moreover, it is a reasonable deduction that addressing the challenges faced by new users who are unfamiliar with the entire system can also lead to an improved charging experience for long-term users concurrently. Respondents were acquired within VanBerlo, one of the stakeholders in this project, and other private EV networks. The survey contained questions about car ownership, their driving behavior, and their charging preference. BEV owners were asked about their satisfaction level of each phase encompassed in the previous defined charging journey, gaining their views on public charging infrastructure in the Netherlands. In total, there are 25 people responded.

3.2.2 Results & Discussion

3.2.2.1 General Characteristics

The respondents' common age categories were "20s" and "30s" (A total of 40% of the respondents aged between 30-39 years old, 24% are aged between 18-29 years old, others are aged beyond 40). A large majority (76%) of the respondents drive fully electric vehicles. Most of them driving a non-Tesla model except three respondents. As for the ownership, 38.1% of the respondents in our study drive their EV privately (private purchase and private lease). More than a quarter (33.3%) of them drive via a business construction (business purchase, business lease as an employee or business lease as freelancer or director of major shareholder). Last but not least, 42.9% of them drive their EV less than 1 year (See figure 14), which offers a great opportunity for the project to select interviewees through the survey.

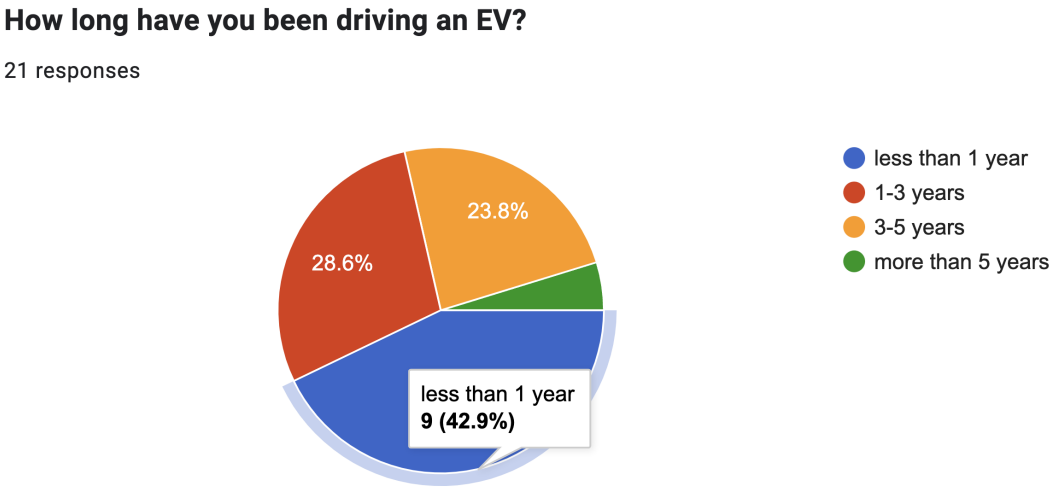


Figure 14 The majority of the respondents are novice driver who obtains less than 1 year driving experience.

3.2.2.2 Charging location and charging network

A total of 42.9% respondents' charging session is mainly completed at home, while the same percentage of them charge their car predominantly at public charging stations (normal public charging points and the fast chargers). This findings is similar to the survey result conducted by Brey et al. (2021). They found that on average 47% of the charging from their respondents is completed at home, 23% at a public charging point, 19% takes place at work, and 11% of them are charged via a fast charger. Reflecting on the percentage, individuals with their own driveway appear to be disproportionately represented among "EV drivers." Still, given that the majority of Dutch households, roughly 75%, lack a private driveway for vehicle charging, Brey et al. (2021) state that the utilization of public charging is anticipated to rise in the future.

Examining the data shown in Figure 15, most respondents (61.9%) charge at various charging networks, which means the need of familiarizing with multiple charging companies' services is still required. They use typically fewer than four platforms, to locate charging stations. Still, there are 19% of them use 5-9 platforms to complete the journey. While 85.7% possess 0-4 charging passes for authentication, 14.3% require 5-9 passes to access more charging points. In contrast to Norwegian drivers (Figenbaum et al., 2022), Dutch users might need fewer passes to pair with public charging stations. However, the following section highlights persistent user dissatisfaction during the process of finding a suitable charger and successfully charging, indicating that a seamless user experience and the number of platforms used, or the quantity of charging cards owned does not necessarily correlated.

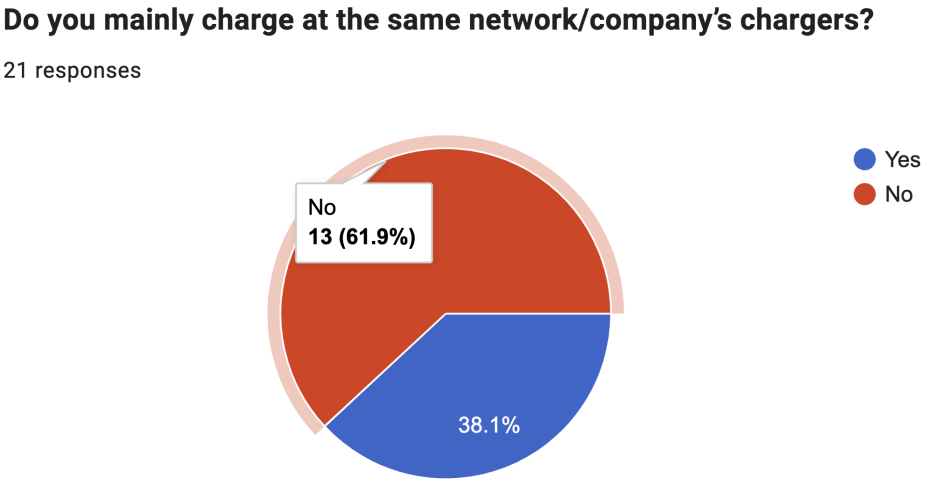


Figure 15 Respondents mainly charge at different charging network/company.

3.2.2.3 Satisfaction of current public charging services

In Figure 16, it can be seen that a five-point Likert Scale was used to assess satisfaction in nine different stages of the charging process. These stages encompassed everything from trip planning, comparing, and selecting charging stations, navigation to the destination, pairing with charging stations, to the final payment process. Detailed questions can be seen in Appendix C. Additionally, a tenth question was included to inquire, "How likely are you to recommend the public EV charging service to someone like you?" This was done to generate a Net Promoter Score (NPS) satisfaction index for current charging stations. However, it's important to note that this can only serve as a reference. Firstly, NPS scores typically require comparative analysis with scores from different companies in the same industry. Secondly, the response rate in this case was low. Nonetheless, it still provides a tool for understanding user perceptions of the current charging experience.

From top to bottom, the phases include Planning, Searching and Selecting, Navigating, Upon Arrival, Matching the connector to the car, Authenticating, Payment, Waiting, and Overall feelings. It's evident that the **authentication phase received the lowest score**, indicating that people often encounter challenges when trying to authenticate their charging pass to initiate the charging session. This issue may be related to the charger not supporting a certain Charging Point Operator's (CPO) charging pass, or it could involve other problems during the interaction with the physical charging point.

Another phase that received negative feedback is when users arrive at the charging station and find that the charging point is either unusable or not immediately accessible. The average score for this phase is 2.8. This findings echoes to the work of Brey et al. (2021), mentioning that one of the prevailing issue reported of charging session was the non-operational public chargers. Additionally, **the early stages of trip planning and charging station selection also received lower scores**. During trip planning, users don't feel they have access to sufficient information. When selecting a charging station, they find the process not as effortless as desired. These two phases have not been paid much attention by the academic research. To act on the survey result, the phases with lower scores in the user experience were further explored during interviews to understand the specific reasons behind users' negative experiences and the underlying issues.

It's worth noting that the phases of matching the physical charging connector to the car and the payment process received higher scores. This reflects what was mentioned in Chapter 2, where the Dutch government and related organizations have invested significant time and resources in achieving the standardization of physical chargers and back-end roaming to integrate existing products in the market and coordinate cooperation among organizations. Therefore, during these two phases, users didn't experience significant obstacles.

After the survey, the participants fitting the criteria are selected and invited to the interviews.

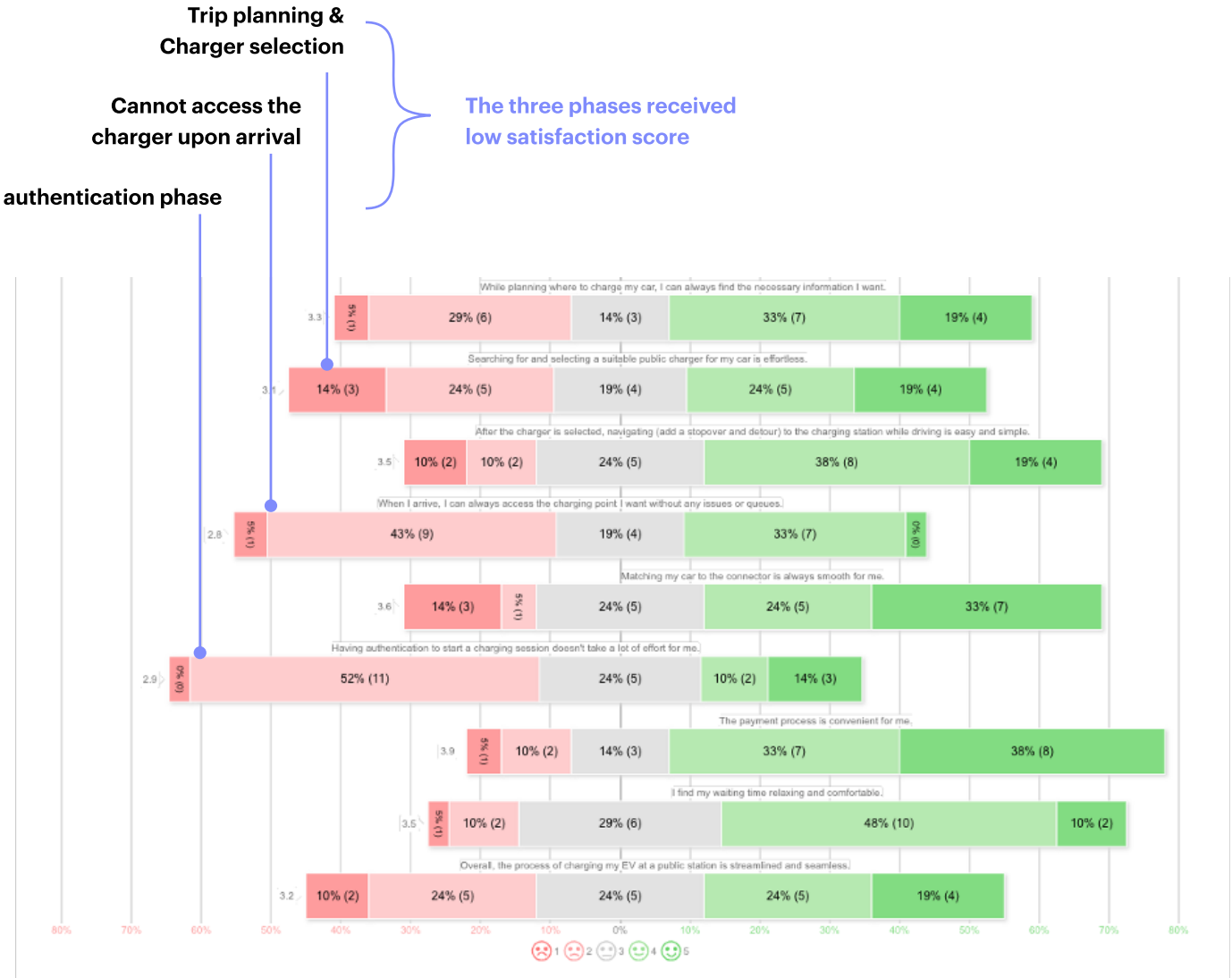


Figure 16 The respondents satisfaction level of current charging services.

3.3 Interviews and Observation

3.3.1 Purpose

The goal of the semi-structured interview and observation is to:

1. Find out the barriers hindering a seamless public BEV charging experience in the Netherlands, focusing on the journey from discovering the need of charging, to routing, to paying the charging fee, to waiting the charging session to finish.

2. Gathering behavioral data from the interviewees to map out journey map and identify influential factors of their charging decisions.

8 interviews and 3 observations (2 with normal public chargers and 1 with fast chargers) are conducted in the research.

3.3.2 Method

3.3.2.1 Participants recruitment

8 suitable interview participants who expressed their willingness to participate and met the criteria were selected from the survey. Some details can be found in Table 2. Among them, three participants have 1-3 years of experience driving electric vehicles, while the remaining five have less than one year of experience. Three of them are private buyers, and three are business leaseholders as employees. Additionally, two participants had previously rented electric vehicles for multiple long-distance trips. One observed driver was not included in the original list of interviewees. He had just acquired a new vehicle for two weeks and demonstrated the process of charging at a standard slow charging point. Furthermore, two of the participants for observation sessions were from the original list of interviewees. In addition to observing how they interacted with the charging points, the interview is also utilized to understand how they use different digital platforms, in-car navigation systems, and other more services throughout enter charging journey. For the interview script, please refer to Appendix C.

	Ownership	EV model	Driving exerience	Normal trip	Charge in same network or not	Numbers of platforms	Mainly used platforms' names	Numbers of charging pass	Most used charger type	Special driving or charging behaviours
01	Private buyer	Skoda Enyag iV60	1-3 years	Dan Haag - Goirle, Eindhoven, Amsterdam	N	5-9	InCharge, Ecotap, Fastned, Shell Recharge	5-9	Home	Researcher type of person. Will check every factors to get the most clever way to charge (less hassle and time, cheaper).
02	Business lease	Polestar	Less than 1 year	N/A	N	5-9	Polestar App, Fastnet, Shell Recharge	0-4	Public	1. Have a file specific for EV Apps 2. Haven't experienced the fast charger.
03	Rent an EV for long distance trips	Rental car from Sixt	Less than 1 year	Dan Haag - Amsterdam/ Delft	N	0-4	Google Maps	0-4	Public	
04	Rent an EV for long distance trips and short trips	Rental car from MyWheel and other companies	Less than 1 year	Delft- Dan Haag / Rotterdam	N	0-4	MyWheel in-car App, Google Map, Shell Recharge	0-4	Public	
05	Private buyer	Skoda Enyag iV60	1-3 years	Within Dan Haag	N	0-4	Google Map, Skoda App	0-4	Home	1. Ask for advices from her husband while looking for a public charger
06	Private lease	Renault Zoe Electric	For the new car is 1-2 year (Total driving years: 3-5 years)	Dan Haag - Rotterdam	Y	0-4	Google Maps, FastNed, ChargePoint	0-4	Home	1. Choose the car model from the consumer council 2. Only charge with green energy
07	Business lease	VOLVO XC40 Recharge p6	Less than 1 year	Eindhoven- Eindhoven/ Den Haag	Y	0-4	Shell recharge, Chargemap and ABRP	0-4	Home	
08	Private buyer	Mercedes-Benz EQA 250	1-3 years	Rotterdam - Eindhoven	Y	0-4	google / E-flux EV app / shell recharge	0-4	Public	Gave every phases high score but when observing how he found a charger is not that fluent as he told.

Table 2 The overview of participants.

3.3.2.2 Analysis

The interviews were primarily conducted using video recordings, although some participants only consented to voice recording. For the observation phase, video footage was recorded. Following the interviews, transcripts were created. The interview data underwent analysis by selecting noteworthy quotes from the transcripts and transforming them into statement cards (See Figure 17). These cards included the quotes themselves, interpretations of their meaning, and concise abstract titles that conveyed the underlying concept. Subsequently, these statement cards were grouped together in clusters to extract latent needs from the BEV drivers' explicit requirements (See Figure 18). This approach is borrowed from the context mapping method as outlined by Sanders and Stappers (2012).

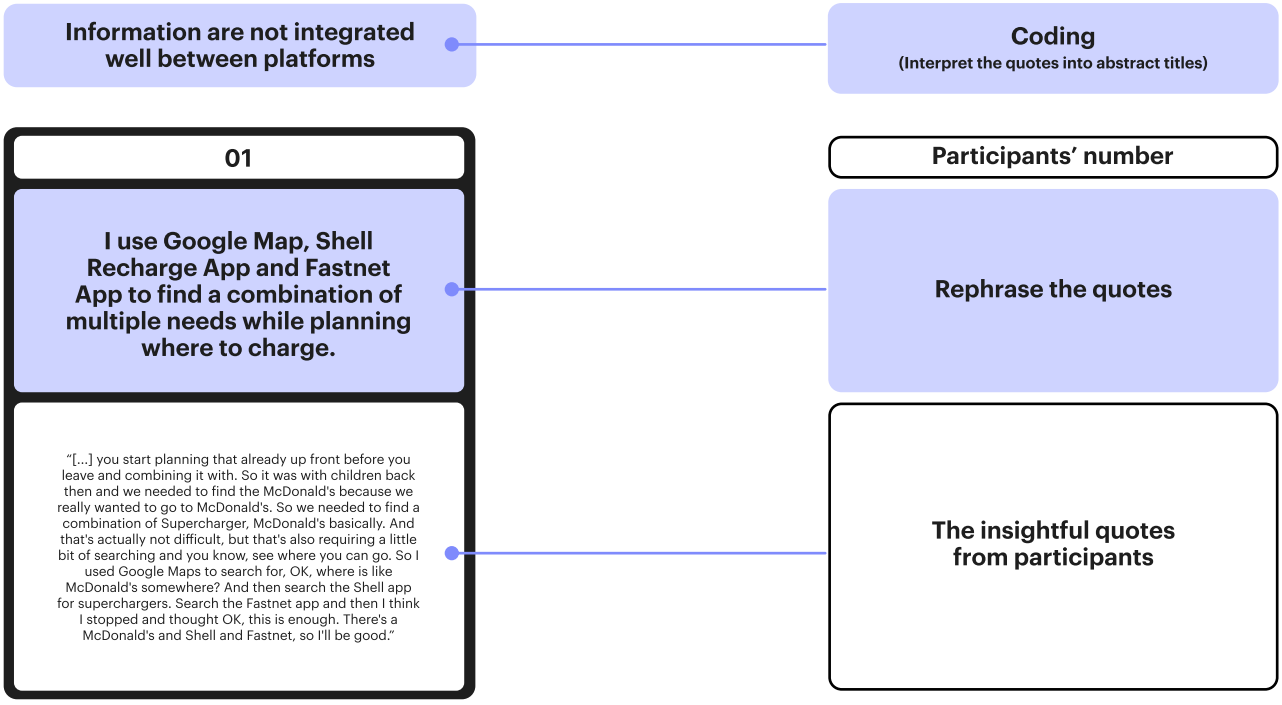


Figure 17 The generation of the statement cards.

3.4 Results

3.4.1 The User Journey Map

After the analysis, the User Journey Map is developed (Figure 19). The entire journey includes six phases: **Plan & Select, Navigate, Access the charger, Authenticate, Charge & Wait, and Leave & Payment.** The following section explain the user journey's structure and what contains in it. For a high-resolution one, please refer to Appendix D.





Figure 18 The statement cards of each participant. And the observation pictures took by myself and offered by participants.

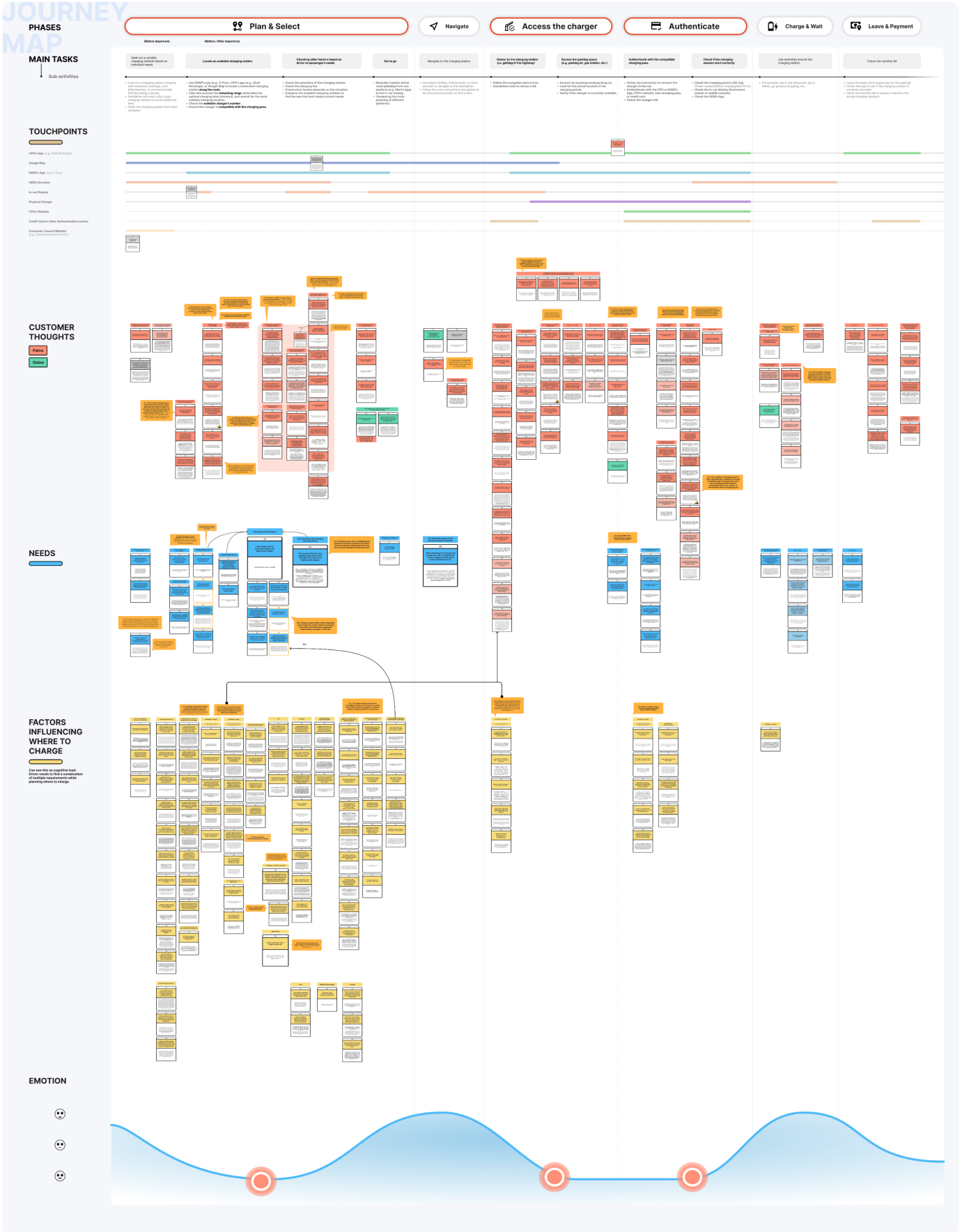


Figure 19 The journey map.

3.4.1.1 Explanation of each phase

Figure 20 illustrates the structure of the user journey map. At the top, it clearly delineates the six major phases of electric vehicle charging. Within each phase, there are main tasks and sub-tasks outlined, providing a comprehensive view of the user's stage-specific objectives. Below, you can see the service touchpoints that users encounter during each step of the process, including various CPO and EMSP apps, navigation systems (e.g., Google Maps), CPO websites, physical chargers, and more.

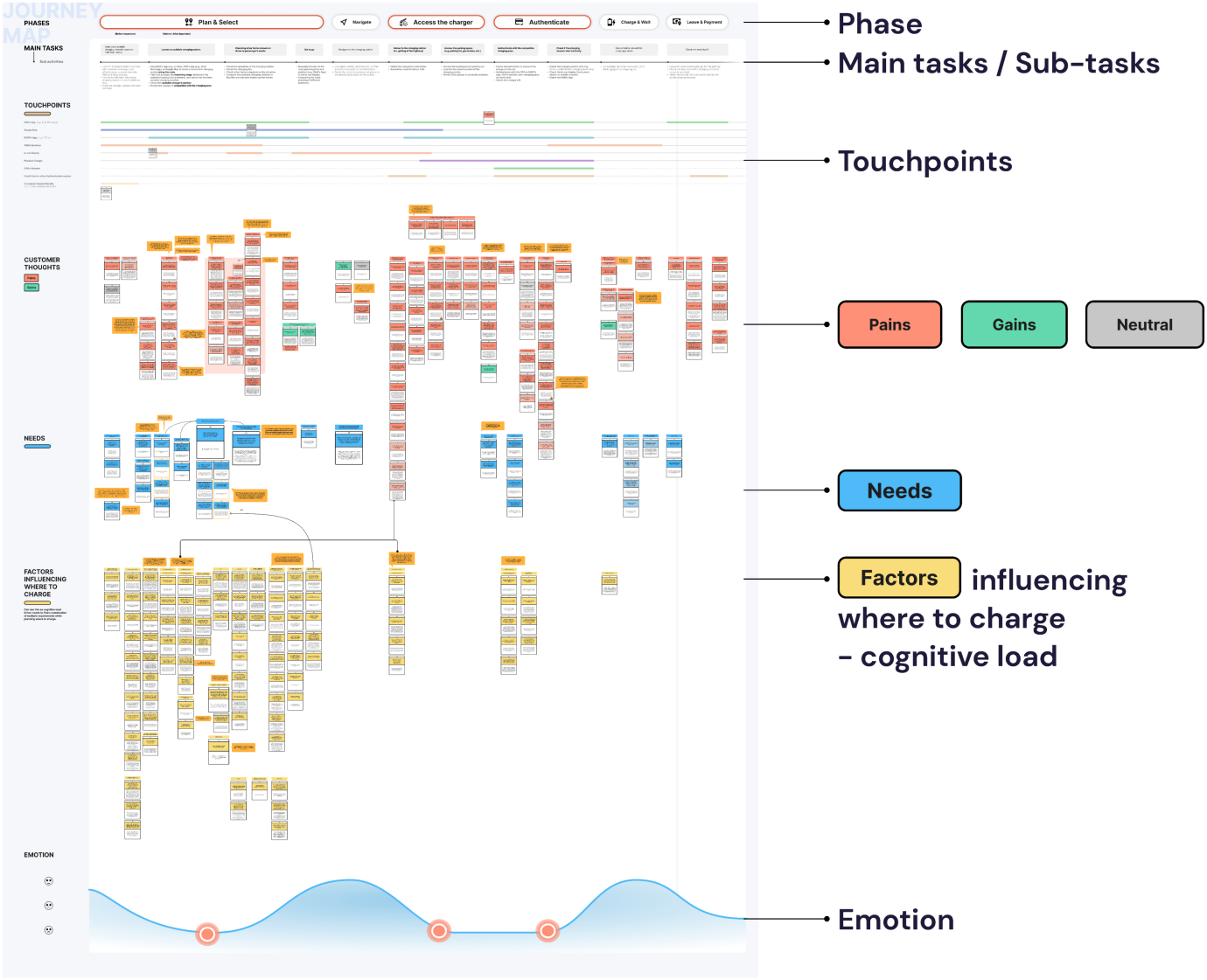


Figure 20 The structure of the user journey map.

Plan & Select

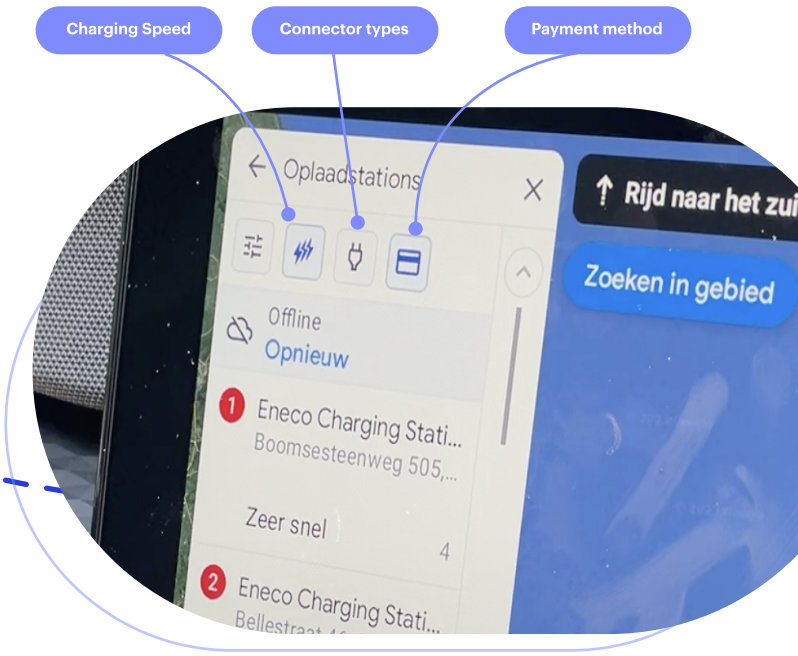


Figure 21 The filter of charging station on In-Car Google Map.

During the "Plan & Select" phase, drivers often take steps to prepare for their journey. **Some use mobile apps provided by Charging Point Operators (CPOs) or Electric Mobility Service Providers (EMSPs), while others turn to familiar tools like Google Maps.** They use these resources to plan their route and locate suitable charging stations. In some cases, drivers even research local native charging networks to determine which charging cards they should have to avoid additional starting fees.

In our interviews, many drivers mentioned using the built-in Google Maps in their vehicles, especially for shorter trips. **Google Maps offers a convenient filter feature that allows users to manually select their charging pass.** This choice influences authentication and payment methods. They can also choose preferred charging speed and the desired connector types (see Figure 21). Additionally, Google Maps provides detailed information about charging stations, including facility amenities, charging point types, and real-time availability (see Figure 22).

Observing users interacting with Google Maps, it became evident that, although occasional technical glitches such as offline access or system crashes occurred, these features seemed adequate for shorter trips. Nonetheless, relying exclusively on Google Maps for long-distance journeys could still result in feelings of uncertainty and discomfort during the trip, as detailed in the chapter 3.4.2.1. As the journey unfolds, additional demands emerge. Therefore, this phase also includes sub-tasks for verifying whether the selected charging points meet the current needs while driving on the road.

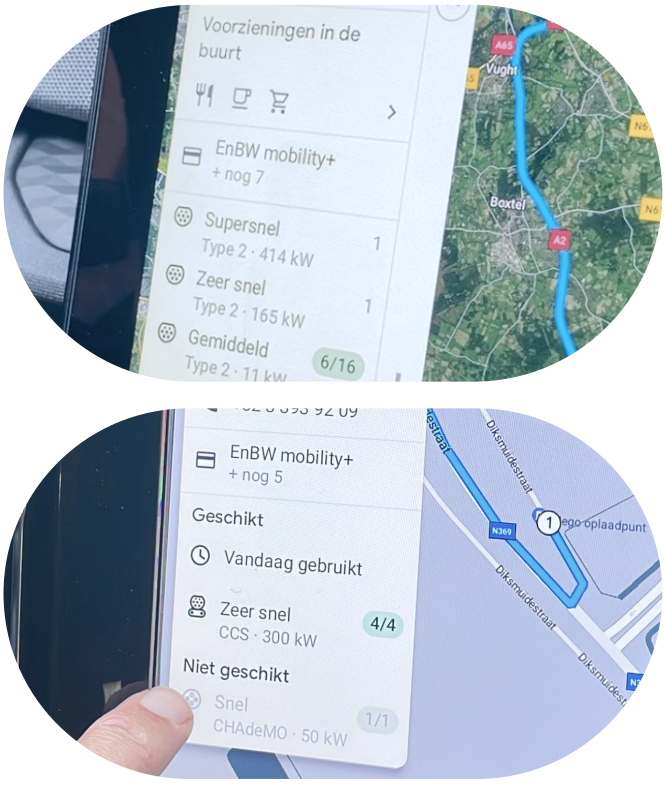


Figure 22 The charging station's information showing on the Google Map in car.

Navigate

In the "Navigate" phase, drivers proceed to their intermediate stop or final destination, where they anticipate having access to charging points. Some individuals opt to connect their smartphones to their vehicle's systems using platforms like Apple CarPlay or Android Auto, depending on whether their in-car system effectively aids in locating charging stations. Others may mount their phones to view charging point locations and complement their in-car navigation system (See Figure 23).



