Barriers to Innovation: Adoption and Diffusion of Wireless Charging and Electric Taxis

An in-depth Analysis of the Adoption Barriers & Diffusion for Electric Taxis & Wireless Charging Technology

Master's thesis in Management and Economics of Innovation & Supply Chain Management

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Abstract

The transition to electrification in the transport sector is crucial to mitigating environmental challenges, especially greenhouse gas emissions. This master's thesis examines the adoption and diffusion of wireless charging technology and electric taxis in urban environments, with a focus on Gothenburg's Green City Zone. The research addresses two primary questions: How do the challenges faced by electric taxi fleets in the past compare to the current challenges these fleets face with integrated 43kW wireless charging? And how do these barriers affect the adoption and diffusion of electric taxis and wireless charging? Data were collected through qualitative interviews with taxi drivers and stakeholders, supplemented by quantitative analysis of charging behaviours. The theoretical framework includes the Technology Acceptance Model, the Unified Theory of Acceptance and Use of Technology, the Diffusion of Innovations Theory, and ADKAR which provide insights into user acceptance and technology diffusion. The results demonstrate that while wireless charging and electric taxis can offer significant operational and environmental benefits, their widespread adoption is hampered by several interconnected barriers. Addressing these barriers holistically is crucial for the broader adoption and integration of electric taxis and wireless charging into urban transportation systems. Future research should focus on mass deployment of wireless chargers, investigating scalability, economic feasibility and impact on the power grid to facilitate wider urban implementation. This study contributes to the understanding of the integration of advanced technologies in sustainable urban mobility and offers practical insights for policymakers and industry stakeholders.

Keywords: Electric Vehicles, Wireless Charging, Electric Taxis, Sustainable Urban Mobility, Green Gas Emissions, Charging Infrastructure, Adoption and Diffusion, User Acceptance, Barriers to Adoption, Environmental Sustainability, Renewable Energy, Urban Transport, Innovation.

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Abbreviations

ADKAR - Awareness, Desire, Knowledge, Ability, and Reinforcement
EE - Effort Expectancy
EV - Electric Vehicle
FC - Facilitating Conditions
ICE - Internal Combustion Engine
PE - Performance Expectancy
PEoU - Perceived Ease of Use
PU - Perceived Usefulness
PV – Price Value
TAM - Technology Adoption Model