*Figure 23 The driver used **E-Flux App** to find a charger compatible with his charging pass. Also, the phone acted as a main tool for him to navigate with Google Map.*

Access the charger



Figure 24 The charger built in Carrefour's parking space in France. The picture is provided by one of the participants.



Figure 25 The "avocado sign" to indicate where the charger is. The picture is provided by one of the participants.

During the "Access the Charger" phase, users may sometimes find it necessary to deviate slightly from the main route to access charging facilities in nearby towns or cities. However, in most cases, **drivers tend to opt for charging at rest areas conveniently situated alongside major roads**, such as highways. Charging points are scattered across diverse locations, including outdoor supermarkets' parking spaces or underground parking lots (See Figure 24). Accessing these charging points can occasionally involve additional parking fees and may demand time and effort in locating the charger.

In larger parking facilities, the design of clear and precise signage for charging point locations becomes crucial to prevent drivers from wandering aimlessly. Some interviewees noted the need to be meticulous in searching for the "avocado" sign, as illustrated in Figure 25, to pinpoint the actual charger's location.

Authenticate

Once the vehicle is parked, the final stretch before recharging begins. Currently, there are three primary methods for authenticating and activating charging points: physically swiping a charging pass, using the CPO or EMSP's app, or scanning a credit card for prepayment to initiate the charging point. **Physical charging passes remain the predominant choice for use**, especially for slow-charging points along the roadside that do not typically offer card scanning or app connectivity functionality. In contrast, **fast-charging points often found at gas stations provide more diverse authentication options** (See Figure 26).

While users who exclusively rely on specific charging networks encounter few authentication challenges, issues tend to emerge when embarking on unfamiliar journeys. The complication arises from the fact that some charging points, though seemingly public, are actually privately owned or operated by businesses. Consequently, standard charging passes cannot be used in such cases. Crossing borders adds another layer of complexity due to variations in roaming protocols between countries and differing collaboration regulations among CPOs. Hence, longer and less familiar journeys are more prone to facing difficulties when it comes to effectively activating charging points. This led to the scenario selection decision in *Chapter 5* to demonstrate the concept.



Figure 26 The left screen shows multiple ways to start charging with the fast charger of Fastned. The right picture demonstrates the user using physical charging pass to start a slow charger.

Charge & Wait

Leave & Payment

Finally, there's a waiting period while the charging completes, and some users will check the accuracy of the recorded charging time and price (See Figure 27). During this time, most users occupy themselves with their smartphones, and some engage in other activities such as eating, shopping, or visiting friends while their vehicle charges. After completion, users who need to report expenses for reimbursement review their charging records. In cases where there was an unexplained issue or malfunction during the previous stages, users check for incorrect charges. One interviewee shared an incident where they couldn't activate the charger due to an unknown fault, so they switched to the adjacent charger, resulting in double charges. They had to contact the CPO's customer service for a refund, which increased distrust in the user's charging experience.

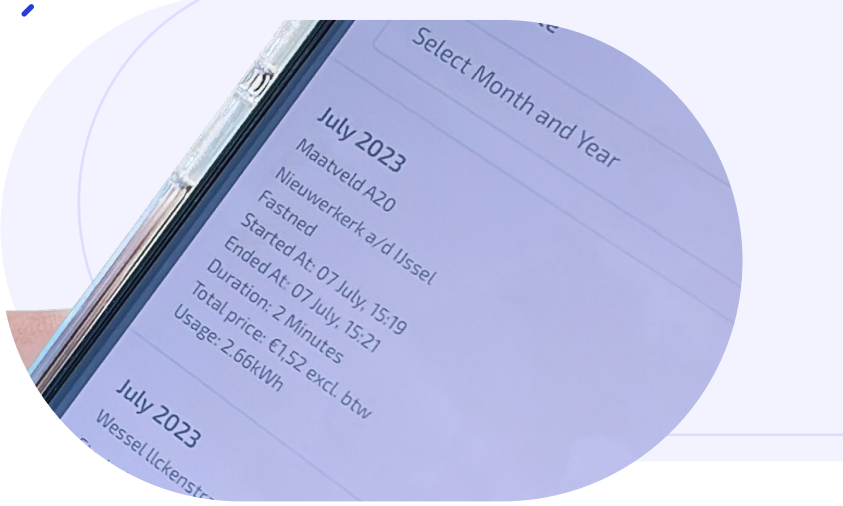


Figure 27 The user checks the charging fee on his E-Flux App after a session with FastNed super charge.

3.4.1.2 User pain points section

The segment filled with red cards is the statement cards interpreted from the user quotes related to the negative feelings they have throughout the journey (See Figure 28). Looking at these processes, respondents' thoughts and feelings on each stage are clustered mainly in the central area, most of which are represented by red statement cards capturing pain points mentioned by users. Positive experiences mentioned by a few users are represented by green statement cards. It's important to note that the interview questions were focus on identifying user pain points, which is why green cards are relatively scarce. This doesn't imply that there were no positive feelings at each stage. These pain points are further grouped into major challenges, which ***answer the Research Question 1*** and will be discussed in *Chapter 3.4.2*.

Identified the Challenges to answer the ***Research Question 1***

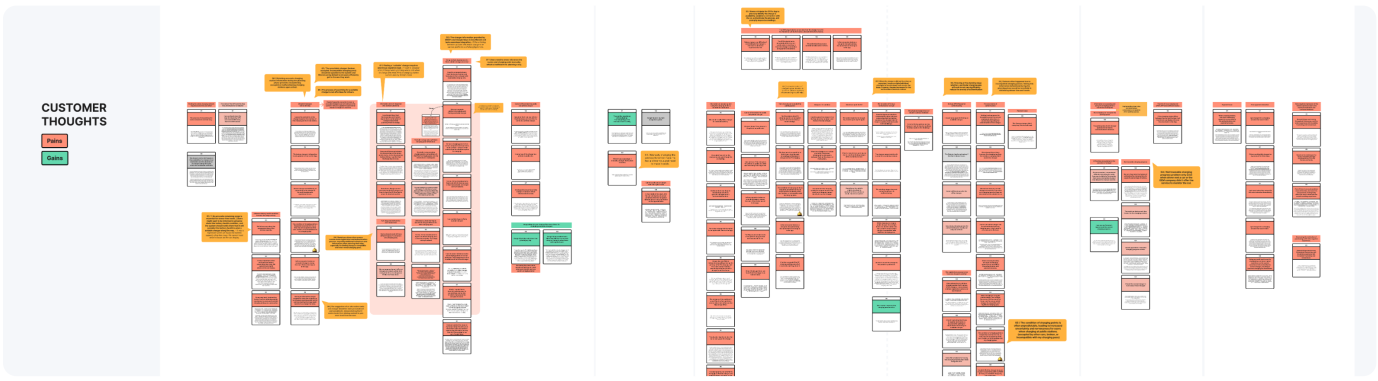


Figure 28 The user pain points statement cards.

3.4.1.3 Other sections

Below the opinion cards are **blue cards derived from quotes where respondents mentioned their needs or expectations. These latent needs serve as the primary source of information for generating design guidelines to inspire future service developers in Chapter 4.2.** The "Plan & Select" phase also includes a distinct group of **yellow cards representing influential factors that users mentioned affecting their choice of charging station** (See Figure 29). These yellow "influential factors cards" were specifically organized to ***answer Research Question 2*** in Chapter 2.4. By comparing these factors mentioned by users with those found in the earlier literature, new factors introduced by this research emerged. This compilation is presented in Table 3 in Chapter 3.4.3.

Last but not least, the emotional graph at the bottom of the journey map clearly illustrates that **users encounter more issues in the "Plan & Select," "Access the charger," and "Authenticate" phases** than the others. In the following chapters, these issues are categorized into three major challenges that hinder users from achieving a seamless charging experience, addressing Research Question 1 in Chapter 2.4.

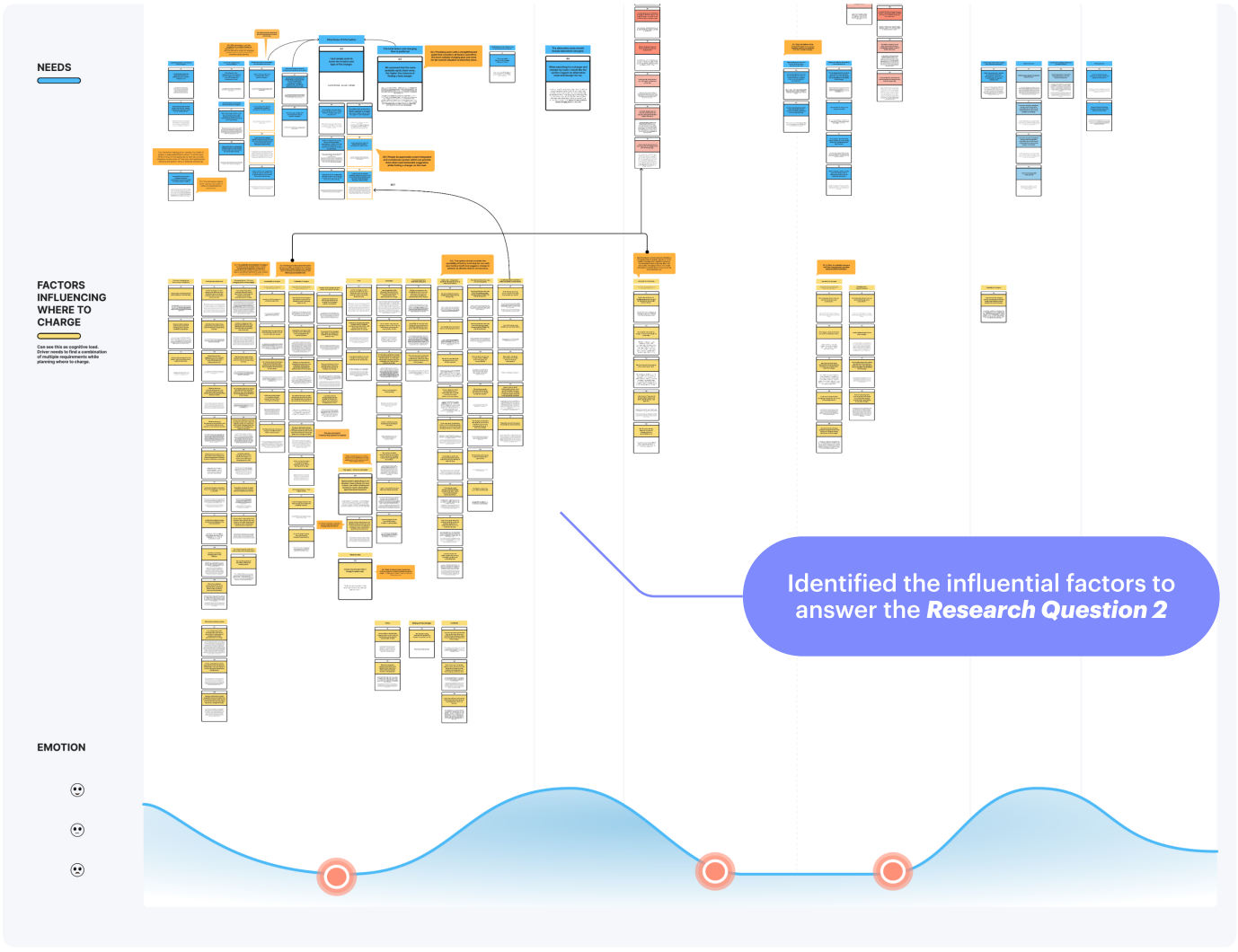
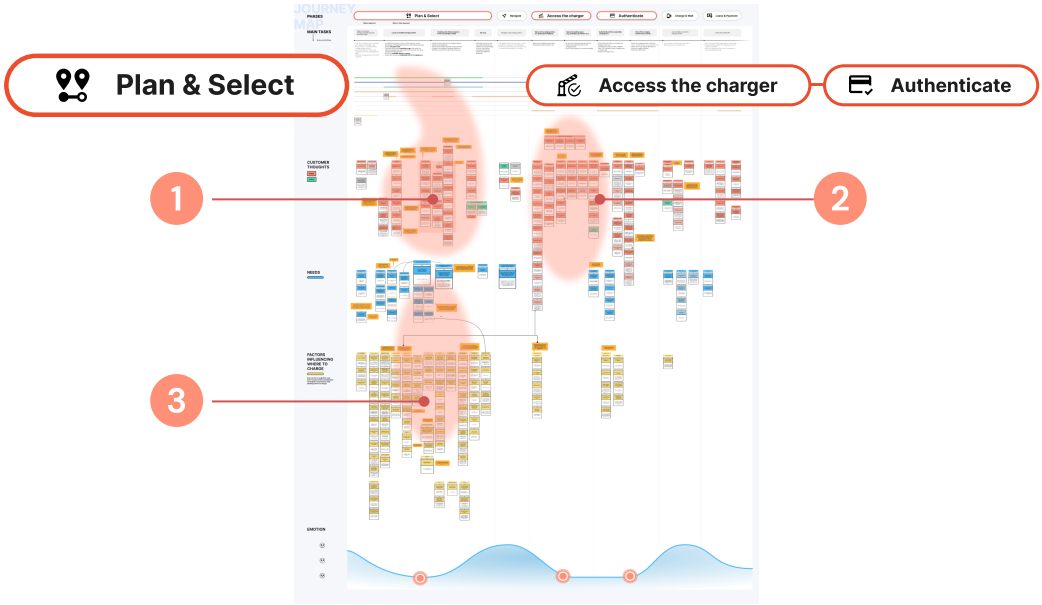


Figure 29 The blue cards derived from quotes where respondents mentioned their needs. The yellow cards contain the influential factors of charging decisions. At the bottom is the emotion graph indicating users' feeling throughout the journey.

3.4.2 The Challenges hindering BEV drivers' seamless journey

Three main challenges (Figure 30) hindering a seamless charging journey is identified as followed: Fragmented Information, Unpredictable Charger Availability, and Insufficient Context Awareness. This findings answer the Research Question 1 in Chapter 2.4.

Challenges identified through mapping out the user journey



01

Fragmented Information

Users are required to cross-reference and overlay information to find a charging station that matches all their needs.

#Hassle #Not Effortless

02

Unpredictable charger availability

Users need to guess charger availability and calculating the likelihood of accessing a functional charger with limited station information.

#Unaccessible #Unavailable #Occupied

03

Insufficient context awareness

Users need to consider and process all the influential factors of their driving context to find a compatible, feasible, and hopefully workable charger manually.

#Not Considerate

Figure 30 Three main challenges hindering a seamless charging journey.

3.4.2.1 Pain points of each challenge

01

Fragmented Information

In the simplest charging scenario for electric vehicle (EV) drivers, several steps come into play. They begin by checking their vehicle's State of Charge (SoC), ensuring compatibility between their car's connector and the charging network, verifying the charging station's availability, and consulting a navigation system to assess traffic conditions and navigate to their chosen destination. Throughout this process, they **frequently must cross-reference and integrate information from multiple sources to locate a charging station that fulfills all their criteria.** Figure 31 provides an overview of the common platforms and steps individuals must navigate when seeking the ideal charger to recharge their EV.

Figure 32 then visually represents the information available across various platforms that users employ. **Electric vehicle manufacturers' platforms**, often provided by automotive OEMs, typically furnish fundamental details like battery status and basic car functions such as unlocking and adjusting in-car air conditioning.

Next in line are **in-car navigation and route planning systems.** Google Maps, recognized as one of the most extensively used navigation systems, offers comprehensive, real-time road information. Individuals can search for both their destination and charging stations en route within Google Maps. It also incorporates uncomplicated filters, as depicted in Figure 21.

Last but certainly not least, the **Applications provided by CPOs and EMSPs** serve as pivotal tools for users in locating chargers compatible with their charging passes and EVs. Within these apps, users can access simple filters such as charging power, connector types, or nearby amenities. However, these filters necessitate manual selection by the users.

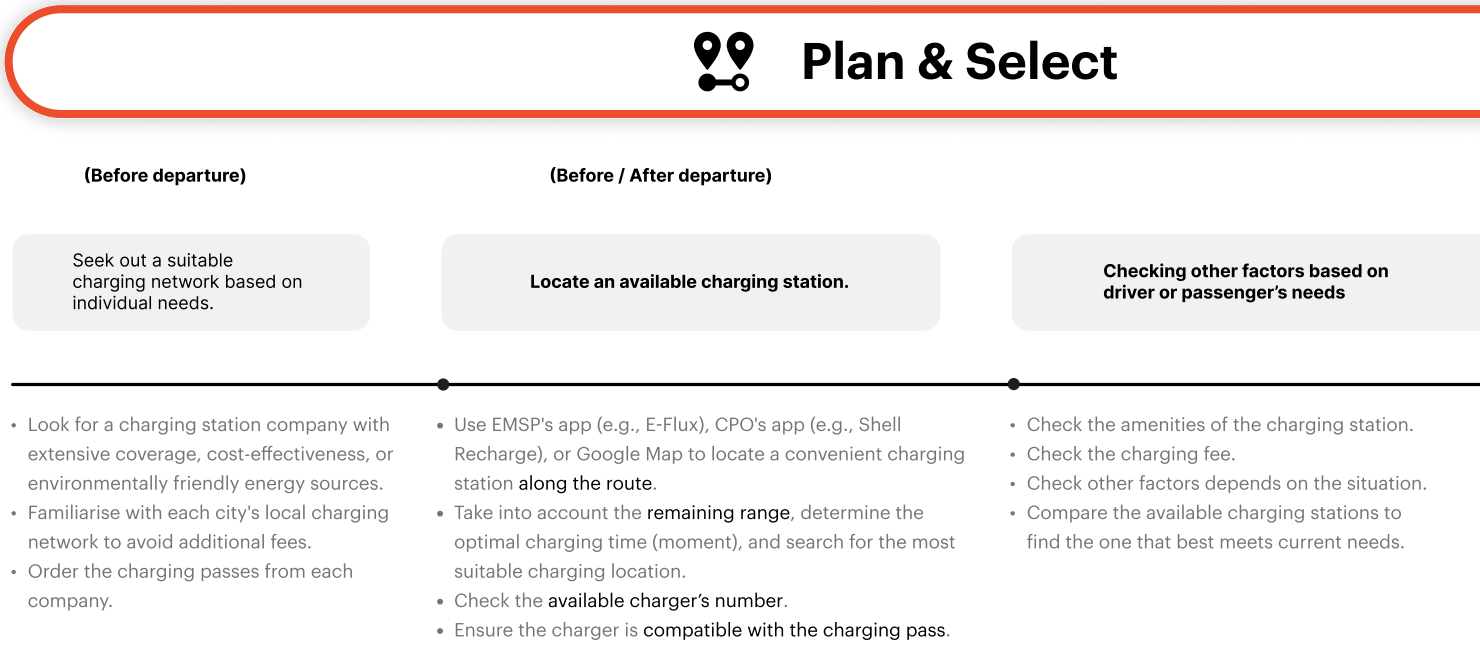


Figure 31 The initial phase of the charging journey.



OEM's APP

In the App, it only contains the climate control and lock/unlock the door function. User can only check how far the battery is charged.



In-car Map

During the observation, the Google Map stuck at one charger and appears to be offline for unknown reasons. Thus, the driver turn to ABMP to search possible route. However, the information there is too overwhelming to be quickly processed.



CPO / EMSP's APP

These kinds of App offer the real-time data of their own charging network. However, when people obtain multiple charging pass, they need to check all those Apps to gain an overview of the compatible chargers on the road. Then, sometimes those services will guide users to Google Map and start a navigation.

Figure 32 Three main service types users use within the charging journey.



Set to go

- Manually transfer all the route planning from one platform (e.g. Shell's App) to the in-car display.
- Comparing the route planning of different platforms.

Navigate to the charging station

- Use Apple CarPlay, Android Auto, or other services to navigate to the destination.
- Follow the voice instructions and glance at the directional prompts on the screen.

Due to the fragmented distribution of information regarding the vehicle, charging stations, and route conditions across these platforms, users frequently find themselves having to navigate through multiple sources to compile enough real-time data regarding the availability and locations of charging stations along their chosen route. Still, some participants opt for only one or two reputable CPO or EMSP) platforms, while others use a combination of platforms. **However, a common challenge is the need to switch between these platforms and the in-car navigation system or manually input charging station locations.** This disjointed experience can lead to additional effort and time spent confirming details. Although some vehicles offer trip plan syncing with the in-car navigation system, not all have this feature. As a result, many users prefer planning longer trips on their mobile phones, reserving in-car navigation for shorter or simpler journeys.

While some EMSP services (e.g., A Better Route Planner, ChargingMap, etc.) offer trip planning with customizable features, manual input and planning can still be time-consuming and overwhelming. Users have expressed the desire for a direct copy-paste function from their plans into Google Maps (Refer to Figure 33). In essence, true seamlessness involves **effectively integrating information from various services into a unified platform or enabling seamless information flow between platforms**, reducing distraction and allowing users to transition between touchpoints effortlessly.

"...why isn't there a way to directly copy and paste what I've planned into Google Maps? That way, I wouldn't have to input each charging station one by one."

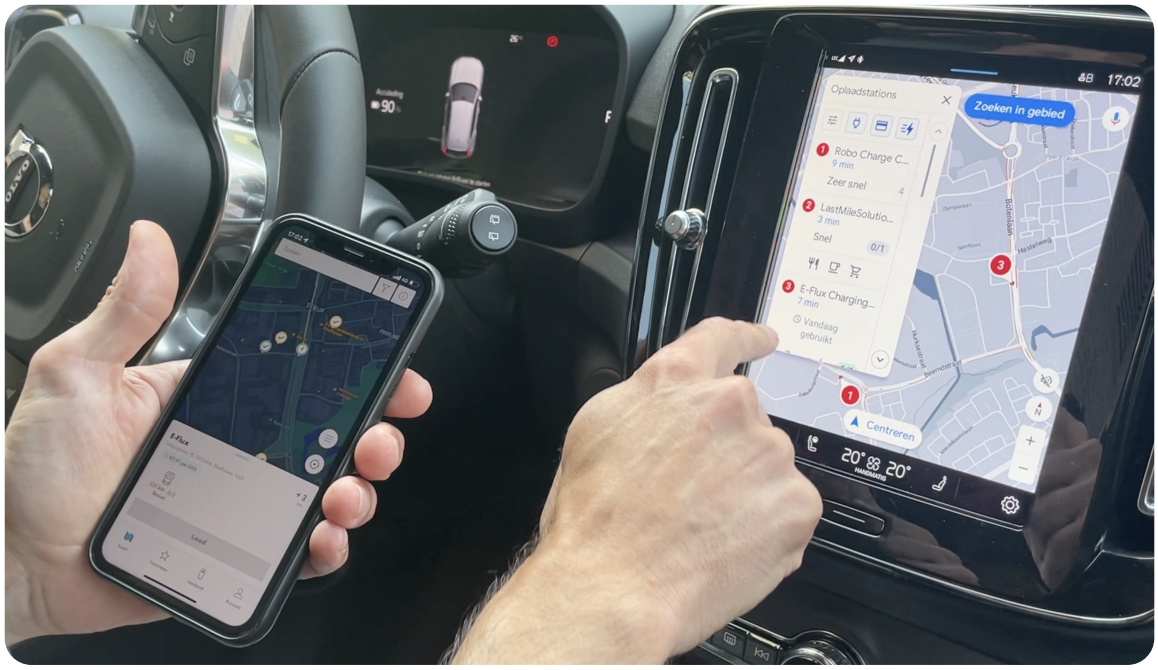


Figure 33 Participant is complaining that he needs to cross-reference information between platforms.

02

Unpredictable charger availability

After finally finding a charging station that meets their criteria, many respondents still expressed that they often encounter situations where the charging station is unusable upon arrival. Most of them straightforwardly conveyed feelings of uncertainty regarding the availability of the charging station before arriving at the location.

"I look up all the charges. However, they are not OK. They're either taken and sometimes they show they're available on the map or in apps. However, they're broken, so they don't know it's broken."

Me: And when arriving can you always access the charging point or it's not the case?

"No, no, that's bit difficult sometimes."

Me: Could I ask what's the experience happen to you there?

"A lot of times there's another car there like I just mentioned, or it's broken, or that the app doesn't work. Nahh (sounds fretful), ***it's always a bit unpredictable****."*

The feelings of unpredictability stem from various reasons. First, **malfunctioning chargers** may not be updated in real-time on platforms, leading to the discovery of unusable stations upon arrival, especially frustrating in urgent situations or low battery scenarios. The second one is authentication uncertainty within the charging network. Users struggle to distinguish between public and private charging stations on maps. They sometimes encounter private company-owned stations that are inaccessible unless they're an employee of that company, despite using the same charging network (e.g., Shell charging stations).

Moreover, **diverse roaming protocols** exist among charging networks from different CPOs and countries. Users must determine **if the charging station supports their specific charging pass authentication.** In the Netherlands, different regions may have diverse dominant charging networks. When users are not familiar with a specific area, they might end up paying higher fees when they don't obtain a native network's charging pass. This further complicates the quest for finding a compatible charger.

Furthermore, **charging spots are sometimes occupied by non-electric or non-charging electric vehicles,** causing significant inconvenience for users. This exacerbates the existing uncertainty, and it's worth noting that current services struggle to address this issue effectively. Additionally, there's a potential risk that the charger could be occupied by other vehicles upon the user's arrival due to the time gap between checking for availability and reaching the station (See Figure 34).

The findings suggest that the implementation of a reliable prediction system, offering real-time information about charging stations and suggesting alternative charging options when the preferred one is unavailable, could significantly improve the seamlessness of journeys, effectively addressing the challenges mentioned here.

Me: While planning where to charge your car, do you always find the necessary information?

"Not always, but sometimes chargers are broken, and you cannot see it."

" OK, let's say for occupation. If it's occupied, it says it, but it could be two minutes before I arrived and uhmm... what I could do? If it's a busy street, I will be really angry about it."



Figure 34 Users express the unpredictable charger status makes her feel uncertain for the trip.

03

Insufficient Context Awareness

Last but certainly not least, users frequently need to consider their car's status and their personal situation when searching for a suitable, practical, and ideally functioning charger. Apart from dealing with fragmented information and the unpredictable status of chargers, **the lack of context awareness within current services poses a significant obstacle to a seamless charging experience.** Based on user research, to recommend the most suitable charger to users on the road, a context-aware system should take into account various factors: the vehicle's status (e.g., battery's State of Charge and State of Health), the compatibility between the charging network and the car, the driver's fundamental profile and current preferences, as well as the real-time conditions on the road and in the environment.

Four categories of “Influential Factors”

Consequently, **four primary categories of influential factors that impact drivers' charging decisions have been delineated** (refer to Figure 35): Charger & Charging Network, Vehicle Features & Condition, Driving Behavior & Personal Preference, and Route & Environment. These influential factors within each of the four categories have been distilled from the "influential factors cards" found in the journey map (Chapter 3.4.1) and are comprehensively detailed in Table 3 of Chapter 3.4.3.

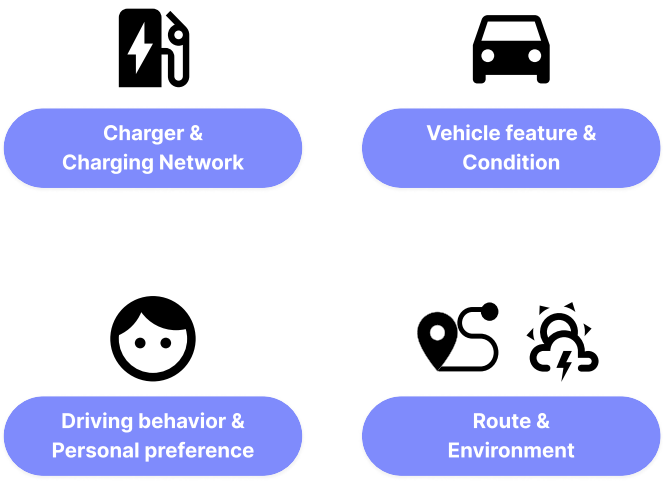


Figure 35 Four categories of influential factors impacting users' charging decisions.

The lack of Contextual Awareness Across Service Types

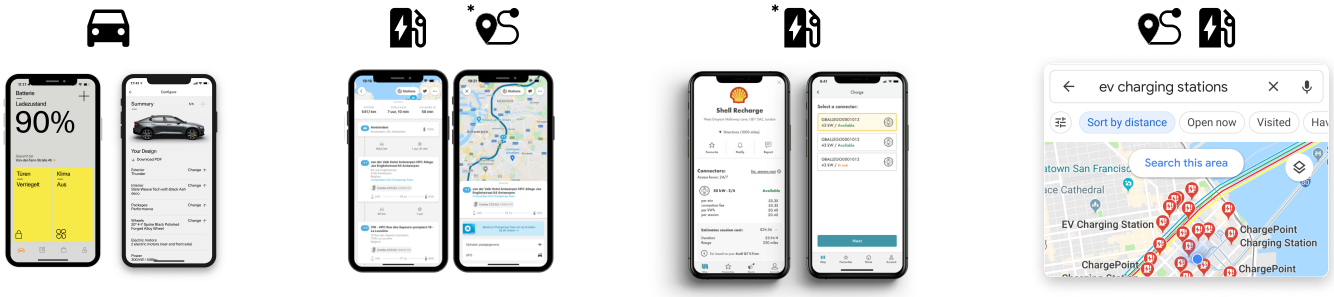
In the "Fragmented Information" section, the primary services relied upon during charging journeys were discussed, including Automotive OEM's App, EMSP's Services, CPO's Services, and In-Car Navigation System. The fundamental functionalities of these services were elucidated in that section. Here, in Figure 36, the primary categories of contextual factors typically encountered within these services are outlined.

The **OEM's App** mainly encompasses vehicle-related data. EMSP's Services, on the other hand, provide comprehensive information about their proprietary charging networks. Most **EMSP services** also offer basic route planning capabilities. For example, ChargingMap's service allows users to customize their charging point and route preferences, such as prioritizing charging network options, specifying the minimum desired battery level upon arrival at a charging stop, or indicating preferences to avoid tolls or motorways, among others. Additionally, users can manually input their vehicle model to refine route planning for more accuracy. However, it's important to note that these customizations still necessitate manual input from users, adding complexity and time to the route planning process. Moreover, pre-inputted information may introduce inaccuracies and may not truly represent the current contextual factors during the journey. **CPO services** exhibit a similar pattern, with their understanding mostly confined to their own charging point information.

Navigation systems like Google Maps excel in providing detailed Route & Environment factors. Nevertheless, beyond technical issues like system crashes, in-car navigation systems lack access to vehicle information and comprehensive drivers' preference. This limitation hinders their capacity to offer superior route and charger suggestions. For instance, they cannot access real-time updates on the vehicle's battery status for optimal charging route planning or prioritize driver preferences of charging networks to provide user-centric recommendations. Therefore, in Figure 37, the user summarizes their thoughts on the built-in navigation system with the following statement:

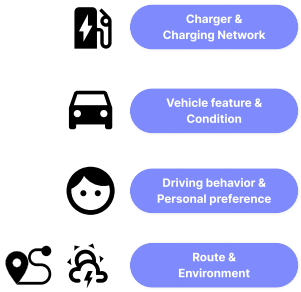


Figure 37 one participant expressed his negative feelings about the in-car navigation system.



OEM's APP	E-Mobility Service Providers	Charging Point Operators	In-Car Navigation system
• Vehicle factors	• Charging network • Driver preference • Route	• Charging network • Driver preference	• Route and environment • Charging network • Driver preference
• Driver preference • Charging network • Route and environment	• Vehicle factors • External environment	• Vehicle factors • Route and environment	• Vehicle factors

Figure 36 The influential factors' categories encountered within each type of services.



3.4.2.2 Conclusion

To answer the first research question asked in the Chapter 2.4, there are three main challenges hindering a seamless charging journey: ***Fragmented Information, Unpredictable Charger Availability, and Insufficient Context Awareness.*** To address these challenges, designers and researchers should think about a solution that equipped with following three things illustrated in Figure 38.

In order to ensure that the proposed solution incorporates the criteria mentioned earlier, **it is essential to explore what information needs to be integrated and what context should be taken into account to predict the availability of a charger and provide relevant recommendations to users.** Therefore, the following chapter will delve into the influential factors that influence charging decisions. This will help explain what factors should be considered in a potential solution when presenting charging options to users.

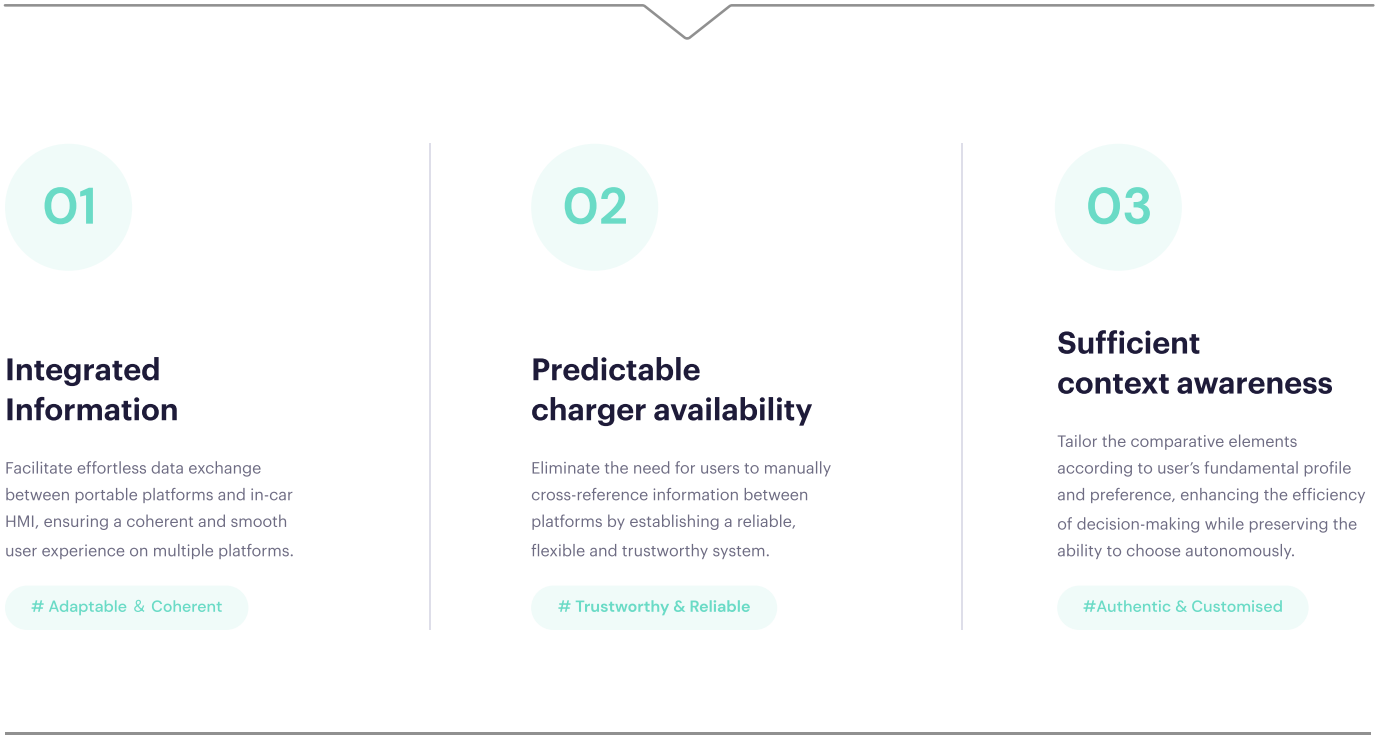


Figure 38 The initial phase of the charging journey.

3.4.3 The influential factors of charging decisions

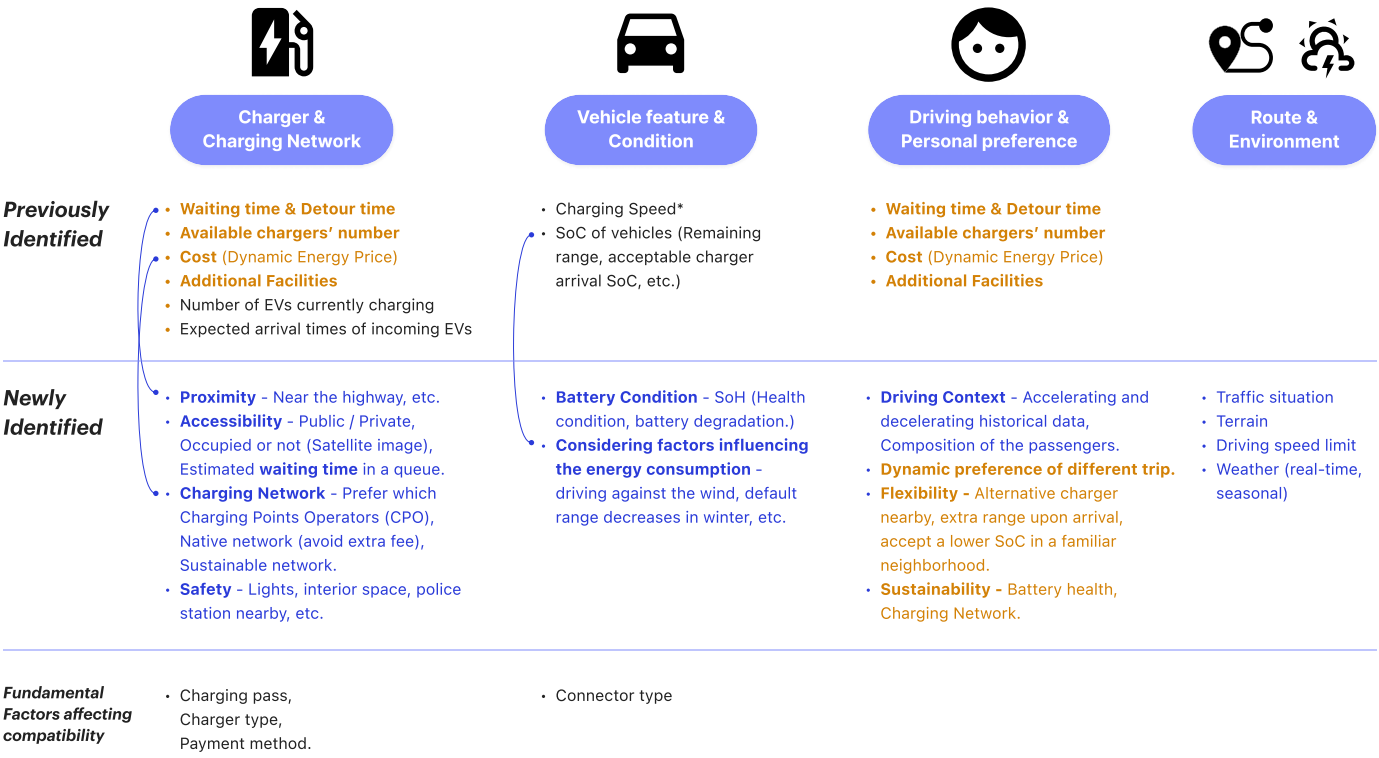


Table 3 Influential factors under the four main categories.

The Table 3 provides a clear distinction between the influential factors previously identified in the literature and the newly discovered factors in this research (highlighted in purple). Additionally, fundamental factors are documented at the bottom of the table. The details within each category are as follows:

Charger & Charging Network

Within the context of charging stations, several factors have been identified based on previous literature. These factors include considerations such as waiting time, detour duration, pricing, the availability of charging points, and nearby facilities. An interesting element can be added on is the **Proximity**. Many respondents expressed their reluctance to leave highways and venture into city areas in search of charging stations. This suggests that users not only factor in the physical distance to a charging station but also have a psychological aversion to detours that involve transitioning from main roads to unfamiliar city streets. This trade-off is reminiscent of the existing feature in Google Maps, which provides options for selecting the shortest distance or the route with the least walking, even if it may take more time. Some users prefer the latter option for the comfort it provides. Proximity is part of minimizing the detour time, which also include walking time when users park their cars and need to walk back to their destination.

In addition to proximity, **Charger Accessibility**, as one of the influential factors, encompasses other important elements. Firstly, the service should distinguish between private and public chargers to prevent users from being directed to inaccessible chargers located in private parking lots or those that cannot be accessed using their regular charging passes. Secondly, users often express concerns about parking spaces at charging stations being occupied by other vehicles. In the case of open, flat parking lots, satellite imagery could be utilized to notify users when these spaces are occupied. Moreover, providing an estimated waiting time at busy charging stations can give users an idea of how long they might need to wait for a charger.

Another identified influential factor is the **preference for a Charging Network**. While EMSP's apps already offer a function to set preferred charging networks, users also need to consider the native network to get the best deal. **Eco-conscious drivers** may also consider whether the charger uses sustainable energy sources. Additionally, users may take into account the **safety** level of a charging station, particularly when driving at night or with family members. Some individuals even care if the charger is equipped with a roof, especially on hot sunny days or during rainy weather.

Basic criteria such as charger compatibility with the driver's charging pass and the vehicle's connector type are included in the **fundamental factors** section.

Vehicle feature & Condition

The first factor this research draws upon is **“Charging speed”**. In previous literature review section, the charging speed is mentioned. It is a simplify representative of charging time. **Charging time** is dependent on many conditions like the car battery size, the capacity of the charger and the battery level percentage desired by the user (Visaria et al., 2022). Since it is mainly related to the vehicle’s battery condition, this research put it in the “vehicle” category. The State of Charge (SoC) is mentioned a lot by the participants as well since it’s a basic information that they check the first while considering if they need to charge or not. Some users would just check the remaining percentage, while others would calculate the remaining range in kilometers and think about how much more they need to get to the destination.

The incorporation of the **battery's State of Health (SoH)** and other energy consumption factors is necessary to estimate a possible stop along the route. SoH significantly impacts battery degradation. Some users want insight into battery health to prevent unexpected power drops, primarily to prevent any unexpected drops in battery power that can exacerbate range anxiety. Others prefer simplicity, desiring to know if remaining range meets their needs, with SoH considered in the background calculations. This need extends to the influential factors like wind resistance and temperature affecting energy consumption. Users seek summarized information rather than detailed reports, highlighting the importance of an inherently context-aware service. This allows the system to calculate crucial data points in the background and offer relevant recommendations.

Driving Behavior & Personal Preference

In the literature review (Ch. 2), user preferences were examined. These preferences align with the factors categorized in the "Charger & Charging Network" section, encompassing waiting time, detour duration, pricing, charging point availability, and nearby amenities. Since these factors are not exclusively tied to the charger itself but also reflect driver preferences, they have been included in both categories in this research.

A novel aspect to consider is **the context of the journey,** which can significantly influence the selection of charging stations. For instance, during a family trip, parents may prioritize amenities near the charging station more than they would on their regular outings. Furthermore, it's crucial to acknowledge that **user preferences are dynamic** and can change based on different trip types and passenger compositions, impacting charger selection in the moment.

Additionally, this research has identified two main supplementary factors that users consider: **"Flexibility" and "Sustainability."** "Flexibility" relates to users evaluating how many extra range (kilometers) an alternative route or charger can provide. Interviewees also noted that when they are more familiar with a region, they may be willing to accept lower flexibility, meaning they are comfortable with less remaining range upon arrival. "Sustainability" is a more straightforward factor, with some participants mentioning that they exclusively choose chargers like Engie's because they purchase green energy. Moreover, car manufacturers may recommend users to maintain their battery's state of charge between 20% and 80% to extend the battery's lifespan. Users might also opt to minimize the use of fast charging stations themselves, as frequent use can impact the battery replacement rate.

The user profile, including the factors highlighted in orange in Table 3, becomes a crucial element for the concept in Chapter 5 to consider when generating relevant suggestions. As previously mentioned, user preferences follow dynamic patterns. Figure 39 demonstrates how the design concept presented in Chapter 5 utilizes these user-centric elements to formulate **an adaptable driver profile**, enabling the service to prioritize and recommend suitable chargers or routes based on individual user needs and preferences.

Route & Environment

The literature review in this research does not delve into the discussion of route and environmental factors. However, during the interviews, participants frequently raised concerns about traffic conditions and weather, which are external factors that can significantly impact battery capacity. Consequently, these factors have also been incorporated into the "Vehicle Feature & Condition" category.

In addition to traffic and weather, alterations in terrain, road speed, and other elements along the route can also affect battery consumption. It is evident that when driving on the road, new influential factors related to the route and external environment may continuously emerge. Furthermore, weather conditions can influence users' preferences regarding charging facilities, such as whether they prefer a charger with a roof or an uncovered one.

Therefore, it is essential to consider these contextual factors related to routes and the environment. Doing so allows the service to provide more thoughtful choices for drivers and offer recommendations to charge earlier in anticipation of potential factors like traffic jams or challenging terrain that may consume more energy than initially expected.

Charging Decision Preference

Dynamic preference of different trip

- **Basic : Available & Compatible Charger**

- **Waiting time & Detour time**
  Including convenience of rerouting
- **Cost**
  Considering dynamic Energy Price
- **Additional Facilities**
- **Flexibility**
  Alternative charger nearby, extra range upon arrival, accept a lower SoC in a familiar neighborhood.
- **Sustainability**
  Battery health, Charging Network.



Figure 39 The concept of dynamic user profile.

3.5 Discussion & Insights

Returning to the research gaps identified in the literature review, this study effectively addresses Research Questions 1 and 2, thereby bridging the identified gaps. Figure 40 provides a clear visualization of the previously acknowledged research gaps and how this research contributes to addressing them.

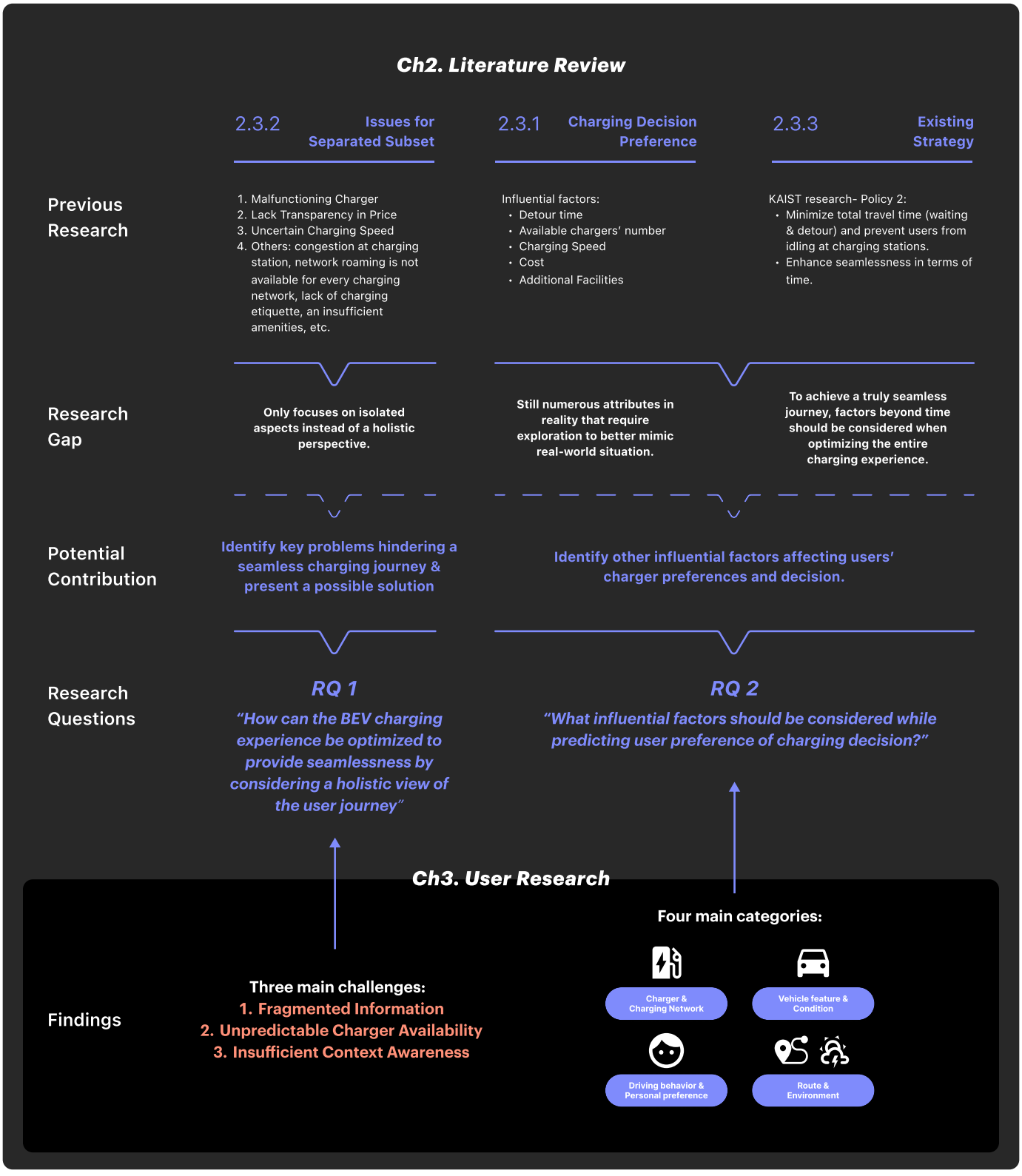


Figure 40 The potential contribution of this qualitative research.

Previous research identifies issues that user faced during the charging journey. However, they only focus on study the isolated aspects instead of looking at the charging journey from a holistic perspective, making the issues hindering a seamless journey remain unknown. Thus, this thesis aims at figuring out the key problems hampering a smooth and integrated charging journey and present a possible solution to address them. Through conducting the survey, interviews, and observations, three main challenges of current fragmented charging journey are revealed: Fragmented Information, Unpredictable Charger Availability, and Insufficient Context Awareness. **In Figure 41, how these three challenges echo to the literature findings is presented.**

Fragmented Information aligns with the findings from Chapter 2.2.2. Despite ongoing improvements in charging infrastructure deployment, standardization, and authentication methods, electric vehicle drivers continue to invest significant time and effort in gathering essential information about charging stations. This includes details such as location, availability, accessibility, charging speed, and pricing, all tailored to meet their specific charging needs. In our user testing, participants frequently raised similar concerns, highlighting the need to cross-reference and combine information from various sources to locate a charging station that fulfills their requirements. This, in turn, adds extra time and effort to their EV journey, resulting in negative feelings during the charging process. This research suggests facilitating a smooth data exchange across platforms or use one-stop solution to integrate all crucial information in order to enhance users' efficiency in finding a suitable charger.

RQ 1.



Figure 41 The challenges identified in this research align with the findings in the literature, and this research also contribute additional influential factors that can inform future solution development.

Secondly, ***Unpredictable Charger Availability*** echoes the findings in Chapter 2.3.2. Existing literature identified various issues within each stage of the charging journey, and our user research participants also mentioned problems like malfunctioning chargers with insufficient guidance for issue resolution and the misuse of charging spaces by non-EV or non-charging EVs. This study not only uncovers additional issues related to a flawed journey but also approaches these problems from a comprehensive and user-centric perspective. In essence, these individual challenges combine into a more extensive charging experience issue: users' inability to easily and swiftly predict the current availability of charging stations during their journey. Users are compelled to rely on limited resources to estimate the likelihood of getting a charger. Instead of individually addressing each minor problem, future design should recognize this underlying user need and provide corresponding solutions.

Lastly, there's the issue of ***Insufficient Context Awareness***. Previous research aimed to identify factors affecting users' charging decisions and predict their preferred routes and charging stations based on qualitative research findings. They listed several factors that users take into account, such as time, charging prices, the availability of charging points, and station facilities. These factors were also mentioned by the respondents in this study. However, this research introduces two additional factors that have not been previously considered: Flexibility and Sustainability. In designing future services, it's crucial to incorporate these five key influential factors that impact users' charging preferences: time, pricing, station facilities, route flexibility, and journey sustainability. These factors should form the basis for recommending relevant options to users. Additionally, beyond the basic information collected during onboarding, future services can proactively gather context by recording each driving and charging behavior. This approach enables the service to become increasingly attuned to the user's real-time needs, ultimately providing a seamless charging experience.

When reflecting on the initial Research Question of this project:
"What are the primary challenges and limitations experienced by Dutch BEV drivers that impede a seamless customer experience when using public charging infrastructure?",
this study synthesizes findings from both the literature review and user research to address this question. During the formulation of the user journey, a possible entry point of design intervention also emerged. The research suggests that by **introducing a charger suggestion service with three criteria mentioned in Figure 38, namely Integrated Information, Predictable Charger Availability, and Sufficient Context Awareness, during the early planning phase, there is an opportunity to alleviate issues faced by users during the subsequent stages of accessing chargers and authentication, thereby enhancing the overall seamlessness of the process** (Figure 42). A similar perspective is also mentioned in Eider et al. (2017)'s study.

Eider et al. (2017) aimed to provide route suggestions that balance the needs of users with those of stakeholders (e.g., grid operators) in the charging ecosystem. However, their solution primarily considers factors such as Battery State of Charge (SoC), State of Health (SoH), sustainability, grid stability, etc. While their research aimed to guide end-users' charging paths to assist in power grid stability or enhance the efficiency of renewable energy usage, the study of this thesis incorporates more elements related to end-user preferences, placing the user at the center of recommendations.

Therefore, armed **with a possible approach of design intervention and the criteria that this solution should encompass, this research employs the "How Might We" (HMW) framework to contemplate the next phase of design objectives, leading to the design goals outlined in Chapter 4.1.**

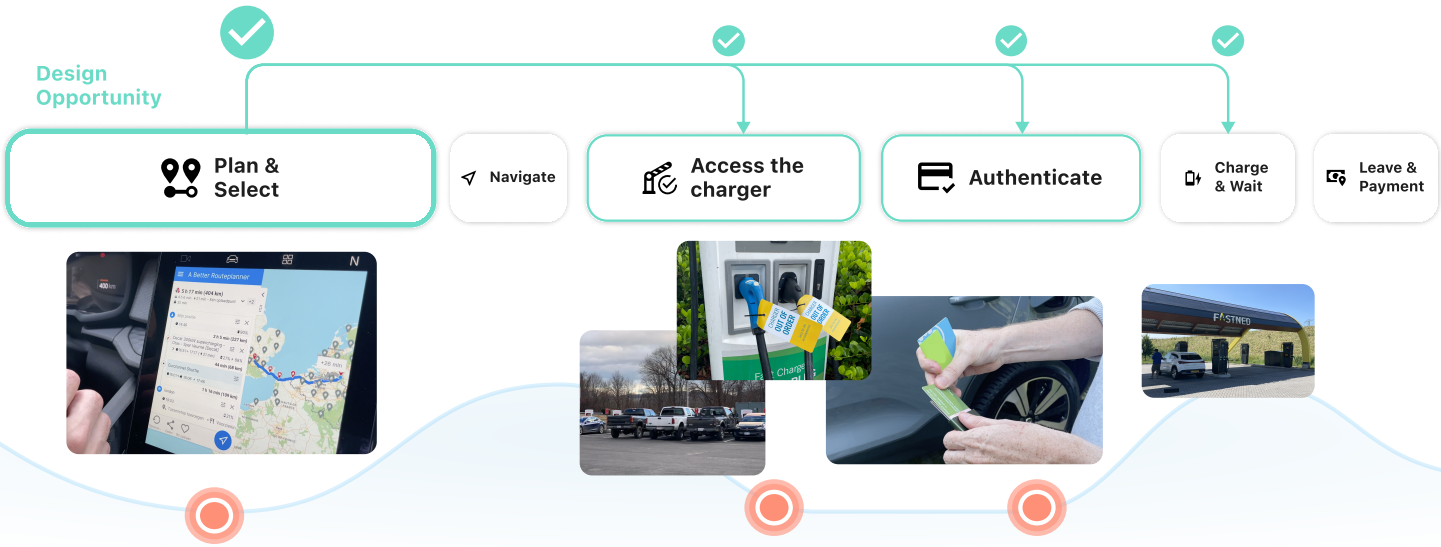


Figure 42 Streamline the overall charging journey with a design intervention at the planning phase.

3.6 Takeaway

1. The user journey map outlines the primary phases of the user's charging journey, highlighting that users encounter **more challenges in the "Plan & Select," "Access the charger," and "Authenticate" stages** than in others.

2. Research Question 1 is addressed through the identification of **three key challenges: Fragmented Information, Unpredictable Charger Availability, and Insufficient Context Awareness.**

3. Research Question 2 is answered by the identification and organization of **newly recognized influential factors** presented in Table 3. These factors offer valuable insights for future service developers, **enabling them to gain a deeper understanding of the driving and charging context and provide relevant recommendations** for a seamless charging journey.

4. Considering user preferences is vital for providing personalized recommendations to BEV drivers. These preferences are dynamic and can be influenced by various factors, such as the type of trip. It is essential to consider five key influential factors that impact users' charging preferences: time, pricing, station amenities, range flexibility, and journey sustainability.

5. A potential design solution involves the integration of a route suggestion system during the planning phase, streamlining the overall charging journey for users.

6. The latent needs identified by users (represented by the blue cards in the User Journey Map) serve as foundational elements for generating Design Guidelines in the forthcoming Chapter.

Design Focus

Intro

Chapter 1 provides the context for studying the "Public Charging Journey" of "BEV" drivers. The literature review in Chapter 2 identifies research gaps, which are addressed in the User Research presented in Chapter 3. This chapter combines the findings from both the literature review and user research to present the design goal derived from these insights. Furthermore, it introduces design guidelines distilled from the interpretation of user latent needs identified through interviews, offering inspiration for developing a concept that makes the public charging journey seamless.

Chapter Overview

4. 1 Design Goal
4.2 Design Guidelines



Develop & Refine

04

4.1 Design Goal

The target audience for the design primarily consists of **novice BEV drivers.** This choice is rooted in the fact that interview participants, who highlighted issues hindering a seamless journey, mostly have less than three years of experience driving BEVs. It's reasonable to assume that these newer drivers, with limited knowledge of navigating various platforms to make charging decisions, may encounter more challenges compared to those who have become familiar with the intricacies and settings of each service over time. However, it's worth noting that **even experienced drivers could face similar issues as mentioned in the interviews.** Therefore, if this concept can effectively address the problems faced by novice BEV drivers, it has the potential to benefit more experienced drivers as well. Additionally, it's important to mention that this research excludes Tesla drivers from its scope, as they have access to their own dedicated network, resulting in a relatively smoother charging experience compared to drivers of other vehicle types.

During the creation of the user journey, a potential entry point for design intervention is identified. It's clear that the current **planning phase** of a charging journey poses challenges for BEV drivers, making it difficult for them to make well-informed charging decisions effortlessly. This often results in a less-than-seamless user journey. To address this issue, our research suggests the introduction of **a new type of charger recommendation service** at the early planning phase, taking into account the three criteria outlined in Figure 38: **Integrated Information, Predictable Charger Availability, and Sufficient Context Awareness.** With these criteria, the service can potentially alleviate the difficulties users face when accessing chargers and dealing with authentication in later stages of the process. This, as shown in Figure 42 from the previous chapter, has the potential to enhance the overall smoothness of the user journey.

Therefore, during the project's design phase, a "How Might We" question is crafted to tackle the challenges:

Design Goal

"How might we create a route and charger suggestion system that adapts to user needs and contextual factors in real-time, providing transparent and insightful information while ensuring a seamless and intuitive user experience."

Figure 43 illustrates the current state of the charging journey with **existing services (the As-Is Journey)** and the potential transformation of the journey with the proposed design presented in this thesis. Under the current fragmented services, BEV drivers often face high cognitive demands when planning their trips and identifying suitable charging stations along the route. At times, this process can lead to a dead-end, leaving users frustrated and unable to locate a functional charger. Even after successfully finding a possibly working charging station and navigating to the charging stop, users may encounter situations where the charger inexplicably fails to operate, lacking any troubleshooting mechanisms. Or they might discover that their expected charging pass does not effectively activate the charging point. Consequently, the red journey depicted in Figure 43 involves numerous trial-and-error processes, sometimes even resulting in dead-ends.

The objective of the design phase, as indicated by the design goal, is to facilitate a seamless journey, as illustrated by the green line in Figure 43 (the To-Be Journey). The concept aims to streamline the charging decision-making process for users, guiding them not only to potentially accessible and available chargers but also recommending chargers based on their preferences and driving context. This approach offers users options that align with their immediate needs and preferences.

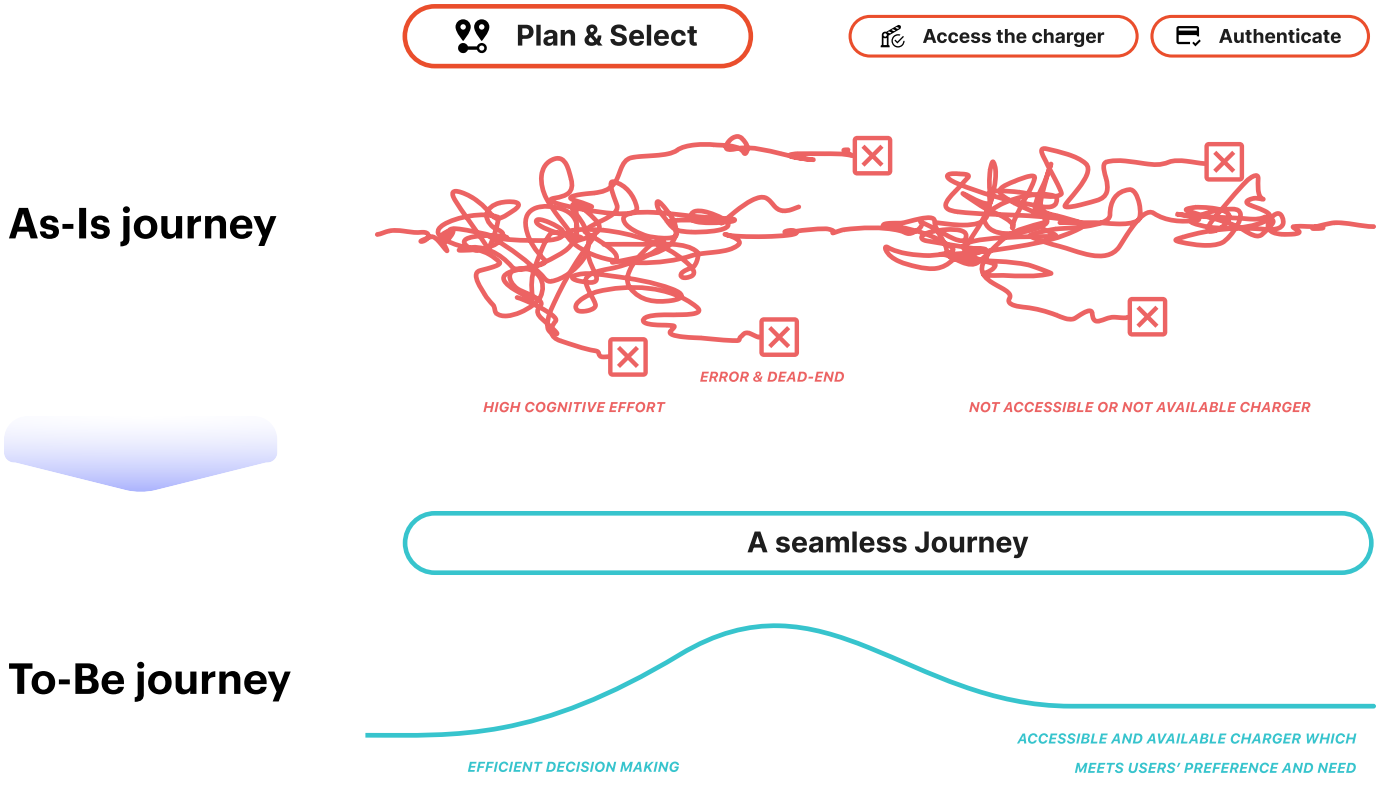


Figure 43 The comparison of current journey (red one) and the potential transformation of the journey with the proposed design presented in this thesis.

The terminology employed in the Design Goal corresponds to five Design Guidelines (Figure 44) derived from the user needs categorized within the User Journey Map. More comprehensive insights into these Design Guidelines will be provided in the upcoming chapter.

Design Goal <-> Design Guidelines

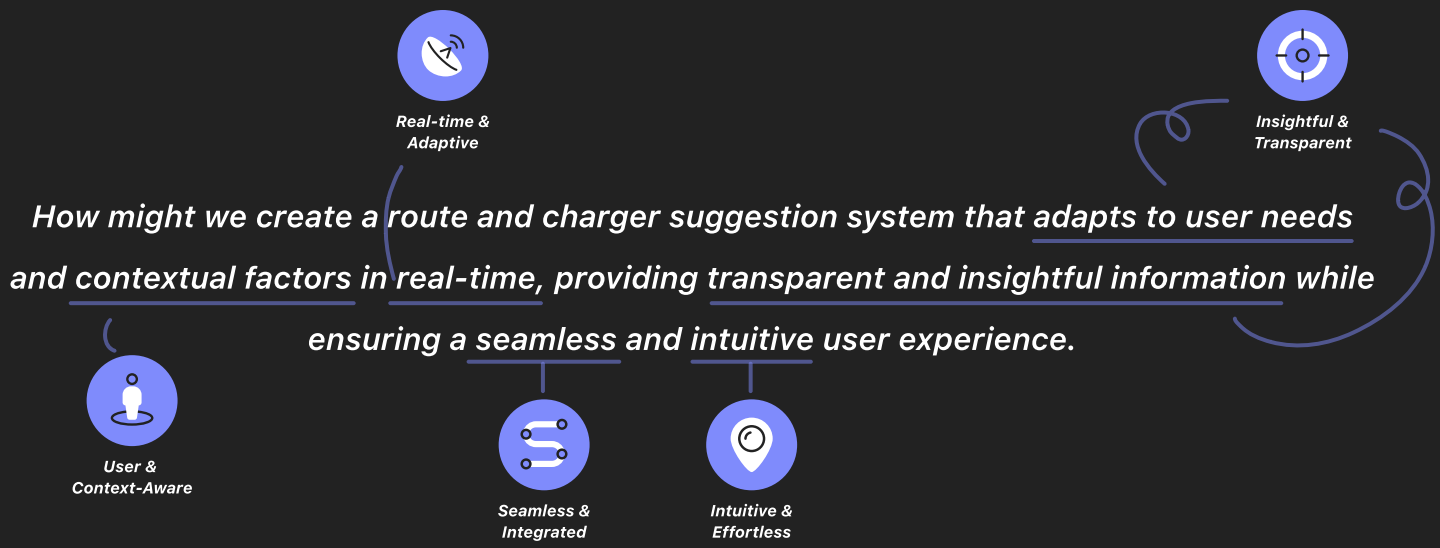


Figure 44 The Design Goal corresponds to Design Guidelines.

4.2 Design Guidelines

To fulfill the three criteria illustrated in Figure 38, which include Integrated Information, Predictable Charger Availability, and Sufficient Context Awareness, the proposed solution must adhere to the following design guidelines. Each Design Guideline's visualization is integrated into the final User Interface developed for concept validation. These principles are considered an integral part of the design concept presented in Chapter 5 of this thesis. Figure 45 is an overview of the Five Guidelines.

Design Guidelines' Overview

Seamless & Integrated

User & Context-Aware

Real-time & Adaptive

Insightful & Transparent

Effortless & Intuitive

Figure 45 The Design Guidelines' Overview.

Seamless & Integrated

- **One-stop solution**
- **Facilitate effortless data exchange**
- **Synchronize the fundamental user profile and preference across platforms**

1. One-stop solution

Offer a unified platform that enables users to seamlessly plan and complete their entire journey. This platform should establish a smooth connection between the vehicle and charger, manage authentication processes, and provide real-time charging status updates (See Figure 46).

2. Seamless Platform Transition

Eliminate the need for users to manually cross-reference information between different platforms. Ensure effortless data exchange between portable devices and in-car Human-Machine Interface (HMI) to create a cohesive and uninterrupted user experience during platform transitions.

3. Automated Profile Syncing

Streamline the automatic synchronization of user preferences and profiles across various platforms, as detailed in the "User & Context Aware" Guideline.

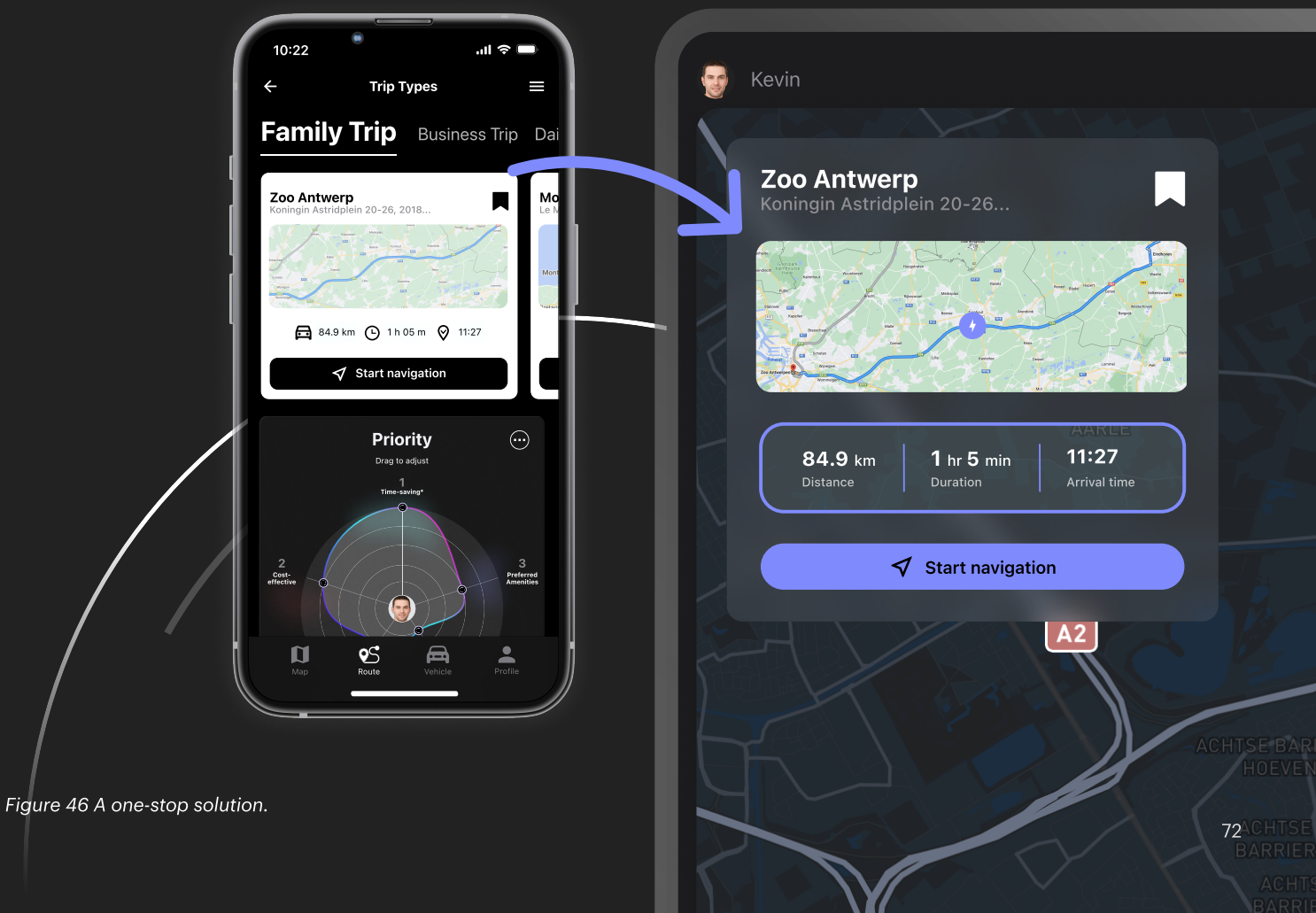


Figure 46 A one-stop solution.

4.2 Design Guidelines

User & Context-Aware

1. Ensure Charger Compatibility
Collect essential information such as the user's charging pass details and vehicle connector type to enable the system to efficiently present charger choices that are compatible with the user's setup.

2. Enhance Relevance of User Experience
Tailor comparative elements to align with the user's preferences, streamlining the decision-making process while preserving the user's autonomy. Recognizing that user perception and experience contribute to their expectations (Context-Aware Computing, n.d.), the system should store information from previous planning and charging sessions, calculate representative features (the influential factors), and compare them with the current context to actively provide relevant charger recommendations.

3. Account for External Influential Factors
Consider external variables such as weather conditions, route status, tariff rates, and other factors that can impact the state of charge (SoC) of vehicles and the user's preferences at the moment. Ensure that these elements are taken into account when making recommendations to the user.

Figure 47 illustrates that the system integrates the four main categories of influential factors identified in Table 3 to provide users with suitable and well-considered suggestions.

- **Provide chargers meeting fundamental criteria**
- **Make Experience Relevant**
  Minimize the "awareness mismatch". Record typical situations and calculate representative features for comparing with a new charging event.
- **Consider external influential factors**



Figure 47 A context-aware service integrating all necessary data from users' driving and charging context.

4.2 Design Guidelines

Real-time & Adaptive

1. Real-time Information and Preparedness

Keep users informed about the outside world by providing continuous updates on available charging stations along their route. Maintain backup routes and charging locations in case of unexpected changes or station unavailability. Automatically suggest nearby charging options that align with user-defined criteria (See Figure 48).

2. Personalized Alternative Solutions

Present tailored alternative routes and charging options based on the user's current driving behavior, in-car context (e.g., passengers), and other influencing factors (Ch. 3.4.3) at the moment. Still, it should empower users with the freedom and control to override historically recorded preferences when making decisions.

- **Stay Informed and Prepared for the outside world**
- **Offer alternative solutions tailored to current user needs**

Figure 48 Real-time information and preparedness.



4.2 Design Guidelines

Insightful & Transparent

1. Offer Easily Understandable and Implementable Recommendations

Utilize real-time data derived from essential context, calculate relevant factors, and assist users in selecting the most suitable charging stations tailored to their specific circumstances. For example, the system can recommend the most time-efficient option by considering factors such as detour time, charging duration, and waiting time for the entire journey (See Figure 49).

2. Offer Predictive Information

Predict the availability of charging stations upon arrival, taking into account factors such as the total number of available chargers, real-time traffic conditions, EV density in the region, and more.

3. Provide Clear and Comprehensive Instructions

Minimize unexpected surprises by offering transparent and detailed information about charging options, fees, regulations, and entrance procedures. This empowers users to make informed decisions and reduces concerns about additional costs.

- **Present digestible and actionable suggestion**
- **Deliver prediction and prevent negative surprises.**
- **Provide transparent instructions**

Figure 49 The service should offer easily understandable and implementable recommendations.



4.2 Design Guidelines

Effortless & Intuitive

1. Effortless Charging Decision-Making

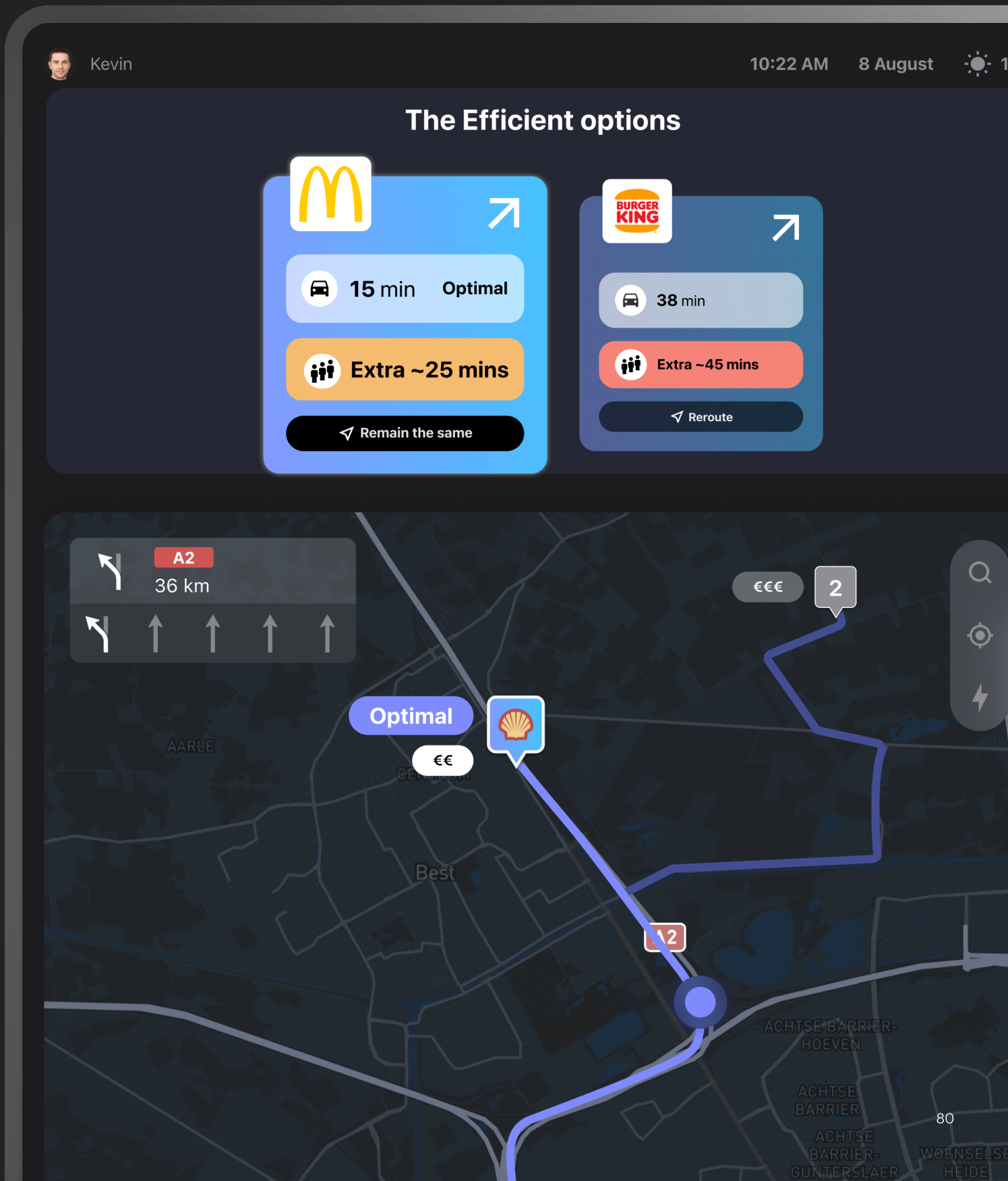
Employ proactive sensing and contextual analysis of the surroundings to predict and suggest appropriate chargers, reducing the need for manual settings and selections, particularly while driving. For instance, Figure 50 illustrates how the service learns from the user's previous settings, recognizing that the user prioritizes route efficiency. Consequently, it emphasizes the time differences between each option to assist the user in making a swift decision.

2. Intuitive Interaction for Reducing Distraction

Implement a multi-modal interaction approach that provides both voice and visual assistance for navigation. Ensure that visual cues and other media elements remain non-distracting to enhance user safety and usability.

- **Easy decision making with low cognitive load.**
- **Require minimal interaction (especially during driving)**
- **Implement a multi-modal interaction to reduce distraction**

Figure 50 The service should offer easily understandable and implementable recommendations.



Concept Development

Intro

This chapter begins by introducing the concept to address the challenges mentioned in Chapter 3.4.2. It then proceeds to address the finding from user research that long and unfamiliar journeys pose more challenges for BEV drivers compared to short and familiar trips. Therefore, this chapter presents two real-life scenarios to explore how to apply our concept under such conditions. Finally, the user interface on the in-car HMI is crafted as a tool to validate the concept proposed in this thesis.

Chapter Overview

5 .1 The Concept
5.2 Prototyping for test the concepts



Develop & Refine

05

5.1 The Concept

5.1.1 What is missing in the current charging journey?

Figure 51 offers an overview of the current challenges that users encounter when navigating fragmented services within the context of the charging journey. Within this landscape, there exists a notable service gap, highlighted by the area enclosed by the red dashed line in the center of the figure. The existing charging experience lacks a comprehensive service capable of efficiently aggregating information, comprehending the nuances of driving and charging contexts, and delivering tailored charging recommendations to users.

At the bottom of the Figure 51 are the four major categories of influential factors identified to address research question 2, as detailed in Table 3 in Chapter 3.4.3. Through user research, the first of the three primary challenges were uncovered, which is the absence of any service capable of seamlessly integrating this wealth of information to assist users in making swift and well-informed decisions about where to charge. Furthermore, due to the fragmented and complex nature of current services, users frequently encounter the frustrating scenario of arriving at a charging station only to discover that their charging pass cannot activate the charging point. The third challenge relates to "Insufficient Context Awareness." For example, although Google Maps can offer insights into road conditions and charging station locations, it lacks the ability to connect to the vehicle's battery status or consider the user's preferences regarding charging stations and nearby amenities. For more details of those three challenges, please refer to Chapter 3.4.2.

In summary, users are forced to invest considerable time and mental effort into comparing information and estimating the likelihood of securing a charging opportunity (and the resulting charge level) when encountering fragmented and sometimes overwhelming information scattered around on different touchpoints. This information-seeking and cognitive calculation process introduces inconvenience and frustration for users during their charging journeys. Consequently, this thesis proposes a service model designed to bridge this service gap effectively.

The Service Gap

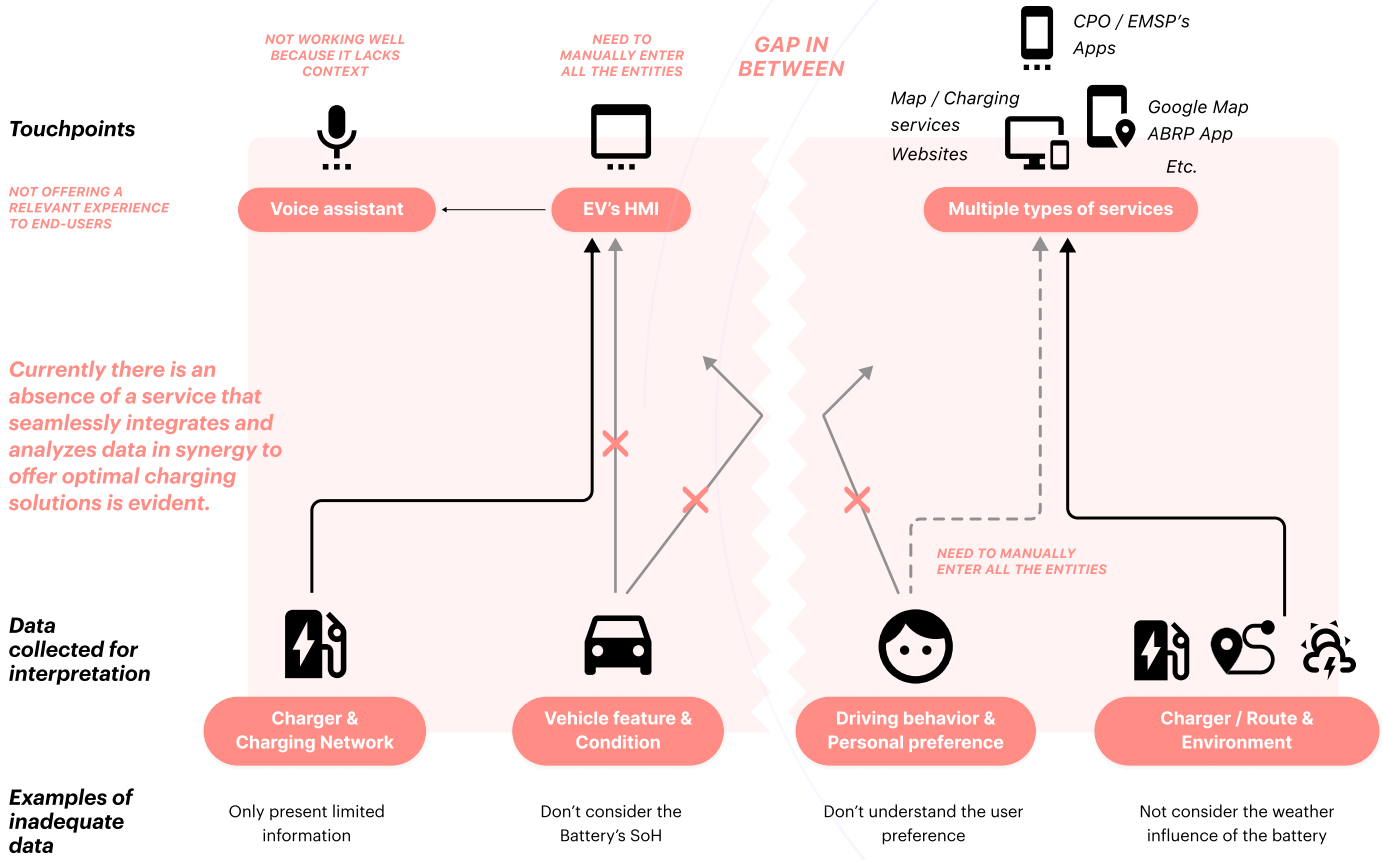
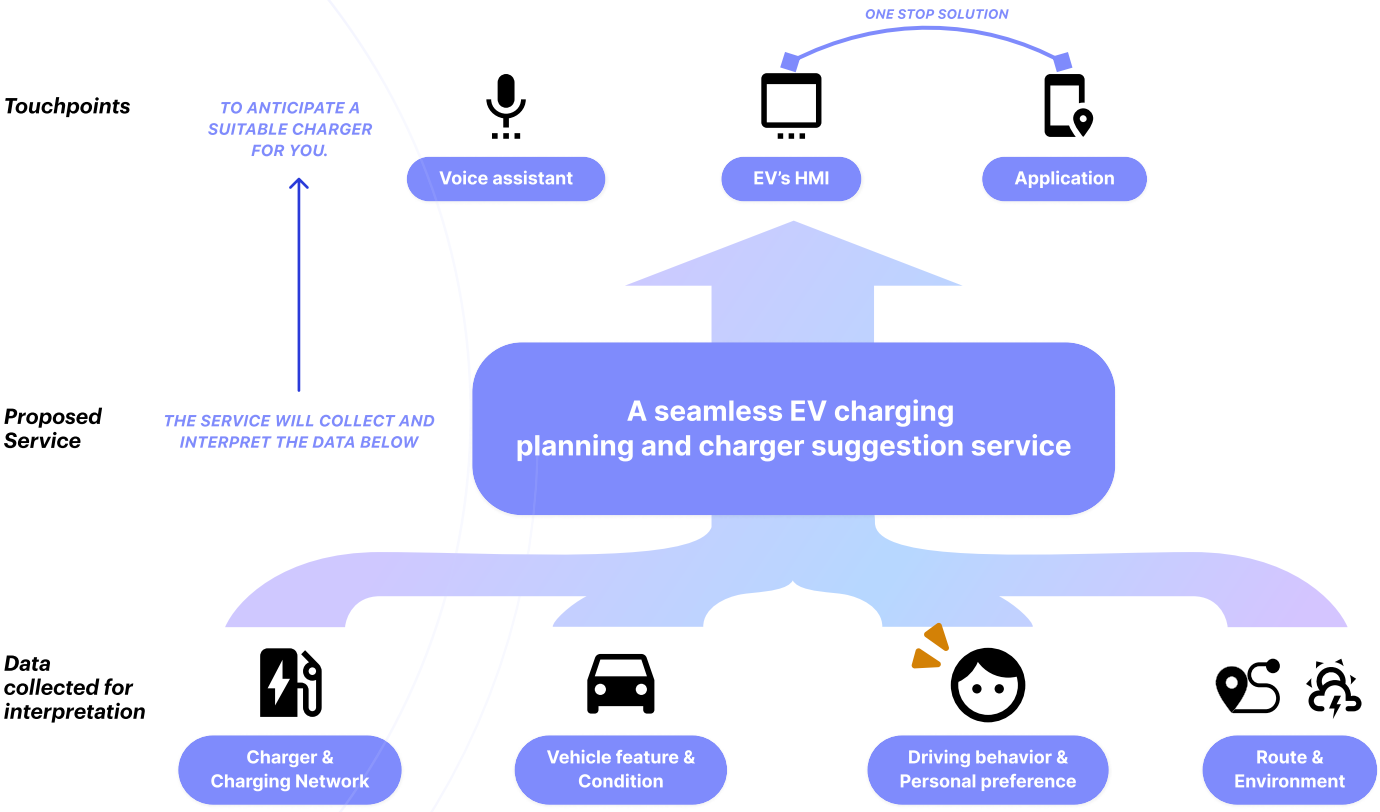


Figure 51 The service gap of current charging journey.

83

5.1.2 Propose

A service model facilitating a seamless charging journey



The concept introduced in this thesis is depicted in Figure 52. It represents an Electric Vehicle (EV) charging planning and charger recommendation service designed to offer a seamless charging experience for Battery Electric Vehicle (BEV) drivers.

Figure 52 The service model presented as a concept to address the challenges found in the user research.

To provide relevant route and charger suggestions for users, this novel service model should integrate and analyze data collected from the bottom four categories of influential factors that users consider when making charging decisions. Moreover, it should adhere to the Design Guidelines outlined in Chapter 4.2 to truly enhance the seamlessness of the journey. **In Figure 53, the relationship between this concept and previous insights in this thesis is demonstrated.** This service is created to potentially address the three major challenges mentioned in the previous chapter and fulfill the three criteria outlined in Figure 38: ***Integrated Information, Predictable Charger Availability, and Sufficient Context Awareness*** (Ch. 3.4.2.2).

To begin, as indicated at the bottom of Figure 52, this service needs to integrate data from various sources, including the charging network, vehicles, drivers, routes, and external conditions, to generate suitable charging plans. Leveraging its understanding of users' basic information and knowledge of charger compatibility with their vehicles and charging passes, it can firstly address users' fundamental needs by suggesting a compatible charger. However, beyond this basic requirement, drivers also consider various other factors.

By **incorporating the influential factors identified in Chapter 3.4.3**, this service can gain insights into users' preferences, derived from their past driving and charging behaviors. It calculates optimal solutions by considering factors such as the chosen route and battery status. Given that users prioritize different factors depending on various driving context, **the thesis suggest applying adaptive weighting methods to the five critical factors users value: time, pricing, station amenities, range flexibility, and journey sustainability (Ch. 3.4.3).** After analyzing those factors based on users' preference, it presents the most relevant information to users on touchpoints where they engage with the service. Consequently, **this service functions as an adaptive entity that responds to the current context and user needs.** In addition to its capacity to calculate routes and charging plans in the background, it tailors information displayed on end-user touchpoints to align with users' current concerns and priorities.

In light of the Design Goal outlined in Chapter 4.1, this service serves as a means to streamline the entire charging experience. It achieves this by comprehending users and their immediate charging requirements, facilitating interactions, and delivering information that is both insightful and transparent. **With the introduction of this service, users no longer need to expend effort searching for and organizing information independently; this service can assist them in swiftly completing this task.** Furthermore, users receive succinct and actionable recommendations, **allowing them to navigate directly to charging stations with a high probability of availability.** This thesis introduces this concept with the aim of resolving the inconveniences and challenges faced by BEV drivers during their charging journeys.

Follow the

Design Guidelines

Chapter 4.2

Be aware of

Driver, Vehicle, and Environment Context

Chapter 3.4.3 - Table 3

To present the

optimized and user-centric charging options.



Figure 53 The concept is a service model including a route and charger suggestion system. It should be created following the design guidelines presented in Ch. 4.2. Moreover, it should be aware of the influential factors identified in Ch. 3.4.3. By doing so, it can offer an optimal charging plan to users which make their charging experience seamless and relevant.

5.2 Prototype for testing the concepts

After proposing the concept, it's natural to consider how this concept could be implemented in real-life scenarios. Therefore, **the Human-Machine Interface (HMI) design of this concept serves as a tool to validate the concept's effectiveness for solving issues faced by current BEV drivers.** Two primary scenarios have been developed to demonstrate how the concept can address the challenges mentioned in user research. The selection of these two scenarios is based on the insights gained from user research, where users highlighted that longer and unfamiliar journeys tend to result in more charging issues (Ch. 3.4.1.1).

The two scenarios are presented below in Figure 54, each of which includes two use cases to illustrate how this service aligns with the Design Guidelines described in Chapter 4.2. These scenarios also encompass different levels of intensity.

In the following concept demonstration, the focus is solely on the interaction between the driver and the system. Additionally, the dynamic priorities of the five main influential factors user cares about while choosing a charger, mentioned in Chapter 3.4.3, are defined within the scenario to illustrate how this service model will present information that aligns with the user's preferences. In the following section, two prototypes is presented, for more prototype iterations, please refer to Appendix E.

Scenarios & Use Cases



- WHO: Kevin and his family on a vacation. Two kids in the backseat.
- Use case 01: Find a suitable charger with the amenities they want on the highway. Select one and add it to the original route.
- Use case 02: Driving there and suddenly get a notification that the place is occupied.



- WHO: Sophia. Driving alone on a business trip.
- Use case 01: The assistant wants to tell her there is an accident on her original route, and would like to suggest a detour.
- Use case 02: Due to a route change, the electric vehicle's battery level dropped more then expected. Consequently, an extra charging station must be included along the route.

Intense level

Figure 54 The scenarios and use cases for demonstrating the concept.

5.2.1 The Prototype

In the first scenario, the user profile of "Kevin," as depicted in Figure 55, is introduced. Kevin is a time-oriented individual, prioritizing quick charging. Pricing comes second on his list of considerations when choosing a charger for his EV. He also places importance on the amenities available around the charging station, as he needs to take care of his wife and kids during the charging process.

In the first scenario, Kevin and his family were on a trip together when their two hungry children requested a quick meal break. Kevin saw an opportunity to charge the vehicle while they had their meal. Consequently, he inquired with the system about nearby charging stations that also had restaurants, allowing them to take a rest and feed the children while simultaneously charging the car.

The following interfaces in Figure 56 illustrate how the concept assist users on the road in Scenario one.

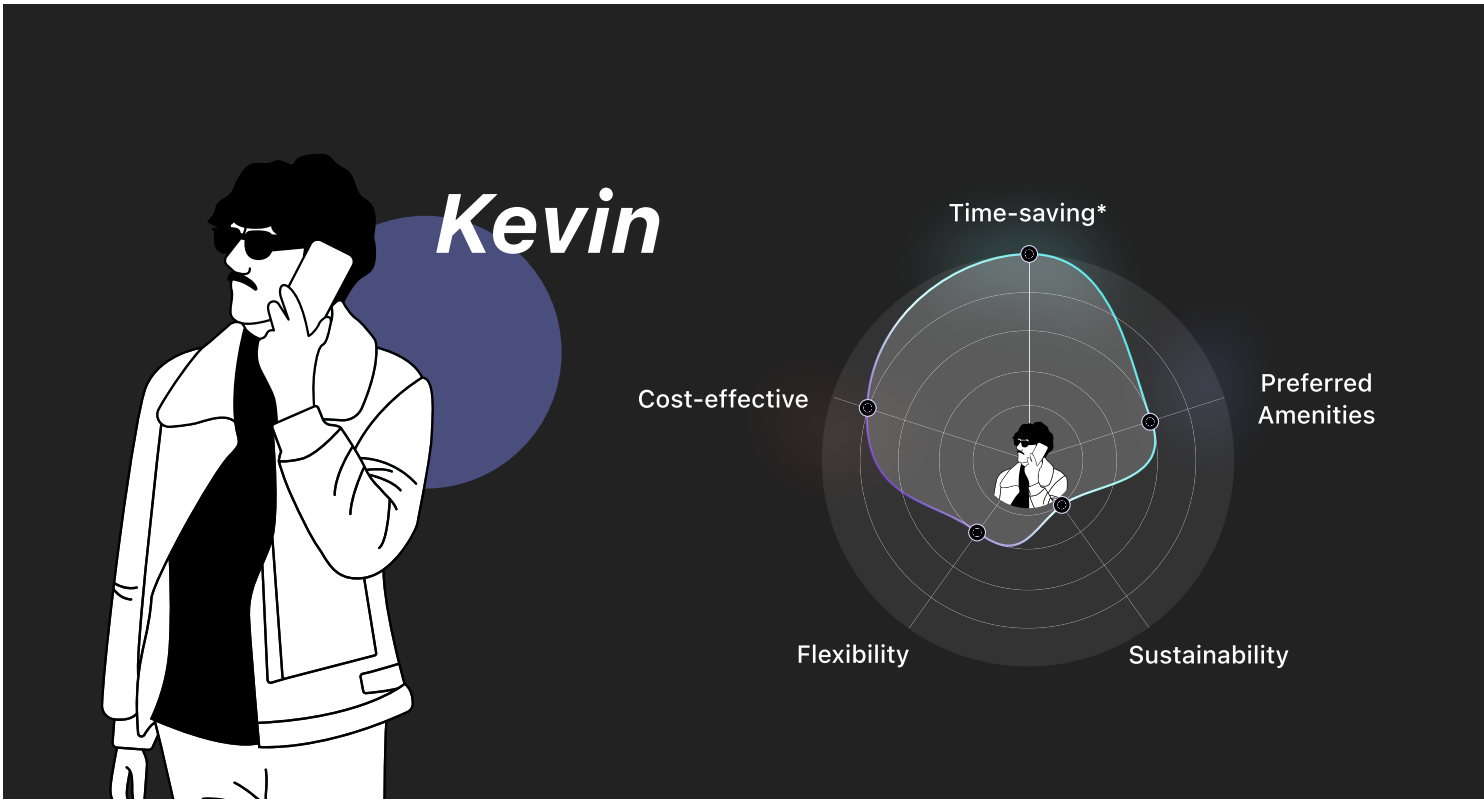


Figure 55 "Kevin's" profile.

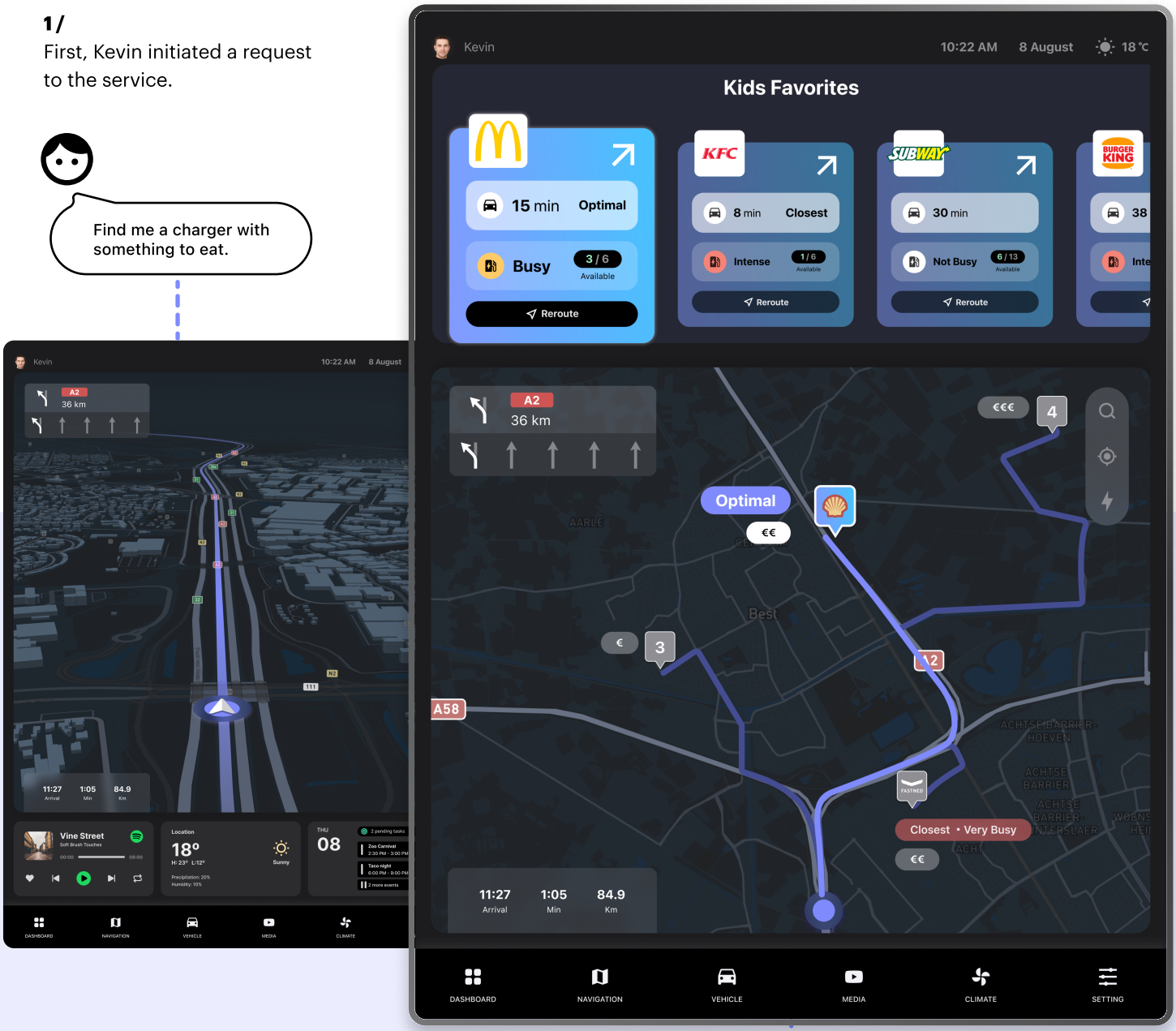
First Scenario

"Hi Kevin! Based on you and your families' preference, here are a couple of recommendations."

"The most recommended one is the nearby McDonald's with a Shell Charger. Would you like me to navigate you there?"

1/
First, Kevin initiated a request to the service.

Find me a charger with something to eat.



2/
Next, the system begins by referring to Kevin's profile and accessing his past behavioral data. It recognizes that today, Kevin is traveling with his family, including two children in the back seat. The system understands that the children prefer fast food and is also aware of Kevin's priority to keep the overall journey time-efficient. Consequently, the interface provides several options that align with the children's food preferences and also offer compatible charging facilities.

Figure 56 Prototype for the first scenario.

The key information displayed primarily revolves around **time estimates**, allowing Kevin to quickly understand the approximate travel time to each option, the current congestion status at the charging station, and whether there is a significant queue of vehicles waiting. The remaining charging slots are also presented in the card.

On the map, Kevin can also clearly see the approximate locations of each option and discern differences in overall charging prices.



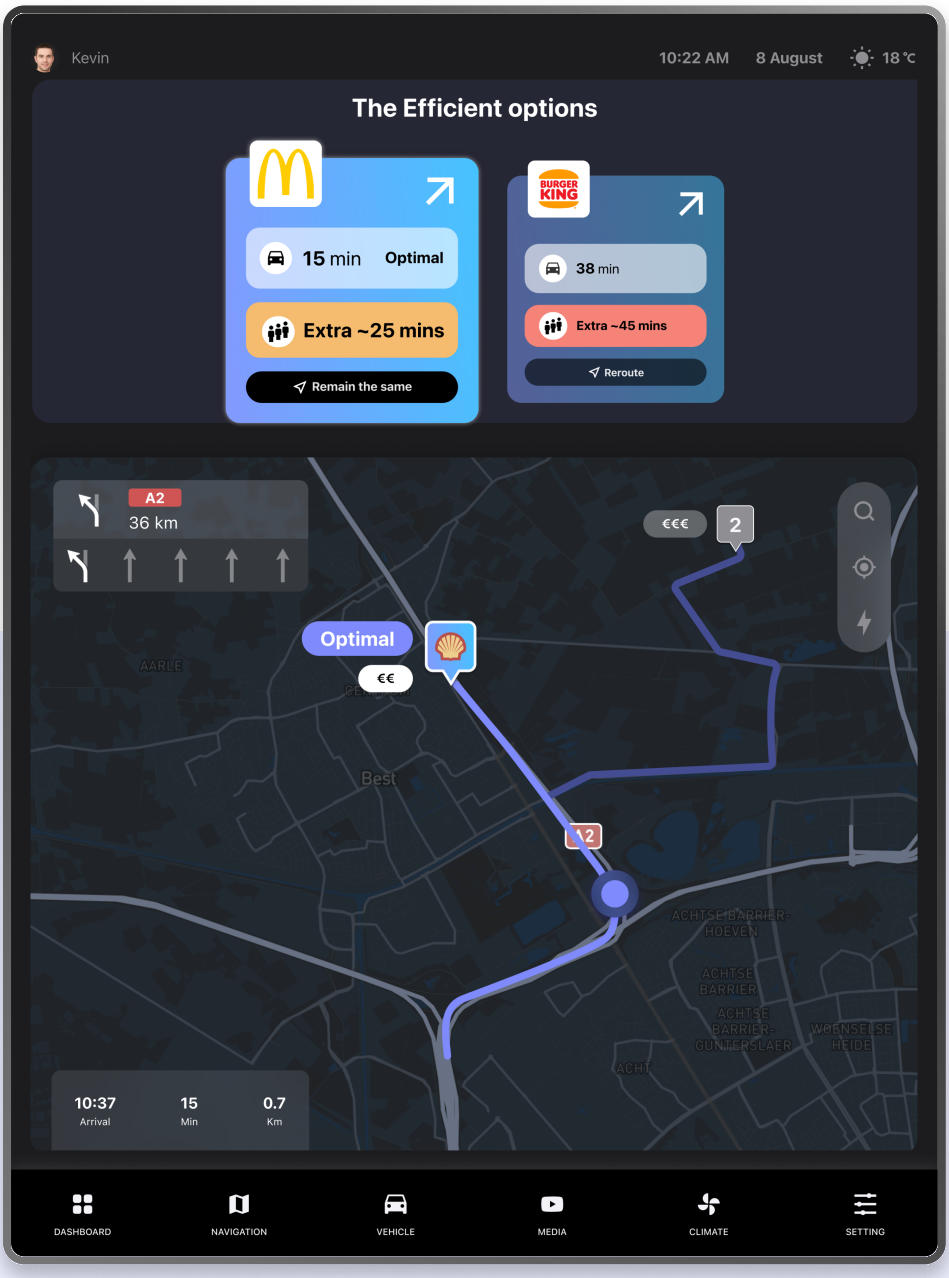
3 /
Subsequently, Kevin swiftly makes his choice as he needs to maintain his focus on the road. The map returns to its default view, incorporating an intermediate stop. It also provides information on the estimated charging duration at the McDonald's charging station and the expected amount of charge that can be obtained.

4 /
However, unfortunately, while en route, the system detects that the remaining charging stations are also occupied. Consequently, it informs Kevin of a potential change in his initial plan through both voice and visual cues. It then asks whether he would like to consider alternative options.



"Apologies, your chosen charging station is occupied. Waiting there might be more efficient based on nearby station availability. Do you want to stick to your original route or explore alternative nearby options?"

I want to see nearby options.



"I found a nearby KFC with similar criteria you may like. However, it would take you longer to get to a charger."

"It seems like McDonald is still the optimal choice for you, and the waiting time is decreasing. Would you like me to stick to the original route?"

5 /

As Kevin wanted to explore new options, the system presents him with a nearby KFC charging station in the same direction of travel. However, it also calculates all the factors that could affect Kevin's wait time for a charging station, providing a comparison of the waiting time difference between the two locations.

From the displayed information, it becomes evident that even if he detours to the new location, the wait time may be longer. Therefore, the system suggests sticking with the original choice because a vehicle at that station is nearing the end of its charging session and is likely about to leave.。

6 /

After considering both options, Kevin opted to stay with the original charging station. It provided the shortest detour and waiting time overall, had a nearby McDonald's for the kids, complete with the children's meal toys they desired.

Moreover, he had confidence in the quality of the Shell Recharge charging station. Kevin knew he could effortlessly connect the charger to his vehicle using his Shell charging pass, enabling him to start charging promptly. Thus, he selected the original charging station and proceeded with his journey.



- **Efficient**
- **Cost-Effective**
- **Amenities**



In the second scenario, the user profile of "Sophia," as depicted in Figure 57, is introduced. She places a high priority on sustainability and is currently on a business trip to a distant and unfamiliar city. Time is also crucial for her since she must attend a meeting promptly. As a business traveler, the cost is her third priority, as her company covers charging expenses. She also values having a flexible range upon arrival to account for unexpected situations. Amenities are of the least concern to her; a restroom is sufficient.

The following interfaces in Figure 58 illustrate how the concept assist users on the road in the second Scenario.

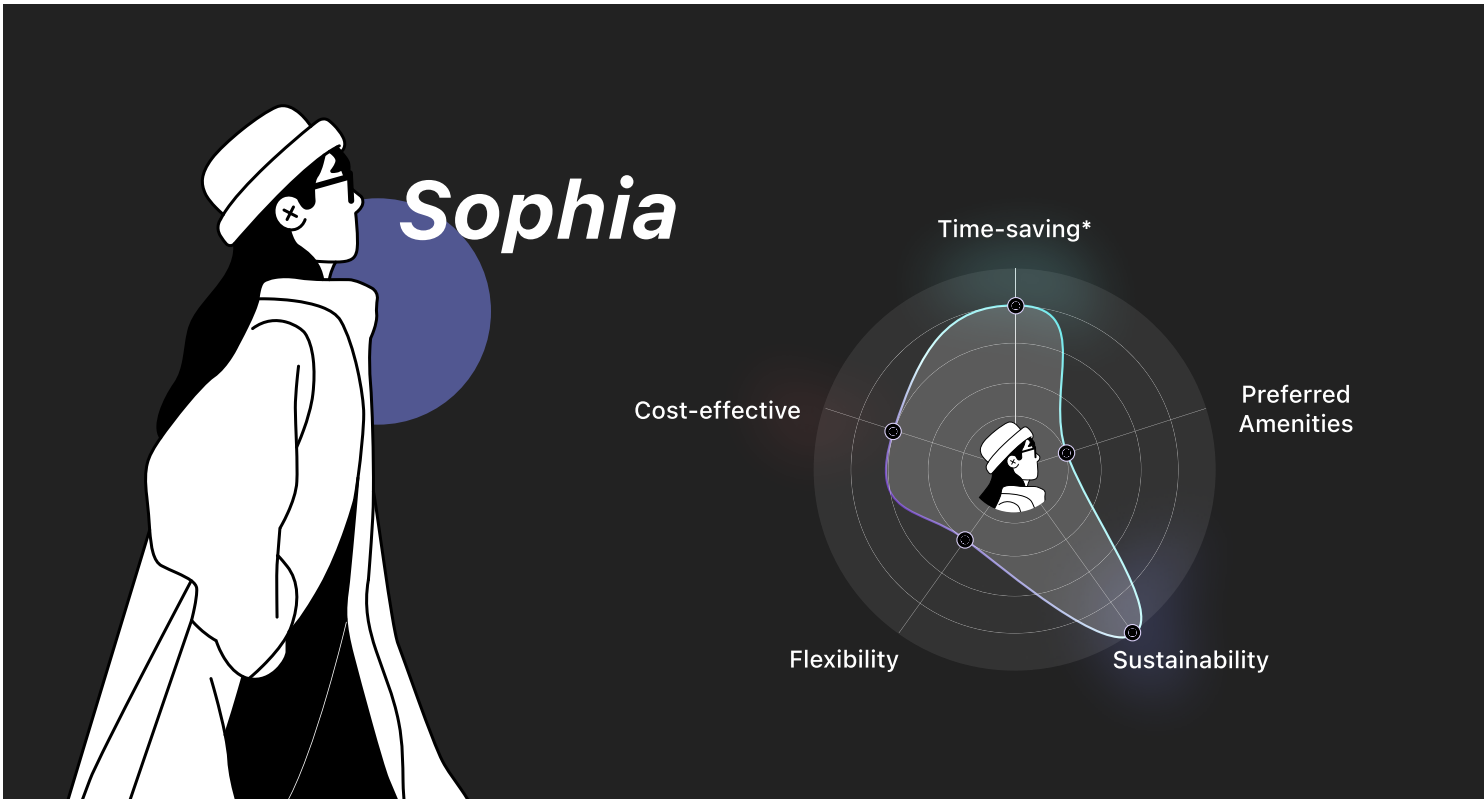


Figure 57 "Sophia's" profile.

Second Scenario

"Hi Sophia. Just a reminder, there's a traffic jam up ahead due to an accident. Would you like me to provide alternative routes that meet your needs?"





1/
Today, Sophia is driving the company's EV to attend a client meeting in France.



2/
She had already planned her trip in advance and smoothly integrated the trip and the charging stations she needed to stop along the way into the car's navigation system. But unexpected situations can always arise on the road. It seems that the road ahead is congested due to a car accident. Therefore, this service gently reminds Sophia through voice interaction and visual cue that her original travel plan may need to change.

Figure 58 Prototype for the second scenario.

"These are possible alternative routes."

"I have calculated the overall carbon footprint of the trip and selected charging stations that purchase green energy for these two routes."

"The most optimal option can help you reduce carbon emissions by 4% and arrive 45 minutes earlier than the original route. Would you like me to reroute you to this one?



3 /

Sophia wants to know what options she has to arrive on time. Fortunately, she left early, so there's no rush. However, she's a very sustainability-conscious driver and wants the charging stations along the way to have green energy sources. The system knows her preferences and recommends the following two new routes for her to choose from.

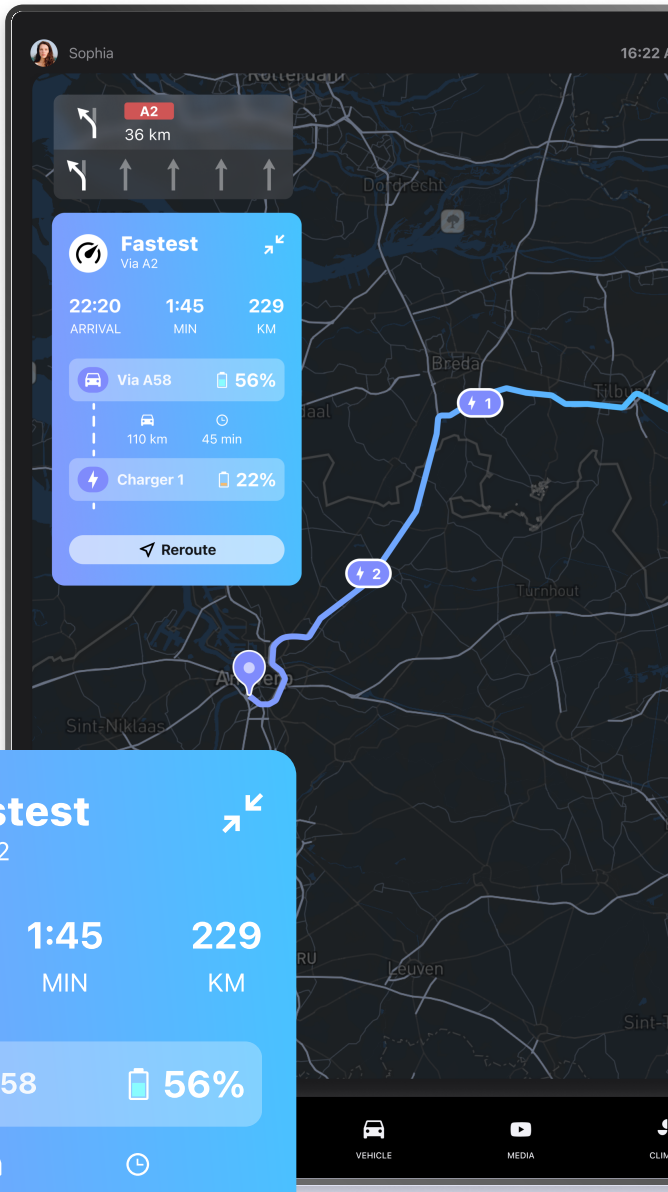
In terms of information presentation, each route's information card prioritizes green energy consumption, keeping in mind Sophia's time preferences. Supplementary details such as pricing are conveniently displayed on the map for swift reference.

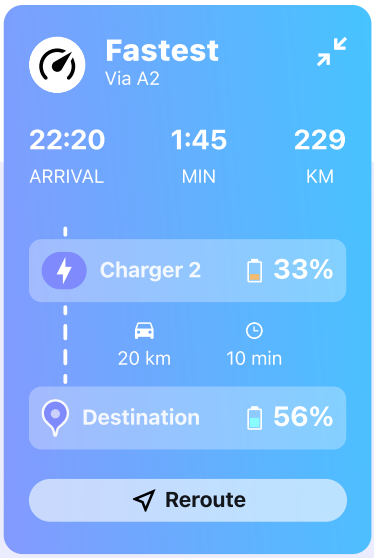
4 /
Sophia swiftly scrolled through the two options in the information bar at the top of the screen to make a comparison. She noticed that while the second route offered a greater reduction in carbon emissions, it also exceeded the time frame she was comfortable with. Consequently, she opted for the first recommended route, which promised the quickest arrival at her destination.



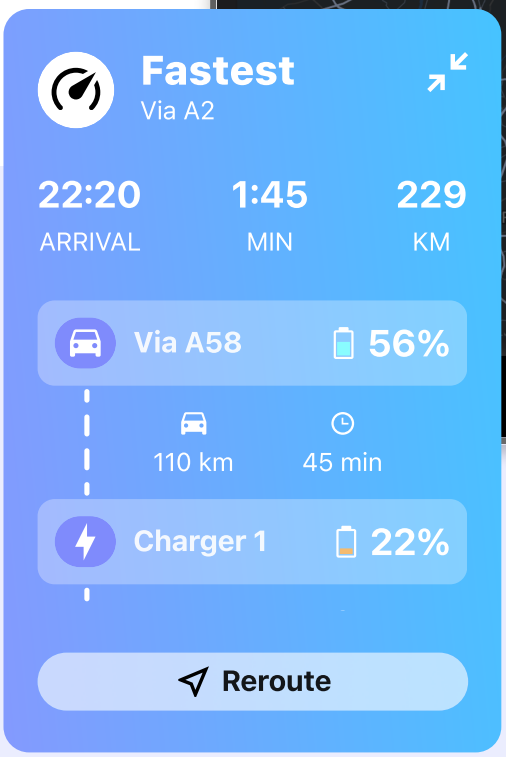
The concise information cards for recommendations adapt their key details based on the current environment and the user's most prioritized criteria. Users can scroll and click to make selections, and each card has a dropdown arrow in the top right corner for accessing more detailed information.

The map provides a quick location overview, and the interface highlights the corresponding routes or locations based on the user's current selection from the information cards at the top. It also uses icons to display other criteria for each option, such as pricing.





Scroll bar



5 /

Sophia chose the fastest route to her destination. Due to the traffic jam, she had a moment to check the charging plan for this new journey. The blue-purple information card first provided the new estimated arrival time, along with the driving time and distance.

Below this primary information are the detailed insights for each charging station. It shows how much remaining battery Sophia will have at each stop. It also provides information on how long it will take to reach each charging station. The route details can be scrolled through to understand the entire process.



6 /
Finally, the new route is planned, and the updated total duration and arrival time replace the original ones appearing in the bottom left corner of the map. With a quickly obtained alternative path, Sophia continues her journey with peace of mind.

The detailed prototypes are available on request.

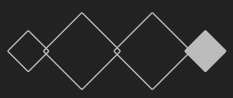
Validation

Intro

In this chapter, the purpose and process of validation are firstly discussed. The aim is to assess whether the concept outlined in Chapter 5.1 complies with the requirements of the Design Goal. The User Interface is a tool to visualize the concept and validate it. Furthermore, it intends to offer insights to potential service providers seeking to develop similar services, focusing on user expectations for future charging services.

Chapter Overview

6. 1 Purpose & Method
6.2 Results & Discussion
User desirability > Technical feasibility > Business Viability
6.3 Conclusion



Finalize

06

6.1 Purpose & Method

The objective of the semi-structured interviews in the validation phase is as follows:

1. To collect user feedback on whether this concept effectively aids in streamlining their charging journey.

2. To gain insights into the expectations of BEV drivers regarding future charging experiences and the potential evolution of this service.

A total of **five semi-structured interviews** are conducted with previous participants, who are novice BEV drivers, and several experts in VanBerlo to validate the concept. Previous participants can, drawing from their experiences shared in previous interviews, compare the current service with the newly proposed service outlined in this thesis. This comparison will help ascertain whether the identified pain points have indeed been understood and effectively addressed. Additionally, experts within VanBerlo possess in-depth knowledge of the EV industry, having developed various electric vehicle-related services in the past. Their expertise allows them to offer valuable industry insights and recommendations.

All participants underwent testing in offline settings. Some of them had iPads placed in their vehicles to demonstrate the prototype, while others engaged in simulated testing by watching videos of driving on the road and using iPads to interact with the prototype (See Figure 59). It is important to note that the purpose of this validation was not focused on the usability of the user interface itself but rather aimed to collect user feedback and insights regarding the concept of "a seamless route planning and charger suggestion service" through this prototype. Therefore, the questions asked were primarily open-ended.

First, participants were briefed on how the system gathers information about their preferences. After a brief explanation of the influential factors considered by the system, two scenarios and their character settings mentioned in Chapter 5.2 were presented to the users. They were encouraged to immerse themselves in the storyline and observe how the prototype operated within these scenarios. Subsequently, participants were asked to share their thoughts and opinions on this concept. The goal was to understand if users had additional expectations for a seamless charging journey, including specific features. Additionally, this validation aimed to reflect on any limitations of the concept and identify valuable directions for future development.



Figure 59 The validation set-up.

6.2 Results & Discussion

6.2.1 The Validity of the Proposed Service

6.2.1.1 Positive feedback and potential improvement regarding the concept

Firstly, the majority of the interviewees expressed that the concept presented in prototypes could optimize their charging experience on the road. Through this service, they no longer need to stop their vehicle or divert their attention while driving to search for charging station information across various platforms. The information presented in the prototype aligns with their priorities and is sufficient to facilitate quick charging decisions.

Moreover, it's important to highlight that participants commonly mentioned their preferences tend to change depending on the specific circumstances. **This observation aligns with the insights gained from user research, which underscore the dynamic nature of users' preferences.** The open-ended questions posed during the validation session have led to **the emergence of more intriguing ideas** related to the concept and the various factors that influence it.

1. Nuanced Flexibility in Different Situations

Users emphasized that their willingness to accept a lower level of remaining power varies depending on the situation. For instance, when driving in familiar areas, they may not be concerned even if their battery level drops as low as 2%, as they anticipate the availability of a nearby charging station. However, on unfamiliar routes, they may prefer to maintain a minimum of 10% battery level for added reassurance. If the service can learn from users' decisions in different scenarios, like **when they consistently skip recommended charging stations near their home, it can gradually develop an understanding of the range of acceptable remaining power levels for users in diverse situations.** Consequently, this learning process enables the service to recommend charging stations at the most opportune times.

2. Enhanced User Control Over Battery Level Settings:

Users have expressed a strong desire for increased control over the configuration of their desired battery level. Presently, Google Maps lacks the functionality that would allow users to adjust their preferred battery level to receive tailored charging recommendations. Users are looking for additional features that would grant them the flexibility to easily modify their required battery level based on their immediate needs. The rationale behind this request is that, for certain users, charging their electric vehicle beyond 50% during extended trips is perceived as a time-consuming endeavor. They envision the integration of a swift and intuitive slide bar during the trip planning phase, which would empower them to promptly set parameters. A one-click button accessible from the in-car map, allowing for swift adjustments, is the preferred approach (See Figure 60). For instance, **they could exclude charging station recommendations when their battery level exceeds 50%, unless specific conditions justify a deviation from this threshold.** Essentially, users are seeking a convenient means to specify both the minimum and maximum desired battery levels, thereby streamlining the efficiency of the charging process throughout their journey.

3. Payment and Authentication process still requires more attention

Users have mentioned that during their journeys, they encountered certain issues regarding payment. For instance, when the service informed them that they could use the Shell card as a payment method, it turned out not to work as expected. As a result, they had to resort to alternatives like Apple Pay or other payment methods.

"The service offers many payments approach in theory, but in practice it would fail a lot of times. So, in the end, you have to download the App, and go through the process, connect your Visa card to the App, and pay with the App... So, it was a very tedious thing. That was a big hassle for me. "

Therefore, understanding the operational procedures at the charging station and the displayed information is essential. This comprehension is critical to ensure the service accurately identifies available payment methods and offers users genuinely compatible and accessible

charging choices. This notion aligns with the first aspect of the Design guideline, which **emphasizes seamlessness and integration.** One of the principles outlined in this guideline is the idea of a "one-stop solution." This platform should establish a smooth connection between the vehicle and charger while managing authentication processes, including payment. Consequently, users can avoid the cumbersome processes described earlier. However, achieving such a platform requires seamless cooperation and data sharing among stakeholders to enable interchangeable information and interoperable services.

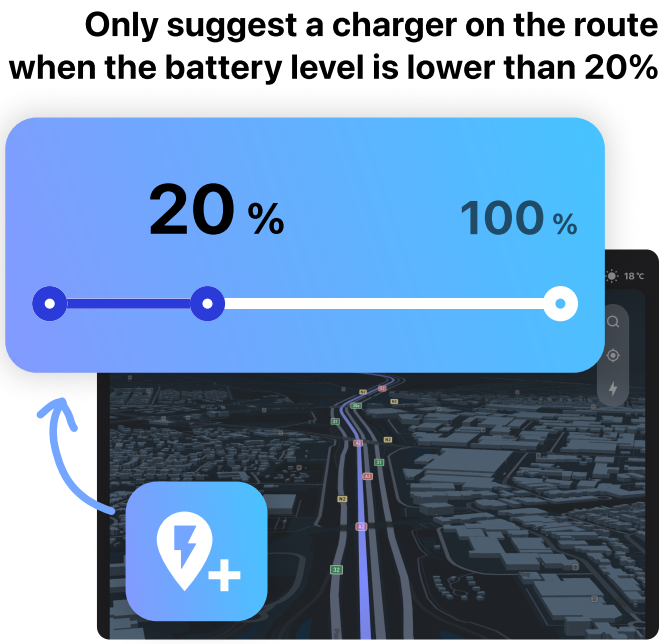


Figure 60 An example of an approach to quickly adjust suggested charger battery threshold.

4. Reservation Features

In the context of discovering occupied charging stations, users may find it confusing when a charging station they expected to use suddenly becomes occupied. Therefore, the need for a reservation feature was discussed during the validation process. For users who wish to reserve a charging station, this is indeed a favorable suggestion. There is literature discussing reservation services in the EV charging field. In the research by Liu et al. (2023), they introduce a reservation system as part of their Hybrid Management System for a new approach to EV charging. Given the high demand for charging, they propose supplementing the current Charging Station (CS) service with a Vehicle to Vehicle (V2V) charging system conducted in Parking Lots (PLs) to optimize energy usage. In this setup, the V2V charging mode can help balance the grid load and reduce charging congestion for EVs during peak hours. When assigning a charging option to users, accurately estimating real-time data for energy consumption and charging time for each EV can be challenging. To address this, they introduce a **charging reservation system that includes information such as EV arrival time and expected charging energy, improving charging recommendations by providing precise information. It acts as a method for gathering data from EVs and selecting either a CS or PL charging point for users.**

However, there might be issues happen along with the reservation system. For instance, if a user who reserved a charging station needs to change their route due to unforeseen circumstances, the system should notify the Charging Point Operator (CPO) of the cancellation promptly so that other users in need can utilize the reserved station. Thus, it might be essential to have a robust cancellation mechanism in place. Simultaneously, for users who cannot make reservations, participants also noted the value of receiving information regarding the expected waiting time, aiding in their trip planning. This waiting duration at charging stations should also be accounted for in the concept.

Nonetheless, contrasting opinions exist. In practice, scenarios may arise where, despite an advanced reservation, other vehicles might still occupy the reserved space. Additionally, there could be instances where electric vehicle owners arrive at a station without comprehending the reservation mechanism, only to discover that a seemingly available charging station is unusable, leading to further confusion and conflicts.

Hence, it can be deduced that there is potential for introducing additional features within the concept. Nevertheless, concerning the reservation system, further research is essential to confirm its practical feasibility. It is worth noting that a reservation system could serve as a means to collect user data and distribute charging events evenly, thereby alleviating the strain on energy resources during peak hours. Moreover, a meticulous examination of the advantages and disadvantages for the involved stakeholders is imperative to determine how to implement a reservation mechanism in specific scenarios without creating extra issues.

6.2.1.2 Strategies to bolster the trust in recommendations

First of all, users need to understand why they can trust the system's recommendations. In other words, they would appreciate a brief recognition of how this service learns about their charger preferences. Some users mentioned their preference for a simple onboarding process, but it should be a one-time, effortless interaction allowing the system to understand their needs. Others preferred the option to skip the onboarding phase altogether. The former group expressed that if the system's recommendations initially do not align well with their needs, they might ignore the service and lose trust in it. The latter group could accept that the service's initial recommendations, while less accurate, would save them time by not having to answer onboarding questions.

It's worth noting that participants mentioned that if the system **recommended a charging station with a clear and concise overview explaining why it was being suggested, based on criteria such as time, minimum detour, and sustainability, they would feel a sense of assurance** (as demonstrated in Figure 61). This overview would **enable them to swiftly review the checklist of criteria for recommended options**, helping them ascertain if the charging station aligns with their preferences. Consequently, after receiving several accurately matched recommendations, even if some options in the future fail to entirely meet their immediate requirements, they would interpret it as the system's understanding that there were no superior alternatives nearby. This would foster ongoing trust in the service's recommendations.

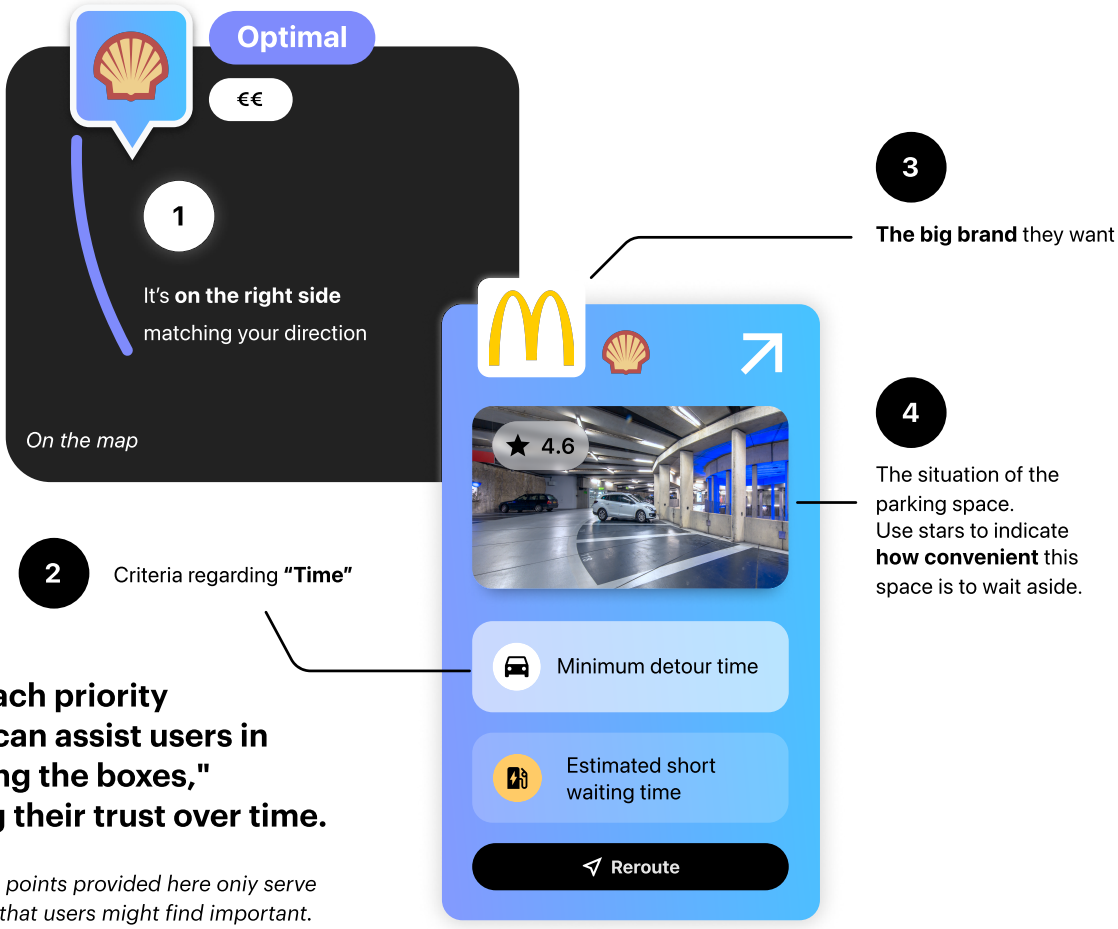
6.2.1.3 Strategies to improve the efficiency of charging decision-making

1. Naturally comprehensible estimated waiting time

It is worth noting that in the use case of discovering occupied charging stations, the information flow is relatively straightforward. However, participants mentioned that they prioritize the expected waiting time over other factors, stating,

> *"I don't care that how many chargers are available or occupied at the moment, I care about the expected waiting time. Because if all the charger is occupied at the moment, but one car's already charged for two hours, then I might get a chance to charge there when I arrive."*

Additionally, participants referred to the design of Google Maps' traffic congestion estimation (Figure 62). When charging stations are occupied, they expressed the desire for the system's information card to use colors to quickly convey the current congestion level at the charging station. For example, they suggested using red to signify significant congestion, indicating that when you arrive, the waiting time is likely to increase rather than decrease. Alternatively, green could be used to indicate that, even if you have to wait an additional 10 minutes, the current charging queue is rapidly decreasing. These two color-coded indicators are familiar to them, as Google Maps has employed a similar approach for years to alert users to road congestion conditions ahead. Implementing such a concept could further enhance the efficiency for drivers to decided where to go at a glance (Figure 63).



An overview of each priority individuals have can assist users in mentally "checking the boxes," gradually earning their trust over time.

**Please note that the bullet points provided here oniy serve as examples of the criteria that users might find important.*

Figure 61 The example of how to gain users trust regarding presenting the key information for them to compare their preference with the one that the service recommend.

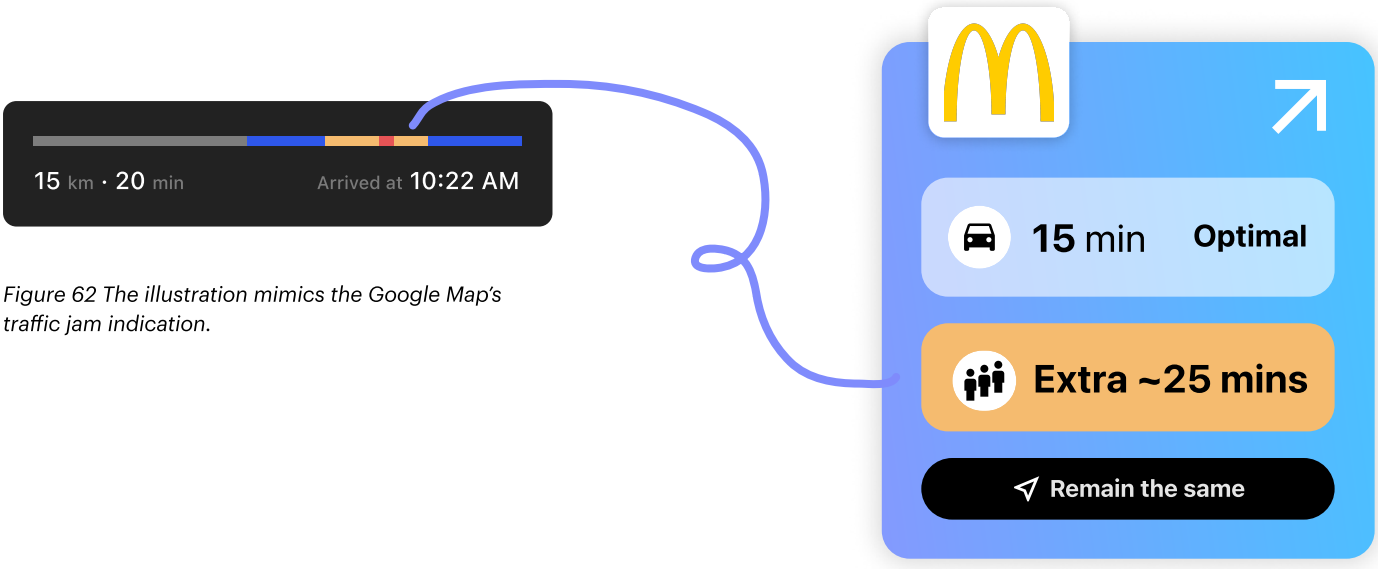


Figure 62 The illustration mimics the Google Map's traffic jam indication.

Figure 63 The original information card also employs color coding to represent the estimated waiting time for users. However, it should utilize colors in a manner similar to the existing system to effectively illustrate the real-time fluctuations in waiting time.

2. The art of selecting presented information

The information card displayed on the left side of Figure 64, which appeared above the map after the user made a selection in the first scenario, was considered somewhat complex to quickly discern while driving. Interviewees mentioned that they already understood they were heading to a McDonald's charging station in the previous step. Therefore, this section could directly display how long the charging will take and what level of charge can be achieved. As a result, the original information card on the left side of Figure 64 could be iterated into the simpler and more easily understandable key charging information on the right side.



Figure 64 The information card on the left still presents an overwhelming amount of information, making it challenging to grasp at a glance. As a result, the users in the first scenario proposed the one on the right. This modification was suggested because they prioritize time, and having quick access to "charging time" is crucial for their needs.

Through discussions with the participants regarding the information displayed on the HMI, **the core concept to enhance the charging decision-making process was also recognized.** Users indeed desire a system that can perform complex computations on their behalf and provide options that are not only straightforward to understand but also directly executable.

For example, in the second scenario, some interviewees mentioned that they might not even look at the second, more environmentally friendly route. Instead, they would directly choose the optimal one for rerouting, as the decision-making time while driving is extremely brief. Alternatively, if they are particularly environmentally conscious, the "greenest" route could be highlighted more to facilitate their quick selection. This finding aligns with the fifth Design Guideline - "Effortless & Intuitive." Additionally, as stated in the fourth Design Guideline, information presentation should be tailored to the users' priorities, providing straightforward information that closely aligns with what they care about. This ensures an informed and efficient charging decision-making process.

3. Provide a summarized overview of the differences

In scenarios where accidents occur and the system recommends alternative routes along with charging options, users find this feature valuable, especially when their battery level might not be sufficient to reach their destination. From an information delivery perspective, they prefer to have a direct understanding of the differences between the charging route and the original route. This entails differences in terms of time, cost, and even restaurant selections. For example, if only arrival times are presented instead of time differences, users would need to calculate these differences themselves, which would increase their cognitive load during the journey. A more effective approach is to present users with the additional or reduced time for each route in comparison to the original one.

Regarding pricing, users also want to be informed about the overall difference, encompassing toll fees and the cumulative charging costs from various stations. Some interviewees mentioned that they appreciate more detailed information when they inquire, but when making decisions, they prefer to have an overview of the price difference.

6.2.2 Fresh insights regarding the Context-Awareness feature

6.2.2.1 Context-awareness for choosing NOT to take an alternative route

Participants are primarily interested in context-aware features. For instance, in the first scenario, they appreciate the service's ability to recognize that there are children in the car during dinner time and provide relevant service options for them to choose from. This convenience helps parents avoid the hassle of asking their children what they want to eat while driving and searching for options themselves. However, it's important to note that they prefer the service to function as an assistant rather than making decisions and guiding to new destinations automatically. They want it to understand their current situation and offer suitable choices when requested.

In the second scenario, the system calculates an alternative route when a traffic jam occurs ahead. However, the concept overlooks the trade-off between the additional travel time and the rationale for selecting the original route. A new perspective arises in certain situations, where individuals may opt to adhere to their original route instead of selecting an alternative. Possible reasons for this choice include:

1. Familiarity with Charging Stations

Some users have pre-planned their familiar charging stations on the original route. Their choice of these charging stations is not solely based on time but could also be because they know that these charging stations may have a convenient restaurant for dining or are operated by a Charging Point Operator (CPO) they trust.

2. Planned Activities

It's possible that the original route includes specific activities or tourist attractions that users wish to visit. Even if the new route saves them 10 minutes of traffic, they may still opt to spend those extra 10 minutes to maintain their trust in the charging stations along the original route and to visit the planned destinations.

Interestingly, some drivers also view traffic jams as a part of their relaxation time, where they can lay back and unwind for a while. As long as the delay is not too significant, it can even be seen as an advantage.

This reveals that there are more factors to consider when making route-changing decisions, and these considerations can vary depending on the current circumstances. The key is to provide users with the control to choose whether to change their route. Additionally, it's crucial to clearly present the differences between the various routes so that users can make quick decisions while driving.

6.2.3 Technology feasibility of estimating an optimal suggestion

Of course, in developing this service, one can draw inspiration from previous research in the field of charging route planning. This service's components can be informed by earlier studies, particularly when determining the most time-efficient charging options.

For instance, **Weerdt et al. (2016) introduced an intention-aware routing system (IARS) specifically designed for electric vehicles (EVs). IARS aims to improve expected travel times by considering the intentions of other vehicles, which is crucial for EVs facing potential charging station queues.** This aspect is also highlighted in the research by Yichan An (2023), who suggests that the prediction system should incorporate real-time factors such as the number of EVs currently charging at each station, the State of Charge (SoC) of vehicles, and the expected arrival times of incoming EVs. Weerdt et al. (2016) conducted simulations using data from the Netherlands, which included information on "charging station locations, road networks, historical travel times, and journey origin-destination pairs." These simulations confirmed the effectiveness of IARS. In specific scenarios, IARS achieved a remarkable over 80% reduction in waiting times at charging stations and more than a 50% decrease in overall travel durations. Hence, it is clear that there are existing algorithms and research findings that can be applied when implementing the concept in this thesis.

Regarding the distribution of charging demands, Gusrialdi et al. (2017)'s research focus on tackling the challenge of efficiently managing EV charging station queues along highways. It uses local traffic data and station status to guide EVs to nearby stations, ensuring fair resource usage. This strategy relies on local traffic data and charging station status to guide EVs to nearby stations, ensuring equitable resource utilization, leading to improved charging station performance, as demonstrated on the Florida Turnpike in the United States.

To sum, **these studies indeed offer various algorithms for allocating charging demand to reduce user charging times.** However, as mentioned in the literature review in Chapter 2, user choice of charging stations involves considerations beyond just time. The context of the charging event is also crucial. Therefore, this thesis provides additional influential factors that can help future route and charger suggestion systems incorporate a user-centric perspective to provide a truly seamless charging journey for users.

6.2.4 Business Viability of this concept

Possible future business model

The conversation with participants also delves into potential business models. One such model under consideration is a subscription-based approach, potentially offered by automotive OEMs. Users could access this service through a subscription, gaining access to information from both CPOs and EMSPs on a single platform. Moreover, collaborations among various stakeholders could be established to provide this service. The rationale behind this lies in the platform's ability to incorporate a referral system, suggesting specific charging networks, nearby restaurants, and shops near the charging station. Instead of regarding these suggestions as intrusive advertisements, users may welcome them, as the service tailors recommendations to enhance their charging journey's relevance to their needs.

Some users have even proposed the inclusion of a pre-ordering system within this service. For instance, if they could place food orders remotely from their vehicles, it would save them time, eliminating the need to wait in drive-through lanes and negotiate meal preferences with their children. From a broader ecosystem perspective, such services might benefit fast-food restaurant operators by expediting food preparation. It could potentially enhance the efficiency of charging stations, as users make quicker decisions, pick up their meals, fulfill their intermediate needs, and depart, allowing the next user to charge more promptly.

Nonetheless, it's crucial to conduct more extensive market research to understand whether automotive OEMs are currently developing similar services. It's worth noting that the scale and brand values of different car manufacturers will influence their approach to developing charging services tailored to their user base. For instance, the charging experience for luxury vehicles may differ from that of mass-produced, mainstream cars. Additionally, the experts interviewed mentioned that manufacturers targeting high-end vehicles may have smaller user bases, making it challenging to allocate resources to mediate with various charging service providers to create an exclusive charging ecosystem. They may opt to acquire existing, well-established charging services of this nature and seamlessly integrate them into their vehicles to offer users a convenient charging experience.

6.3 Conclusion

In this chapter, the validity of the proposed service has been examined, and insights from user feedback and potential features have been explored. Strategies to enhance trust in recommendations, improve the efficiency of charging decision-making, and assess the technology feasibility of estimating optimal suggestions have been discussed. Additionally, potential business models and their viability in the context of the proposed concept have been considered. Based on these findings, several key conclusions and future recommendations can be drawn:

1. Nuanced Flexibility in Different Situations:
Users' preferences for minimum remaining power levels vary depending on their specific circumstances. To cater to this, the service should incorporate machine learning to adapt to users' decisions in different scenarios. Providing a user-friendly means to adjust desired battery levels is essential for streamlining the charging process.

2. Payment and Authentication Process:
Ensuring a seamless payment and authentication process at charging stations is crucial. This aligns with the principle of a "one-stop solution." Cooperation among stakeholders is necessary to achieve this seamlessness, and users should be informed about compatible payment methods.

3. Reservation Features:
While the concept of reservation features has potential, further research and careful consideration of implementation are required. Robust cancellation mechanisms and clear communication about waiting times are essential for a successful reservation system.

4. Strategies to Bolster Trust:
Users need to understand why they can trust the system's recommendations. A transparent onboarding process, with the option to skip, can help build trust. Presenting concise overviews of recommended options based on key criteria can enhance user confidence.

5. Efficiency of Charging Decision-Making:
Users prioritize estimated waiting times when choosing charging stations. Implementing color-coded indicators for congestion levels and presenting key information clearly can improve the efficiency of decision-making.

6. Context-Awareness:
Users appreciate context-aware features but prefer the service to act as an assistant rather than making decisions for them. Clear presentation of route differences is crucial for informed choices.

7. Technology Feasibility:
Existing research, such as intention-aware routing systems (IARS) and demand allocation algorithms, offers valuable insights for optimizing charging route planning. These can be incorporated into the proposed service to improve efficiency.

8. Business Viability:
Consideration of subscription-based models, collaboration among stakeholders, and the inclusion of additional services like pre-ordering can enhance the business viability of the concept. However, extensive market research is needed to align offerings with user needs and preferences.

Figure 65 illustrates a service (the car in the center) that understands what people need.

In conclusion, the proposed service has garnered positive feedback and presents significant potential to enhance the charging experience for electric vehicle users. To realize this potential, future development should focus on adapting to users' changing preferences, improving authentication and payment processes, building trust through transparent onboarding and presentation of recommendations, and optimizing the efficiency of charging decision-making. Furthermore, exploring context-aware features and business models can help create a seamless and user-centric charging journey.



Figure 65 The service (the car in the center) that understands what people need.

Conclusion and Recommendation

Intro

This chapter serves as a comprehensive summary of the findings derived from each phase of this thesis project. It delves into the limitations encountered during the user research phase, providing suggestions to address these constraints effectively. Furthermore, it provides suggestions for future research related to the topic of seamless charging experiences.

Chapter Overview

7 .1 Summary of Findings
7.2 Limitation
7.3 Future Recommendation

Reflection



Finalize

07

7.1 Conclusion

The increasing adoption of Battery Electric Vehicles (BEVs) underscores the importance of a seamless public charging experience. While previous research and regulations have primarily focused on standardizing public charging stations and enabling backend data exchange through roaming, there has been a notable neglect in addressing the fragmented charging experience. Although some discussions aim to streamline the User Experience of public charging, the recommendations have predominantly centered on stakeholder collaboration. This paper identifies two research gaps: first, certain studies focus on predicting user-preferred routes based on limited factors, which may not accurately represent real-world situations; second, some empirical studies uncover individual user pain points, but the broader issues affecting a truly seamless journey remain unexplored.

To address these gaps, two Research Questions guide the subsequent User Research:

"How can the BEV charging experience be optimized to provide seamlessness by considering a holistic view of the user journey, encompassing selection, navigation, authentication, and use of public charging infrastructure, to address the challenges posed by the complex and fragmented charging sector?"

&

"What influential factors should be considered when predicting user preferences for charging decisions?"

Following interviews and observations in the User Research phase, **three main challenges** hindering a seamless charging journey are identified through user journey mapping:

1. Fragmented Information: Users frequently need to cross-reference information between various platforms to make informed charging decisions.

2. Unpredictable Charger Availability: Charger availability is hard to predict due to unexpected factors like non-EV vehicles occupying charging spots or failed charging pass initiation.

3. Insufficient Context Awareness: Users must handle a variety of charging-related data while considering dynamic context-influenced preferences, yet there is currently no integrated context-aware service to help streamline this process and reduce cognitive load.

These challenges address the first research question and establish criteria for a possible solution to enhance the public charging journey.

To address the second research question, influential factors in charging decision-making are identified and categorized into four main categories: Charger & Charging Network, Vehicle feature & Condition, Driving Behavior & Personal Preference, and Route & Environment (Ch. 3.4.3). These factors provide valuable insights for future service developers, enabling them to better understand driving and charging contexts and offer relevant recommendations for a seamless charging journey.

The **Design Goal** formulated based on these insights is:

"How might we create a route and charger suggestion system that adapts to user needs and contextual factors in real-time, providing transparent and insightful information while ensuring a seamless and intuitive user experience?"

Additionally, **five Design Guidelines** have been recognized, which help potential service developers, such as automotive OEMs or EMSPs, understand how to design a seamless electric vehicle user's public charging experience.

In the design phase, this paper primarily seeks to fill the service gaps within the existing BEV charging service ecosystem. A new service model is proposed to address the challenges identified in the user research section. This service integrates factors that users consider when selecting a charging station, offering the most suitable route and charging option based on the current driving context. The service's functionality and user interactions are align with the previously identified five design guidelines.

Next, the validation phase demonstrates that this service concept aligns with user desirability. Users expressed varying preferences for the desired remaining battery level depending on different contexts. They also expressed a desire for more in-car HMI functionality to make one-click adjustments to charging recommendations. It is evident that empowering users to choose and modify settings with ease is crucial in designing this suggestion service.

Furthermore, strategies to enhance user trust in the service's recommended charging options and improve the efficiency of decision-making have been discussed. Changes in information hierarchy have been considered as well. Finally, the potential for making this concept technologically feasible and economically viable has been explored in the validation phase, offering future designers and researchers a direction to realize this service model.

In summary, this project aims to optimize the public charging journey for BEV drivers in the Netherlands. It addresses a gap in research related to user preferences when selecting an EV charger. The project identifies the primary challenges faced by current users and categorizes influential factors into four main groups, providing a foundation for in-depth research on how individuals make their charging decisions. The proposed service model as a design concept has received positive feedback from end-users and holds potential for future iterations tailored to various stakeholders. However, this project does have certain limitations, which will be elaborated on in the following chapter, along with suggestions for further research on this topic.

7.2 Limitation

Reflecting on the research journey of this project, several limitations have emerged, along with potential areas for improvement. The first constraint stems from the project's timeline, which did not allow for a simultaneous exploration of both stakeholders' and end-users' perspectives regarding the EV industry, public charging infrastructure, and the optimization of the charging experience. Consequently, this project did not include interviews with experts from academia, charging point operators (CPOs), e-mobility service providers (EMSPs), or automotive original equipment manufacturers (OEMs). Ideally, a more comprehensive approach would involve gaining an understanding of how various stakeholders within the EV industry collaborate to identify specific service gaps. Nonetheless, this project did provide valuable insights into service models and potential design opportunities that could be of interest to VanBerlo and its automotive OEM partners. From an academic perspective, it contributed by shedding light on end-users' pain points in non-seamless public charging journeys and offering a set of influential factors for researchers exploring user preferences in charging decisions.

The second constraint relates to the focus of this project, which was exclusively qualitative research. During the user research phase, interviews and observations were conducted to collect drivers' opinions about their experiences. Qualitative research undoubtedly offers advantages, such as gaining a deeper understanding of user needs in terms of specific problems (Queirós et al., 2017). Maxwell (2013) also emphasizes that qualitative research delves into the realm of people's thoughts, emotions, and beliefs, going beyond mere quantification. It explores the intricate connections and interplay among various elements. However, qualitative research does not aim for numerical representativeness. Therefore, after identifying influential factors, it is advisable to complement the findings with a broader quantitative study to assess the varying degrees of influence of these elements on users' decision-making processes.

Furthermore, during the survey phase, only approximately 25 responses were collected, making it challenging to establish distinct personas for different BEV drivers. Personas play a pivotal role in guiding design and development teams toward creating an ideal user experience (Matthews et al., 2012). Developing distinct personas allows for the segmentation of customers, enabling more accurate charging recommendations for various user groups. In future research, it is recommended to explore clearer distinctions, such as price- or convenience-oriented drivers, or leverage established models like the Technology Adoption Curve (Rogers, 2003) to differentiate between conservative and innovative drivers. This approach can provide insights into their acceptance of new technologies and their preferences for alternative routes, among other factors.

7.3 Future Recommendation

Firstly, as discussed in the limitations section, the **influential factors guiding users' charging decisions require additional validation through extensive data analysis.** This thesis has provided valuable insights within the confines of a master's thesis. However, the decision-making process for drivers in diverse real-world scenarios remains inherently complex. Conducting large-scale quantitative research could prove invaluable in precisely quantifying the impact of the identified influential factors across different situations. This would ensure that the service's recommendations align closely with the emotional needs and desires of users. Additionally, delving into in-depth qualitative research across a range of scenarios may uncover further hidden determinants of decision-making.

Furthermore, within the concept proposed in this thesis, the most critical aspect to comprehend and manage is **how individuals weigh attributes such as convenience and price in different contexts**. Decision-making across various domains often involves the consideration of multiple objectives, each with its set of inherent trade-offs (Oprean et al., 2019). Therefore, investigating human decision models may equip future service developers with a deeper understanding of how to design services that facilitate efficient decision-making. For example, understanding decision models among EV drivers in different scenarios has the potential to enhance the accuracy of predicting demand levels at specific charging stations, as outlined in section 6.2.3, consequently reducing wait times and optimizing the charging journey.

Moreover, exploring potential business models for this service is a worthwhile endeavor. However, it necessitates a more **profound understanding of how the EV charging ecosystem operates**, including the possibility of stakeholders aligning their interests or facing conflicts due to practical constraints in information sharing. For instance, enhancing user experiences at public charging points could place an increased electricity demand burden on energy grid operators (Mahmud et al., 2023). Striking a balance between these interests and achieving mutually beneficial outcomes warrants thoughtful consideration. Therefore, future research that delves into the operational mechanisms of government organizations, grid operators, or CPOs within the charging station landscape could unearth real-world factors influencing who can develop such a service, how it can be developed, and whether this concept holds potential for a sustainable business model.

Additionally, staying attuned to current technological trends is important. For instance, both industry and academia have been engaged in discussions about **harnessing EV batteries for storing electricity generated from intermittent renewable sources** (Eider et al., 2017). Implementing smart charging mechanisms to leverage this potential could significantly impact the EV charging experience. EV drivers are also increasingly considering the synergy between their electric vehicles and home electricity grids to maximize energy usage derived from sources like rooftop solar panels. Understanding user preferences and considerations across various charging contexts may optimize their allocation of resources between public charging points and those located at or near their homes. This, in turn, could have a profound effect on their experience at public charging stations.

Lastly, but certainly not least, considering that an in-vehicle service could significantly impact drivers' behavior, it is crucial to investigate how the service proposed in this thesis might influence drivers' attention while on the road. Furthermore, it is worthwhile to explore how interactions between drivers and passengers may evolve when such service is introduced. As indicated in the section proposing a business model, there's a possibility that **passengers could become the primary users/operators** of this service. With a shift in the target user, the depth of interaction could become even more substantial. Additionally, it might be intriguing to explore the feasibility of implementing this service in future **autonomous vehicles.** In an autonomous car, the dynamics of interaction between the in-car human-machine interface (HMI) and humans would differ significantly from the current context of EVs. This presents a unique realm to investigate, as the interactions in autonomous vehicles would occur in an entirely distinct context.

In summary, the seamless public charging journeys of BEV drivers are influenced by numerous factors and variables. To genuinely facilitate a smooth and efficient charging journey planning process, it is imperative to understand why different customer segments make specific decisions across diverse contexts and circumstances. Taking a broader perspective to encompass the functioning of various stakeholders within the entire ecosystem may unveil additional avenues for service implementation. Additionally, future research should incorporate the latest technological trends to determine whether there are still unexplored factors beyond the vehicle context that impact users' public charging journeys.

Reflection

Looking back on this project, I've come to realize that the knowledge and teamwork skills I acquired during my first three semesters at TU Delft, coupled with the experiences gained during my internship, have been instrumental in shaping the project's workflow, research planning, execution, and the final design outcomes. For instance, during the user research phase, I applied analytical methods I learned in the "Context Mapping" course to deconstruct user stories and uncover the underlying difficulties and hidden needs. Throughout the teamwork, I learned how to plan projects and drive them forward with a diverse team, gaining insights into effective project management. My internship at VanBerlo provided me with new design tools that significantly improved the quality of iterations and design outputs in the later stages.

Reflecting on my initial personal ambitions outlined in the project brief, the first goal was to improve my ability to visually represent the research process and communicate research findings effectively. I regularly prepared slides for meetings to convey interim findings, and I must thank my mentors for helping me refine the visual logic in these presentations. I challenged myself to make complex research processes accessible to audiences new to the topic, and although there is still room for improvement in presenting complex research early on, through continuous practice and mentor guidance, I found myself capable of producing clear and conceptually sound graphics and research flowcharts later on—a significant improvement.

The second goal was to enhance my communication and active listening skills, a skill set that proved pivotal in this graduation project with six mentors. Balancing academic and corporate demands and ensuring that all mentors were on the same page regarding project progress presented an ongoing challenge. I try to address this by holding regular meetings and striving to share resources, allowing all coaches to stay informed about my progress and potential roadblocks. I also realized the importance of preparing thoughtful questions to facilitate efficient discussions. In interviews and observations, I trained myself to ask users about their thoughts on specific experiences actively. However, this is a skill that requires continuous refinement. Despite room for improvement, I gained confidence during this project that I can independently execute such research and deliver research findings in accessible formats, such as User Journey Maps, to assist collaborative teams in understanding research outcomes.

Looking ahead, I see room for further improvement in two anticipated learning objectives. First, I initially aimed to execute frequent validation and iteration as a means to continuously shift between analytical thinking and creative exploration. However, I found myself becoming engrossed in the design interface, losing sight of the need to validate the proposed service model. In retrospect, I might have approached presenting the service model from a different angle or used alternative tools, engaging in conversations with more experts in this field to gain insight into the pros and cons of the service. Nevertheless, revisiting the literature, I discovered that the conclusions from my user research did indeed address the initial research questions, and these findings were effectively utilized in the design phase. Thus, I did learn how to switch perspectives between analytical thinking and creative exploration and leverage discoveries to fuel conceptual development.

The final learning objective was to enhance my proficiency in data-driven decision-making. Unfortunately, this remains an area where I feel I could have done better. I didn't have many opportunities to explore quantitative research approaches, and gathering substantial user data within the project's time constraints proved challenging. Apart from small-scale surveys, I had limited exposure to data-driven decision-making methods. I hope to have more opportunities to achieve this in future UX research projects to enhance research credibility.

In terms of areas for improvement, I believe that defining the project scope more precisely from the outset could have been beneficial. I underestimated the complexity of understanding the relationships, collaborations, and conflicts among different stakeholders within the entire EV ecosystem. This led me to allocate the first half of the project to understanding the relationships between various stakeholders in the existing EV charging industry, hoping to produce a comprehensive stakeholder map as an output. However, the scope was too ambitious for a Master's thesis project. Later, with mentor guidance, I learned to focus solely on the end-user's perspective to achieve in-depth research outcomes.

In hindsight, I would have defined the scope more narrowly at the outset, concentrating solely on end-users and delving deeper into the literature review, specifically reviewing the charging preference literature, to enhance my academic understanding and contributions. The issue of project scope also affected the project's timeline. Reflect on it, I could have better allocated my time, dedicating more to researching end-users' charging preferences. I might have also sought opportunities to engage with the EV driver community, potentially obtaining a broader research base to collect information and expedite the presentation of interim findings and design concepts. This would have made the project progress more efficiently.

In summary, I have learned the desired skills and research methods during this project, which I hope to continue practicing in the future, regardless of the field. I also aim to address my areas of improvement, ultimately aiding me in developing more creative, innovative, and empathetic designs. Lastly, I hope that this project has contributed in some way to everyone involved, even if just a little.

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Appendix A

Graduation brief

Personal Project Brief - IDE Master Graduation

TU Delft

Synergy Unleashed: Exploring Possibilities of Creating an Integrated Electric Vehicle Charging Service for Driver's Seamless Customer Experience

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 22 - Mar.- 2023 15 - Sep.- 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

[Context]

The global Electric Vehicles (EVs) market is expanding rapidly. In 2021, electric cars, comprising Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), accounted for 9% of the global car market, which is four times their market share in 2019. (IEA, 2022) This trend is also reflected in Europe, where electric car and van registrations rose in the share of total new car registrations from 10.7% to 17.8% in just one year in the EU-27 from 2020 to 2021. (European Environment Agency, 2022)

EVs are gaining popularity among European customers due to various factors. One of the major catalysts for EV growth is the tighter CO2 emissions standards for cars and vans. (Council of the European Union, 2022) The European Union (EU) has proposed legislation to completely eliminate CO2 emissions from passenger cars and light commercial vehicles by 2035. This means that theoretically all new cars and vans sold in the EU after 2035 should be zero-emission vehicles. To meet the emissions reduction targets, many EU countries have expanded purchase subsidies and tax benefits, further accelerating the growth of electric car sales. In addition, according to the 2023 Global Automotive Consumer Study conducted by Deloitte, consumer perception that operating an EV is cheaper than a gasoline car is also fueling the shift towards EVs. However, from the EV user perspective, main concerns include long charging times, shorter driving range and, especially, higher initial investment continue to persist, even if running costs are lower for EVs compared to internal combustion engine vehicles (ICEVs). (Madina et al., 2016)

To alleviate the concerns mentioned above, the expansion of commercial and residential charging infrastructure is the prerequisite for the adoption of EVs. (Baresch & Moser, 2019) Moreover, end users will gradually have greater expectations for the same level of convenience, ease of use, and autonomy with EVs as they have with ICEVs. (IEA, 2022b) Existing studies have mostly focused on improving the allocation and quantity of public charging stations to better distribute charging demand. (Xi et al., 2013; He et al., 2022) However, the cooperation of the underlying system behind the deployment of EV chargers has received less attention in these studies. One of the main challenges in building an adequate EV charging infrastructure and offering a seamless charging service today is the coordination of stakeholders. (S&P Global Mobility, 2022) The EV charging business ecosystem is complex in Europe. It involves stakeholders such as governments, grid operators, car manufacturers, charging point operators (CPOs), energy suppliers, etc. If these parties' divergent perspectives cannot be reconciled, they could impede the deployment of charging infrastructure as well as a seamless and satisfied user experience. (Wolbertus et al., 2020) For example, to find the best deal and obtain a home charging point, a user is required to interact with various entities, including the CPOs, installer, and grid operator (DSO), which can be time-consuming and a hinder to starting the journey smoothly.

Although the conflicts and general consensus of the stakeholders in the charging infrastructure ecosystem have been previously described (Bakker et al., 2014; Wirges, 2016; Wolbertus et al., 2020), the empirical research on integrating stakeholder products and services to meet the needs and expectations of recent end-users is still rarely explored. Additionally, it is essential to understand the city attributes, the demographic factors, and how they influence EV driver charging behaviour (Lee et al., 2022) to find precise intervention opportunities and to develop a customized suggestion for a particular region.

[Stakeholders]

VanBerlo (part of Accenture), TU Delft, and Korea Advanced Institute of Science & Technology (KAIST) are the primary stakeholders in this project. Their common goal is to gain a clearer understanding of the current EV charging landscape. VanBerlo, as a design agency involved in numerous industry projects, seeks to identify opportunities for a seamless EV charging experience, while TU Delft and KAIST have conducted extensive research on the impact of urban attributes on travel behaviour and charging station deployment strategies.

[Opportunities and Limitations]

Opportunities:

From an academic perspective, this project might identify extra demographic or behaviour data variables that could be incorporated into the quantitative research conducted by both institutions to bring it closer to real-world applications. From the business point of view, it might reveal the potential service model for VanBerlo to develop in the future EV charging domain.

Limitations:

The fast-paced growth of the industry and evolving EV charging technologies pose challenges in considering all hardware variables for a graduation project. Additionally, due to regional differences in regulations and stakeholder tasks, this project might mainly focus on the Netherlands' market.

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Personal Project Brief - IDE Master Graduation

TU Delft

introduction (continued): space for images

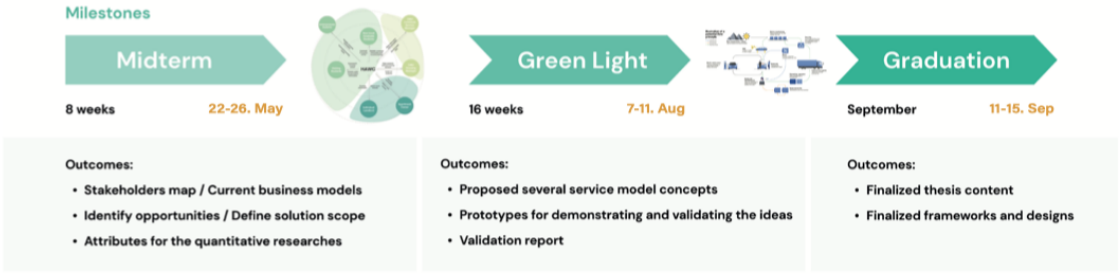


image / figure 1: The project milestones and expected outcomes

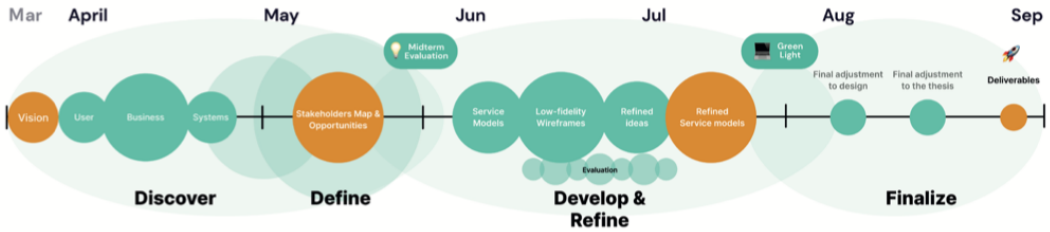


image / figure 2: The visual of the project's design process

Personal Project Brief - IDE Master Graduation

TU Delft

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The EV charging experience for end-users has room to be improved due to the fragrant products and services, outdated communication methods internally and externally of stakeholders, and other underlying factors.

Some pertinent questions to be addressed are:

1. What are the different sets of assets, incentives and roles of the industry participants?
   a. What are the current business models in the EV charging value chain? Is there any example that has already integrated part of the services well?

2. What are the barriers for the participants to synergize their strengths? How can they be addressed and prioritized?
   a. Which segments in the value chain should be focused on? How can the participants in the segment align their incentives?

3. How can a new service model be designed to address specific issues hindering an optimal user experience?
   a. What metrics should be employed to define an optimal charging experience, such as waiting time, detour time, NPS rate, etc.?
   b. What attributes should be taken into account regarding implementing charging services in a specific region?

This project aims to explore the EV charging landscape and identify opportunities for businesses and academics to enhance the EV charging experience, with a focus on the Netherlands' market. By gaining a clearer understanding of the current ecosystem and contextual demographic information, this research can benefit users, industries, and academic researchers seeking to validate their frameworks with real-world data. The outcome, for now, is focus on the B2C solution. However, it might also shift toward the B2B solution depending on what we find along the way.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

By using service design approaches to conduct research on the primary stakeholders in the EV charging industry, I aim to identify valuable design interventions for both industry and academia and develop product-service combination idea(s) that showcase how to optimize the EV driver experience by creating a synergistic EV charging service.

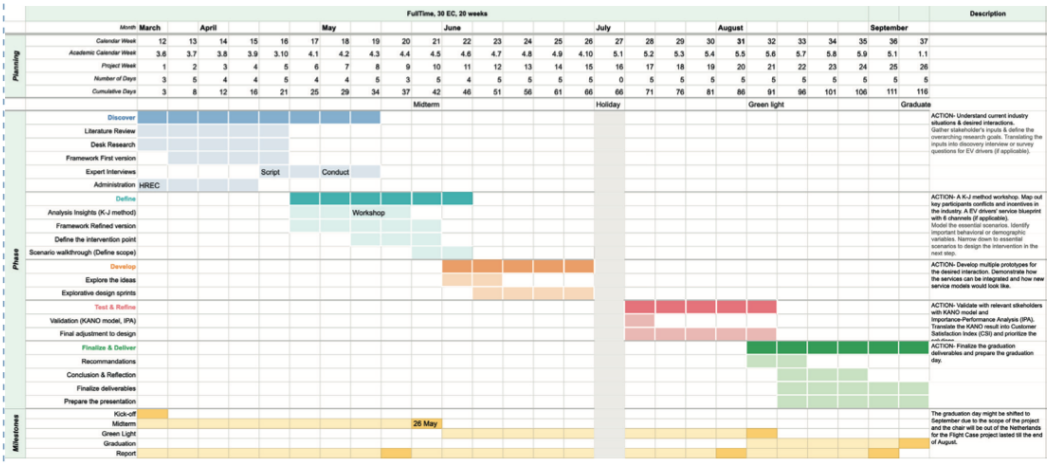
The project will include a literature review, desk research, customer surveys(if applicable), and semi-structured interviews with experts to understand the industry's context better and uncover participants' latent needs. The experts might include the senior managers and consultants in the EV charging domain, EV charger designers, installation specialists, etc. Stakeholder maps will be created to showcase conflicts and consensus in the current EV charging ecosystem. A service framework or prototype will be designed as an example of a possible applicable outcome that is measurable and can be validated by relevant stakeholders.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 22 - Mar. - 2023

15 - Sep. - 2023 end date



APPROACH -
The setup of the project is based on an adjusted triple diamond model: discover, define, develop, test & refine, finalize & deliver which is illustrated in figure 2 (see page 4). Between every phase, there is one week of overlap in which the previous phase is finalized, and the new phase is started.

PLANNING -
I will execute my graduation project on a full-time basis. The kick-off takes place on Wednesday the 22nd of March and the Graduation Day will likely be planned at the beginning of September due to the committee's schedule and the project scope. At the beginning of summer vacation, I will take one week of holiday. Due to national holidays and the reasons mentioned above, the total number of project weeks is 26.

TU Delft

Personal Project Brief - IDE Master Graduation

MOTIVATION AND PERSONAL AMBITIONS
Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

During my internship at VanBerlo (third-semester elective), I had the chance to work on several projects related to the EV charging industry, which sparked my interest in this field. I have always been fascinated by human-technical wicked problems and the mobility industry, and I am eager to explore this complex system further. Through this project, I aim to deepen my knowledge and skills in the field by researching EV charging contexts, mapping out stakeholder relationships, identifying potential opportunities, and using data-driven approaches to support decision-making.

I have gained various competencies during my studies, including design methodology, research-related skills, and analytical thinking. Additionally, my internship experience has provided me with practical knowledge of developing digital products and improved my Figma prototyping skills. Moving forward, I have outlined the following personal learning objectives for my graduation project to further enhance my competencies:

1. **Improve my ability to visually represent the research process and communicate research findings effectively** - Given the substantial amount of data and information involved in the project, it is essential for me to tell a compelling story of the current market and stakeholders' needs and challenges. To achieve this, I aim to enhance my skills in creating storyboards, infographics, and stakeholder maps that clearly represent complex information and intertwined stakes and incentives of the participants in the EV charging industry.

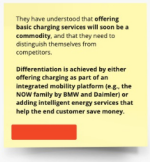
2. **Enhance my communication and active listening skills –** As a person who is comfortable with reading and writing, I recognize the importance of improving my skills in engaging with key stakeholders and extracting valuable insights from user and expert interviews. As a researcher and designer, effective communication and active listening are crucial to understanding the needs and pain points of the stakeholders and users.

3. **Execute frequent validation and iteration as a means to shift continuously between analytical thinking and creative exploration -** I tend to spend too much time in the diverging phase due to my desire to know and understand everything about a topic. To address this, I plan to use a triple diamond and design sprints approach, which will motivate me to deal with uncertainty and research through concept prototypes. Compared to a traditional linear process, the quick design sprints will allow me to fail fast and progress ideas through multiple evaluations, leading to a more healthy learning process.

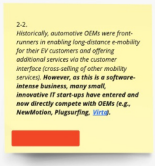
4. **Enhance my proficiency in data-driven decision making -** As an interaction design student and former industrial designer, I have primarily relied on qualitative research methods and design intuition to drive my decision-making process. In light of this project, which involves experts in quantitative research, I aspire to develop a solid foundation in quantitative analysis, which involves utilizing metrics, facts, and data to guide strategic business decisions in alignment with the project's goals, objectives, and initiatives. I aim to expand my knowledge of the relevant tools to perform analysis that provides me with a clear understanding of the problem at hand and supports well-informed decision-making.

Appendix B

Stakeholders' Role Explanation

Stakeholders Needs, perspectives, assets, incentives	Definition	EV-related Needs & Interests	Potential threats for the entity	Relationship with other parties & EV drivers
EV driver	The EV driver is the electric vehicle driver. The consumer who currently is driving the car and needs to charge it to be able to drive it.	• A smooth experience from discovering the EV options, purchasing one, driving on the road, to maintaining the EV-related equipment. • Intelligent management and optimization of energy		
Charge Point Operator (CPO) / Charging equipment provider	The CPO is responsible for the management, maintenance and operation of the charging stations (both technical and administrative). The role of CPO can be segmented into 1. CPO responsible for the administrative operation (e.g. access, roaming, billing to MSP etc.) and 2. CPO responsible for the technical maintenance, which is often done by the manufacturer. Sometimes the CPO is also called a Spot Operator. CPO "does the work of finding a host; brokering the legal and real estate arrangements; working with a power company to wire the site; building the station; and handling the customer financial transaction, repairs and customer service." - Link	• For CPOs, it is pretty simple: **EV charging is a scale game, and the winner takes it all**. Besides expanding their networks by aggregating smaller players, CPOs must **secure the most attractive charging locations right now – especially for fast charging** services. - Source [Detailed needs] • A reliable EV charging management systems notify them when a problem arises with the chargers – or automatically fix it where possible, analyzing business and technical data for efficient decision-making, reducing operating costs and minimizing impact on EV drivers. • A platform that enables CPOs to integrate with multiple EMSPs using established EV roaming platforms like Hubject, GIREVE, and e-clearing.net , will allow them to serve EMSPs across different regions and increase charge point utilization.		• Hands-free "plug-and-charge" payments are lightly adopted but increasingly attractive to customers, with some vehicle OEMs, such as GM and EVgo, collaborating with CPOs to enable this functionality.
E-Mobility Service Provider (EMSP/ MSP/ EMP/ eMobility Operator)	Offer service contracts to end customers and provide the user interface for access to and usage of charging infrastructure. Today, practical access to charging is mainly through RFID cards and apps.	• Source: For MSPs, it is mainly about diversification. MSPs must **either have the most intelligent energy services or offer charging as part of integrated mobility platforms.** (OEM-related MSPs have the additional advantage of being able to lock EV customers in if plug & charge becomes the market standard.)		The entity with which the **EV driver has a contract for all services related to the EV operation**. Typically the eMobility operator **will include some of the other actors, like an energy provider or a CPO, and has a close relationship with the distribution system operator and meter operator. A car manufacturer or utility could also fulfil such a role.**
Regional Grid Operator - Distribution System Operator (DSO)	The organization that designs, operates and maintains the public **distribution medium and low voltage grid** through which charging spots are supplied. The charging spots are connected to a **private grid (home, building, installation site**...) connected to DSO grid.	Grid stability through balanced supply and demand at the micro level 	The demands from EVs exceed the grid capacity.	• Grid operators (who are not allowed to sell electricity) **aim for a top-down configuration in which a smart grid decides which cars are to be charged and how fast this can be done.** • the majority of grid operators founded an association: **E-Laad. E-Laad has installed 2000 charging stations in response to requests from municipalities and EV drivers (E-Laad, 2012).**
Charge location owner	This is the owner of the charge location and often the owner of the charge point, such as shopping centers, restaurants and gas stations. Depending on the location (public, private) **the energy is purchased by the charge location owner or by the charge point operator.**	Depends on who is the owner. If it's shopping center or gas station, then they might want to boost their business by attracting waiting drivers to buy their service. If it's CPOs, then the stability and usage data of the station might be interested to them.		
Energy supplier - Electricity producer	The energy supplier offers the energy for the electric car via (public) charging points. There are various suppliers who produce energy or buy energy themselves.	• Balance of demand and supply at the macro level - The cumulative capacity of the batteries of future EVs could make it possible to store renewable energy in times of energy surplus. In the long run, EVs could then also be used to deliver this energy back to the grid. • Market expansion		• Electricity producers hope to influence charging behavior through price incentives
Roaming Platform	A central organization that facilitates information exchange between multiple market players. Roaming platforms connect different market players to create a digital and cross-border charging network for electric vehicles.	Their key success factor is offering MSPs and CPOs access to as many partners as possible.	• For eRoaming platforms, it will be extremely difficult to remain in the game. 	Act as **aggregators of the two other roles, connecting CPOs and MSPs**. Aggregators such as Hubject and Gireve were put in place by energy and automotive companies.
EVRoaming Foundation - Open Charge Point Interface (OCPI) protocol	The objective of the EVRoaming Foundation is to facilitate roaming services for charging electric vehicles and provide transparent information to consumers about charging locations and prices, by use of the open and independent **Open Charge Point Interface (OCPI) protocol**.	The goal is to allow any EV driver to charge at any charging station in the EU: simplify, standardize and harmonize.		**OCPI - Open Charge Point Interface protocol/ NKL Nederland** OCPI is an independent roaming protocol that makes it easy to exchange data. It can be used both by companies (peer-to-peer) and via a roaming hub or platform. The protocol is supported internationally. With OCPI EV drivers get an insight into the availability and costs of charging points.
Transport System Operator (TSO)	A party that is responsible for a **stable power system (high voltage) operation** (including the organization of physical balance) through a transmission grid in a geographical area. The System Operator will also determine and be responsible for **cross border capacity and exchanges**. If necessary he may reduce allocated capacity to ensure operational stability	The stability of the power system. Grid stability through balanced supply and demand at the macro level.		

B

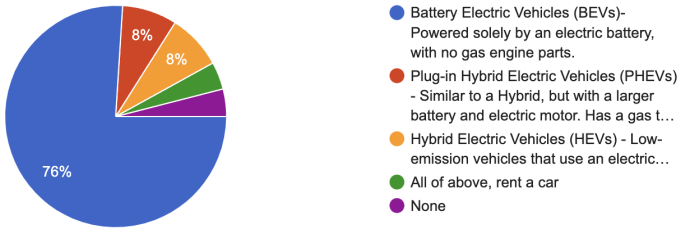
Stakeholders Needs, perspectives, assets, incentives	Definition	EV-related Needs & Interests	Potential threats for the entity	Relationship with other parties & EV drivers
National government	The Dutch national government, and in particular the ministries of Economic Affairs and Infrastructure and the Environment	Reduced carbon emissions, improved air quality, reduced fossil-fuel dependence, economic growth		
Local governments	The Dutch local governments. The strategies and underlying rationales of local governments regarding EVs vary. Some of them have provided financial and non-financial incentives to encourage citizens and local businesses to adopt EVs. They are responsible for the provision of a city-wide public recharging infrastructure.	Improved air quality, reduced carbon emissions, (These standards must be met to avoid an EU ban on further urban development and a national plan of action to improve air quality was agree upon) , and optimal use of parking space	Large numbers of charging stations and attached cables could have a negative impact on the street environment and safety. Also, the parking spot reserved for EVs possibly increase parking pressure in inner-city areas.	
Car manufacturers - Automakers - OEMs	Companies manufacturing the Electric Vehicles, such as Toyota, Audi, BMW, Volkswagen, etc. Some choose to follow an incremental hybridization route while others aim for full-electric vehicles or even fuel-cell EVs (powered by hydrogen).	Long-term viability of business, compliance with emissions regulations; freedom to develop product portfolio (level playing field for all options) Depending on their product portfolio, car manufacturers plead for incentives that include only full-electric vehicles or incentives that include also plug-in hybrids.		
Oil and gas firm	A business entity that engages in the exploration, production, refinement, and distribution of oil and gas.	Sustained market share for oil and gas-based products in the transport sector.		
Start-ups (IT players)	**IT players** such as NewMotion, Virta and eMotorWerks (Enel X), are currently frontrunners in developing V2G/V2X solutions.	Growing their business.		

Appendix C

Survey Questions & Results

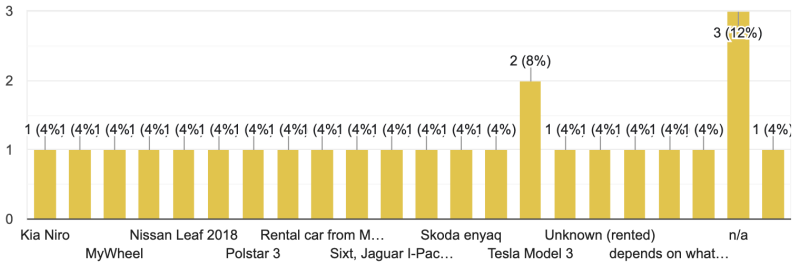
What type(s) of electric vehicle are you driving? clone

25 responses



Which EV model(s) do you have? clone

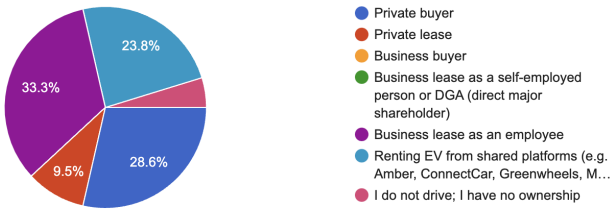
25 responses



Driver types

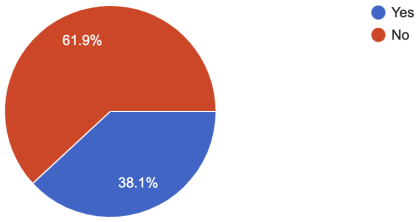
Through which form of ownership do you drive your EV? clone

21 responses



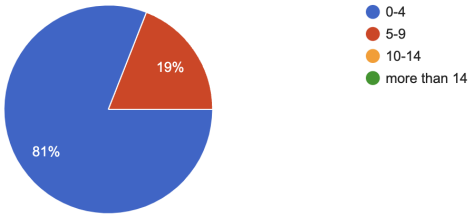
Do you mainly charge at the same network/company's chargers?

21 responses



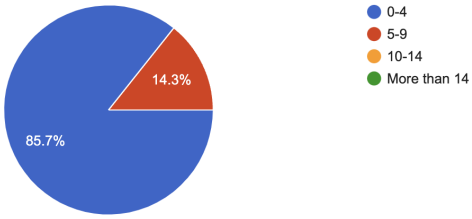
How many platforms (e.g. Apps, Webs) do you use for charging your EV on the road?

21 responses



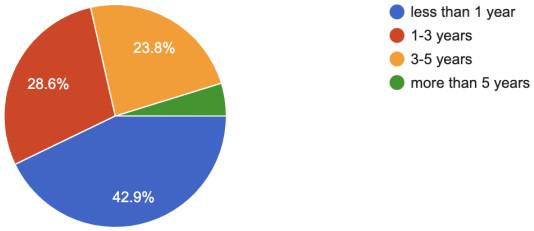
How many charging passes do you have?

21 responses



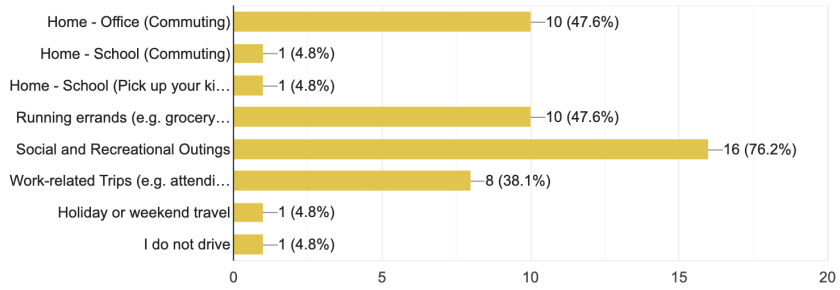
How long have you been driving an EV?

21 responses



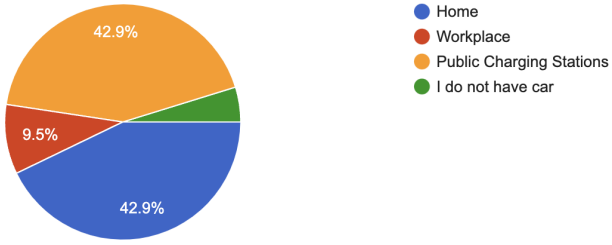
What are the 3 most frequent reasons to drive your car?

21 responses



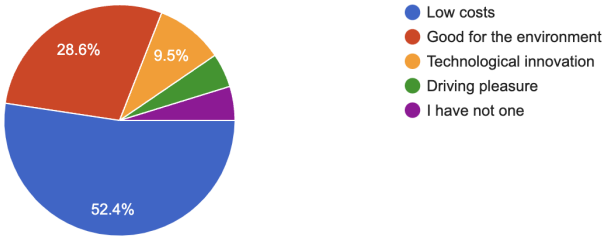
Where do you usually charge your car?

21 responses



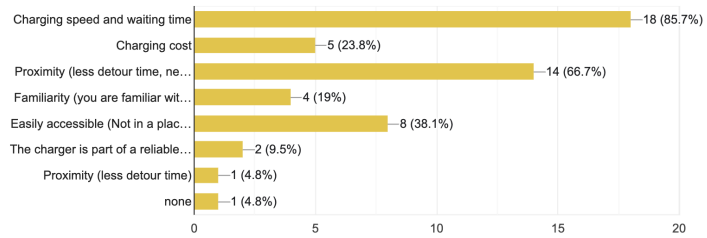
What is the most important reason for you to drive an electric vehicle?

21 responses



When selecting a public charging station, which three things are most important to you? clone

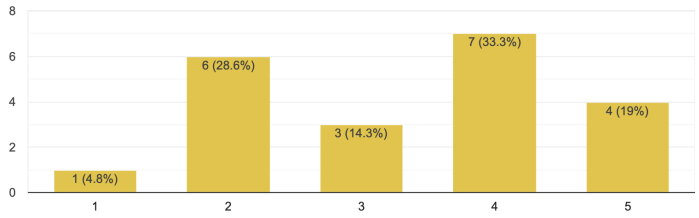
21 responses



Satisfaction of current public charging services

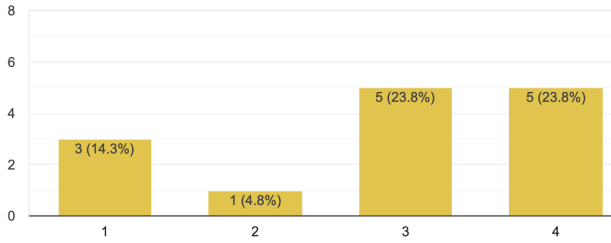
While **planning where to charge my car**, I can always find the necessary information I want. clone

21 responses



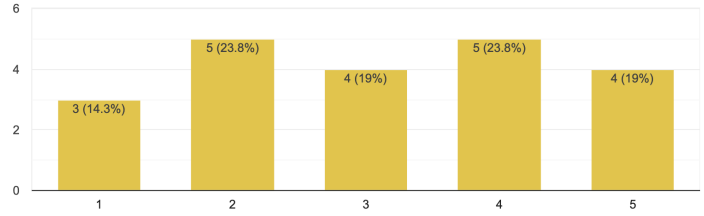
Matching my car to the connector is always smooth for me.

21 responses



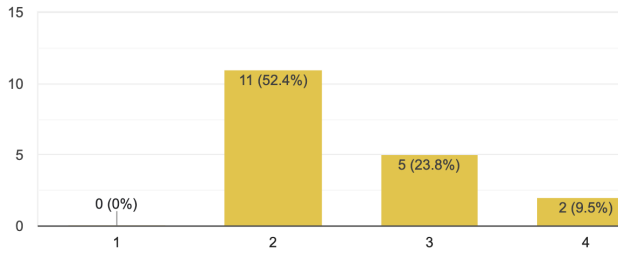
Searching for and selecting a suitable public charger for my car is effortless. clone

21 responses



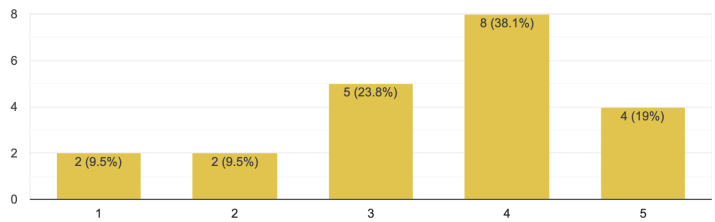
Having authentication to start a charging session doesn't take a lot of effort

21 responses



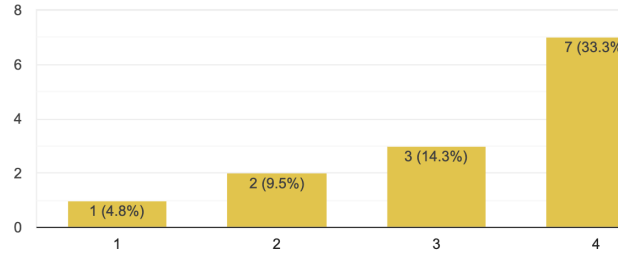
After the charger is selected, **navigating** (add a stopover and detour) **to the charging station while driving** is easy and simple. clone

21 responses



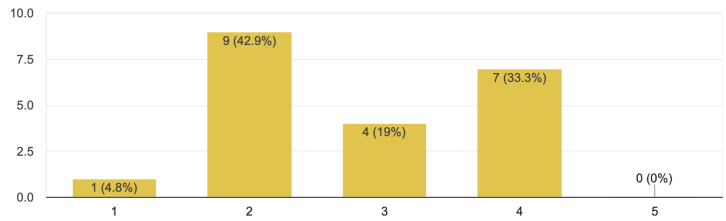
The **payment** process is convenient for me.

21 responses



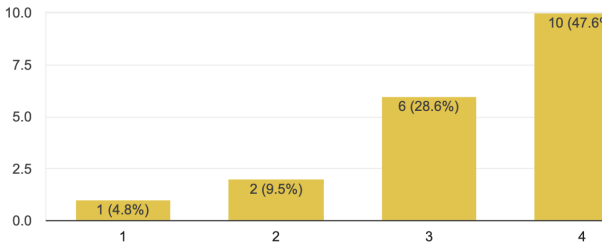
When I arrive, I can **always access** the charging point I want without any issues or queues. clone

21 responses

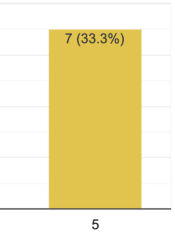


I find my **waiting time** relaxing and comfortable.

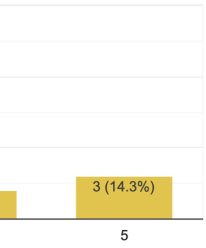
21 responses



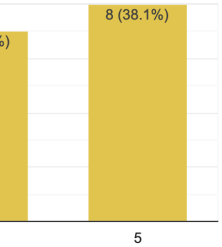
clone



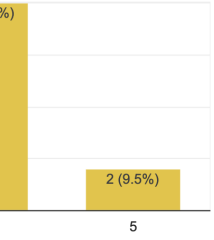
for me. clone



clone



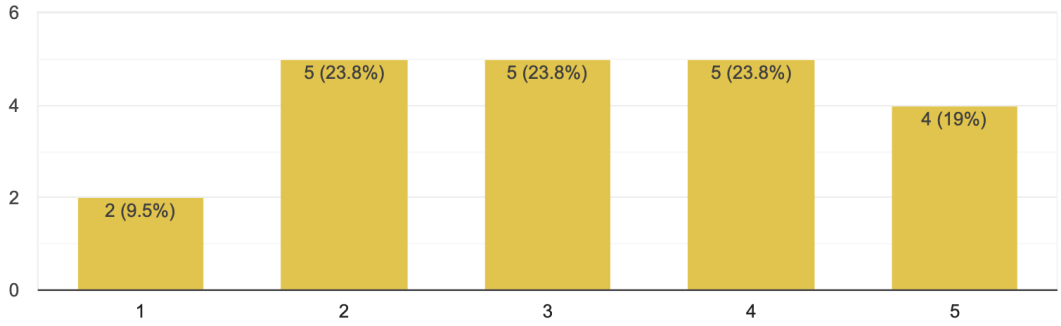
clone



Overall, the process of charging my EV at a public station is **streamlined and seamless**.

clone

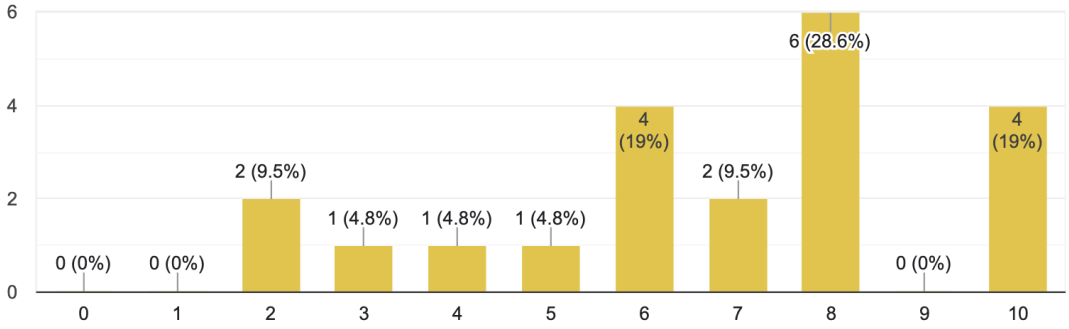
21 responses



How likely are you to recommend public EV charging service to someone like you?

clone

21 responses



Please note that since this survey includes responses from a few Tesla drivers, the final scores for overall process satisfaction and the NPS score might be higher than the actual situation.

Interview Script

Script of Interview

1. Welcome (2mins)
Introduce the project and ask general info of the interviewee.

Thank you for participating in this study. I am Chiapei, who is recently doing a Master thesis at TU Delft / VanBerlo. My project is about understanding the charging experience of battery electric vehicle drivers in the Netherlands at public charging stations.

I am curious about how you plan your charging session, navigate to the 'right' charger, and your experience of charging your car AT the station.

This interview will last around 45 mins. Feel free to talk about anything. Everything will be anonymised. If you have any questions during the interview, please feel free to ask me.

[Ask for consent]
This interview will be recorded. It's just for me to reflect on the session and will not leak to the people outside of the project. Is that ok for you?

2. General question (5-10 mins)

2-1. I saw you wrote in the survey that __is your main barrier to charge your car in public space. Could you tell me a little bit more about it?
[If they didn't write the barriers]
- What is the most troublesome experience for you recently when you need to find a suitable public charger (navigating to the place and finding the charger is not working? Is the support team reply in time?)

2-2. How many Apps do you need to go through generally? You mentioned that you need __(Apps) to access a 'right' charger. Which one is used predominantly, and why? (because of the crucial info they have? Fluent usage?) What info do you want to know but didn't integrate well there?
Could you tell me how you normally switch through those platforms to find the information you need?

3. Planning (10 mins)
Understand the interaction between users and OEM's dashboard, OEM's specific App, Navigation App, or other platforms.
3-1. How do you usually determine when and where to charge your car (planning your route)?
- Do you usually plan the route ahead? Why? (Still have range anxiety? Or because of personality, stopover numbers, or other reasons?)
- Will you consider your schedule to plan a stopover to charge? How do you plan the route and is that intuitive for you?

3-2. Are you provided with enough info (like battery capacity, schedule, etc.) you need?
- How would you like to have better access to this information?
- How do you normally monitor your battery capacity? (In car HMI? OEM App?)
- Is the info clear and intuitive? Why?

4. Selecting and Navigating (10 mins)

4-1. Imagine you suddenly needed to visit a sick loved one who didn't live nearby. You were driving your car and found out there was only 25% capacity left. Now, you need to find a suitable and available charger for it on the way there. What would you do first?

4-2. In this situation, what information is crucial for you to know? (Do you actually get it?)
- Does the information communicate in a clear and intuitive way? If not, what do you need but haven't been provided in a proper way?
- What info about the charging points do you need the most? Is 'understanding the context' important for you?

4-4. So when it comes to a normal situation to choose one charger on the road, what are the top three priorities for you? (Time, detour time, proximity, waiting time, facilities, etc.) >> pause, let them talk first
[Or ask them to elaborate the answers]

5. Arrive & Authentication (5 mins)

5-1. What matters the most to you when you arrive at the charging station?
(no queue, the CP you want is available, which CP I should pick, facilities aside it, etc.)
What do you wish you knew in advance that you can't find out immediately from
existing services?
- When it didn't work? What did you do?

5-2. How do you feel about using multiple approaches to authenticate and pay for public EV charging?

5-3. What is, in your opinion, the perfect authentication and payment process, and why?
- Is the authentication process usually fluent or hassle for you?
- Would you consider the payment process trustful? Why?
- Did you encounter some unexpected fee before? (charge you with the session that is not yours)

[Can skip this one if have no time]
5-3. Do you have any preference for the charging service company/brand? Why? (Maybe it's just because the contract or price, not because of the good experience or loyalty)

6. Charging & Waiting (10 mins)

[If they already mention it, skip]
6-1. How do you feel about the charging points' physical/digital information?
- Is the information on-site (screen, LED, or physical manual) clear enough for you to understand how to proceed? If not, which part do you feel the most confused about?

6-2. What do you do while you are waiting?
- What was your most comfortable and least comfortable waiting experience?

6-3. How do you usually observe the charging progress?
- Do you monitor it from the on-site screen, the HMI in the car, or any other way?

6-3. [If no time, skip] What actions do you do after the session is finished?

7. Other drivers [If no time, skip]

7-1. Just curious, do you share the EV with other family members?
7-2. Is the experience different for them?

[Finish]
- Do you have any suggestions, remarks or want to elaborate on a previous answer (survey and interview)?
- Would you like to participate in the validation phase of my project? (If not, it's also fine.)

Thank you for sharing your experience with me! Here is the link to the general survey I mentioned at the beginning. If you think of any important experiences that you forgot to mention, please feel free to add them in the survey or contact me directly. Here is my contact info:...

Appendix D

User Journey Map - High Resolution

JOURNEY MAP

PHASES

Plan & Select | Navigate | Access the charger | Authenticate | Charge & Wait | Leave & Payment

(Before departure) | (Before / After departure)

MAIN TASKS

Sub activities

Plan & Select		Navigate	Access the charger		Authenticate		Charge & Wait	Leave & Payment
Seek out a suitable charging network based on individual needs.	Locate an available charging station.	Checking other factors based on driver or passenger's needs	Set to go	Navigate to the charging station	Detour to the charging station (i.e. getting of the highway)	Access the parking space (e.g. parking lot, gas station, etc.)	Authenticate with the compatible charging pass.	Check if the charging session start correctly.	Use amenities around the charging station.	Check the monthly bill
• Look for a charging station company with extensive coverage, cost-effectiveness, or environmentally friendly energy sources. • Familiarise with each city's local charging network to avoid additional fees. • Order the charging passes from each company.	• **Use EMSP's app (e.g., E-Flux), CPO's app (e.g., Shell Recharge), or Google Map to locate a convenient charging station along the route.** • Take into account the **remaining range**, determine the optimal charging time (moment), and search for the most suitable charging location. • Check the **available charger's number** • Ensure the charger is **compatible with the charging pass**.	• **Check the amenities of the charging station.** • **Check the charging fee.** • Check other factors depends on the situation. • Compare the available charging stations to find the one that best meets current needs.	• **Manually transfer all the route planning from one platform (e.g. Shell's App) to the in-car display.** • Comparing the route planning of different platforms.	• Use Apple CarPlay, Android Auto, or other services to navigate to the destination. • Follow the voice instructions and glance at the directional prompts on the screen.	• **Follow the navigation instruction.** • **Sometimes need to detour a bit.**	• **Access the (underground) parking lot.** • **Look for the actual location of the charging points.** • **Verify if the charger is currently available.**	• **Follow the instruction to connect the charger to the car.** • **Authenticate with the CPO or EMSP's App, CPO's website, own charging pass, or credit card.** • **Check the charger's ID.**	• **Check the charging point's LED ring** (Green-available/Blue-charging/Red-Error) • **Check the in-car display (Instrument cluster or middle console)** • **Check the OEM's App**	• For example, eat in the restaurant, go to toilets, go grocery shopping, etc.	• Leave the place (and maybe pay for the parking) • Check the App to see if the charging session is correctly recorded. • Verify the monthly bill to ensure it matches the actual charging sessions.

TOUCHPOINTS

- CPO's App (e.g. Shell Recharge)
- Google Map
- EMSP's App (e.g. E-Flux)
- OEM's Services
- In-car Display
- Physical Charger
- CPO's Website
- Credit Card or other Authentication system
- Consumer Council Website (e.g. Consumentenbond in NL)

CUSTOMER THOUGHTS

Pains

Gains

NEEDS

The information helping driver maintain the health of battery is appreciated before driver hit on the road. While driving, it's not appreciate to have too complex indication or instruction of 'how your driving behaviour affecting the battery' since it would be distracting.

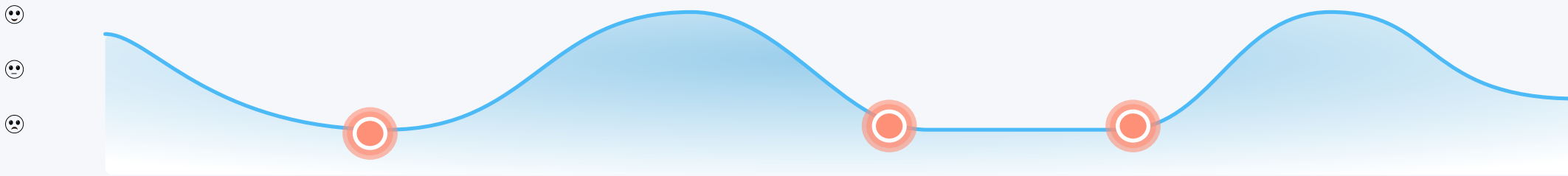
BUT

FACTORS INFLUENCING WHERE TO CHARGE

Need to find a combination of multiple requirements while planning where to charge

Can we see this as a cognitive load?

EMOTION

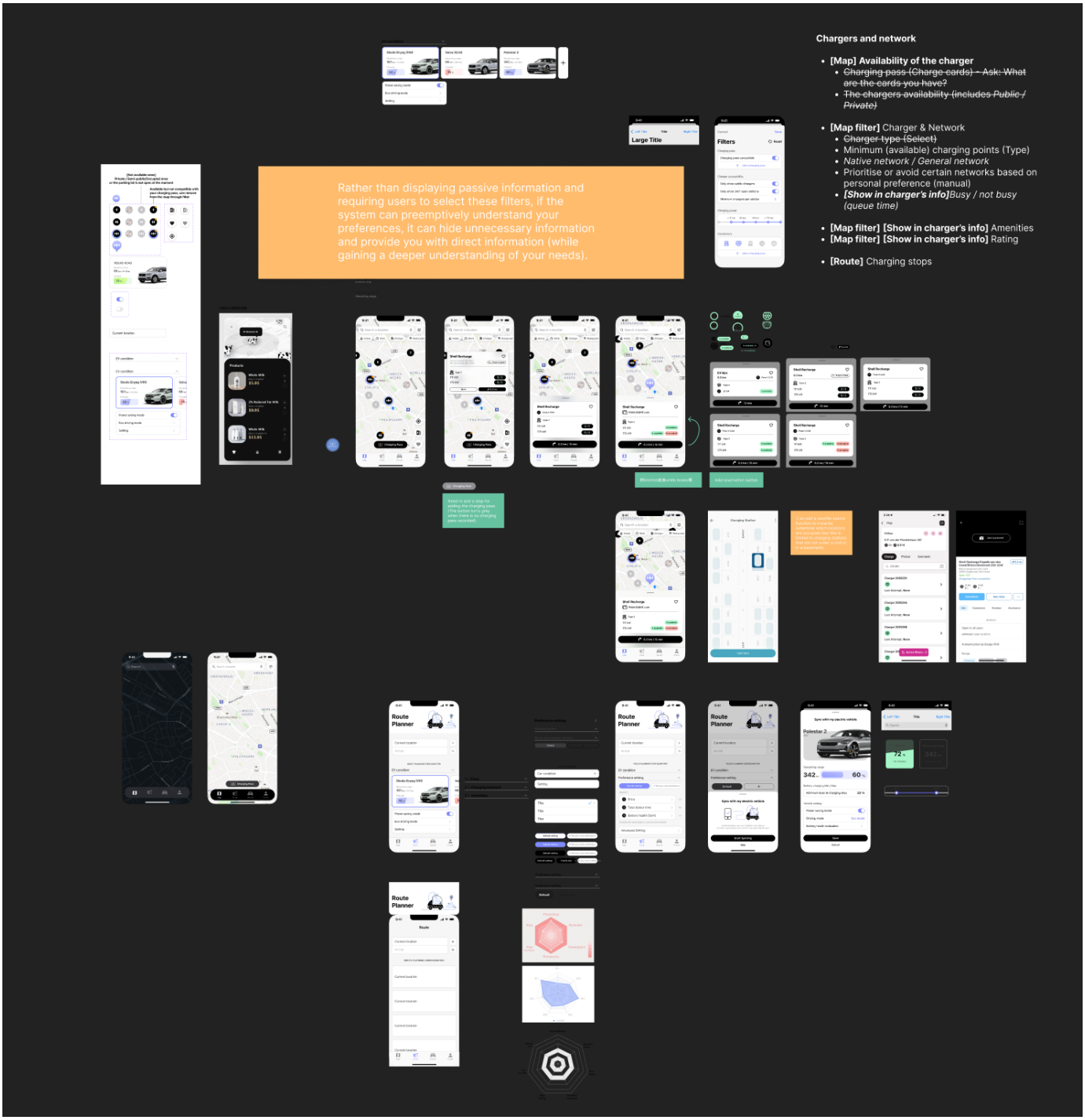


Appendix E

Prototype iterations

Firstly, an App is develop.

However, we decided rather than displaying passive information and requiring users to select these filters, if the system can preemptively understand your preferences, it can hide unnecessary information and provide you with direct information (while gaining a deeper understanding of your needs). Therefore, we change the plan to focus on the in-car display and demonstrate how the system can assist users on the road.



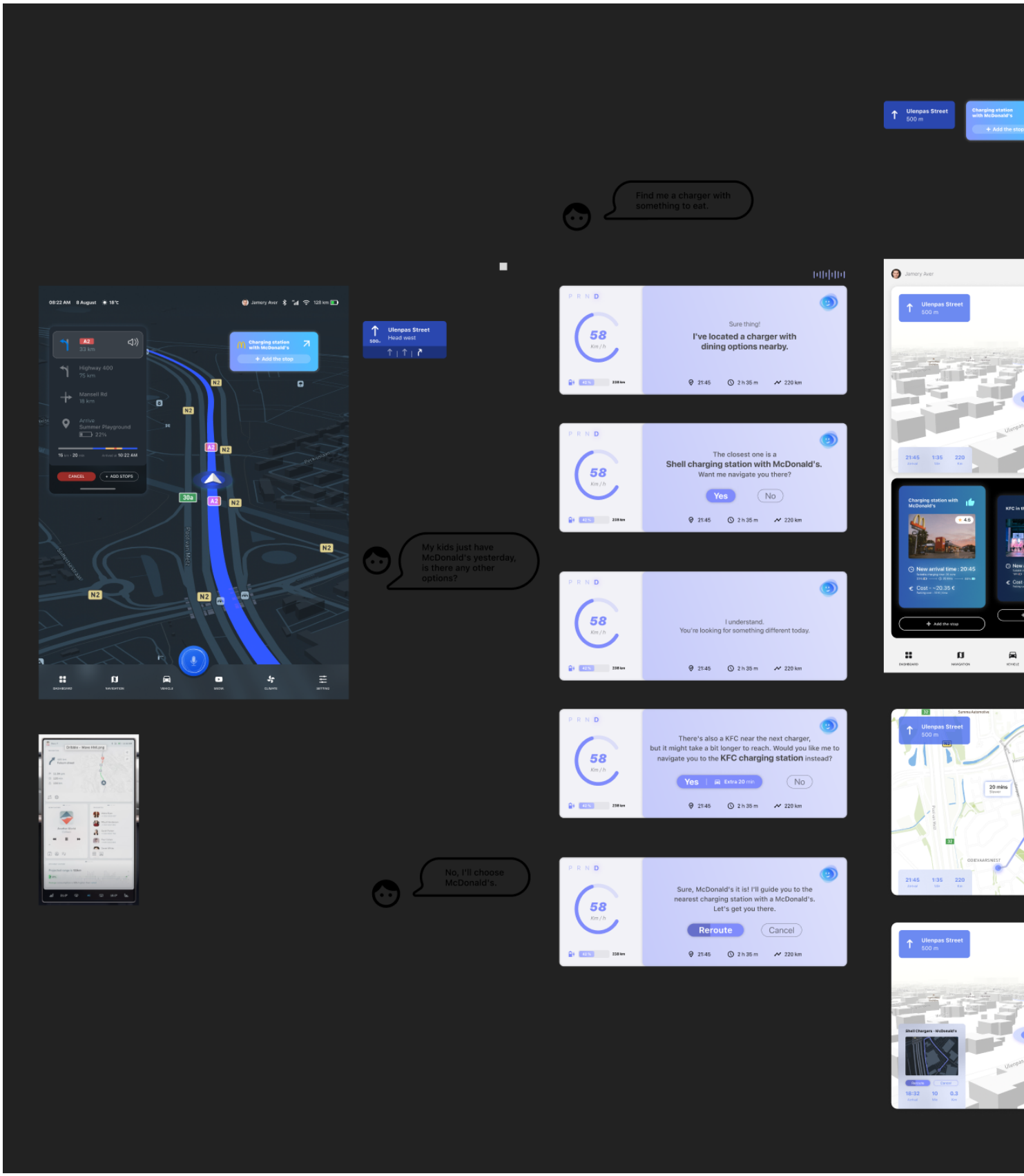
The second prototype

The second one is too complicated for participants to grab the concept idea swiftly. Therefore, we minimize the screen size and see what can be highlighted in the interface.

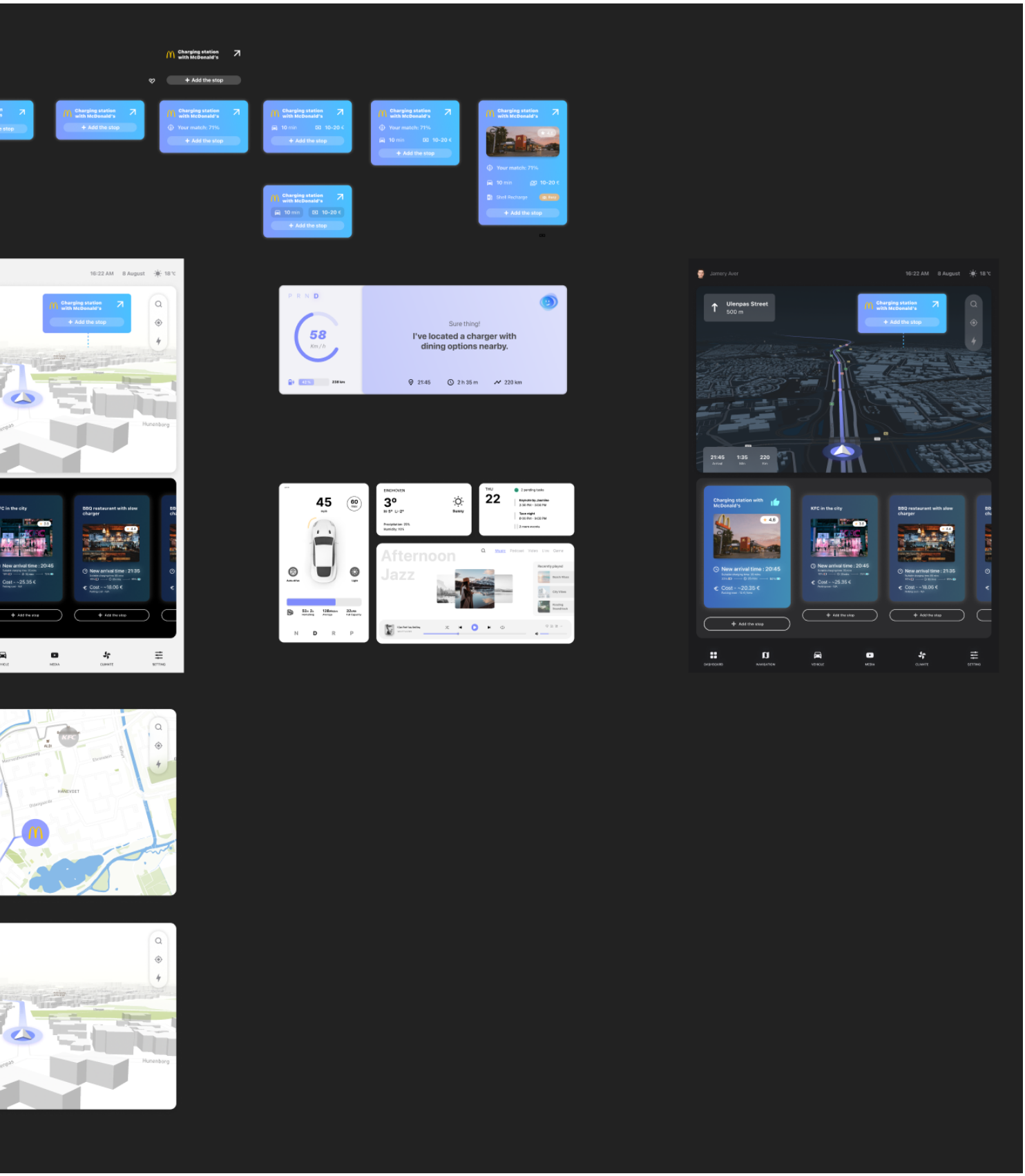


The third prototype

The third one's structure looks almost like the final prototype. However, it contains the instrument cluster's screen and the central console's interface. Displaying information in this way would distract users from understanding the concept itself. They might be feel confused to think where should they look and what's the information in different screen relates to each other.

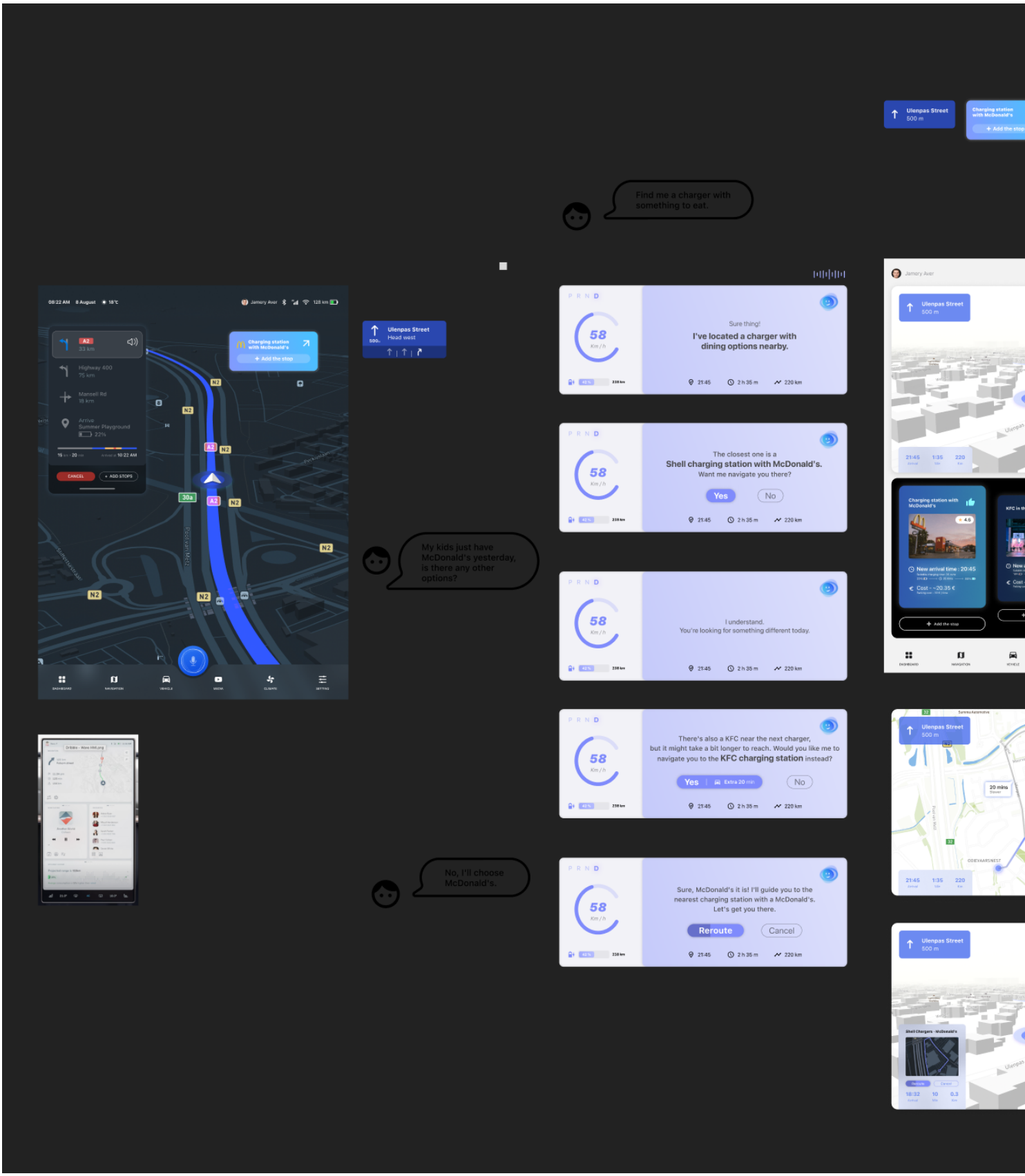


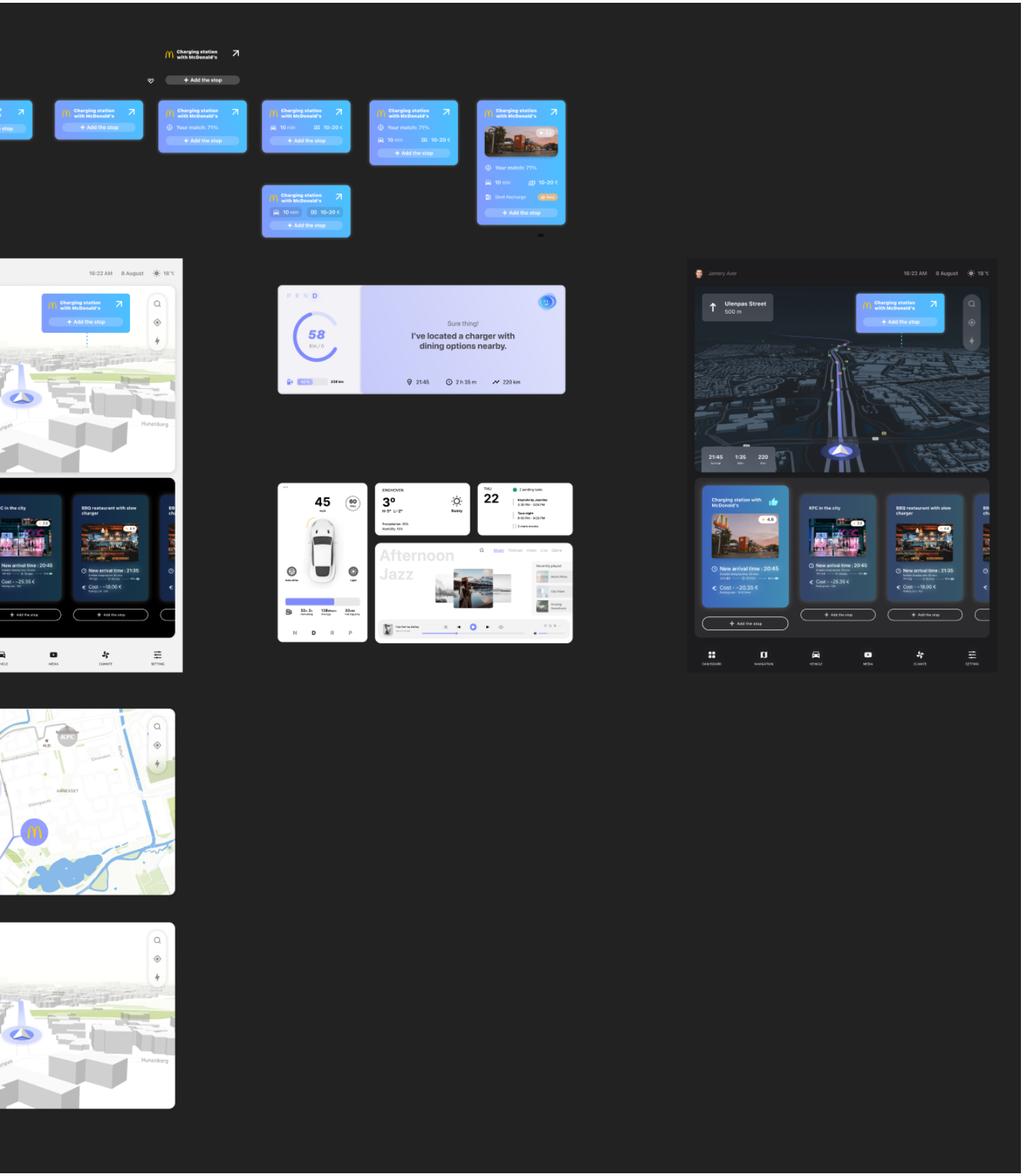
E


Charging station with McDonald's
+ Add the stop
Your match: 71%
10 min
10-20 €
Sure thing!
I've located a charger with dining options nearby.
58
Km/h
21:45
2 h 35 m
220 km
Ulenpas Street
500 m
New arrival time : 20:45
Cost - ~20.35 €
KFC in the city
BBQ restaurant with slow charger
New arrival time : 21:35
Cost - ~18.06 €
Afternoon Jazz
Hunenborg

The third prototype

The third one's structure looks almost like the final prototype. However, it contains the instrument cluster's screen and the central console's interface. Displaying information in this way would distract users from understanding the concept itself. They might be feel confused to think where should they look and what's the information in different screen relates to each other.




Charging station with McDonald's
+ Add the stop
Your match: 71%
10 min
10-20 €
Shell Recharge
Sure thing!
I've located a charger with dining options nearby.
21:45
2 h 35 m
220 km
58
Km / h
Ulenpas Street
500 m
Afternoon Jazz
45
3°
22
Hunenborg

2023. collaboration with VanBerlo and KAIST

Chiapei Lai
Design for Interaction
Delft University of Technology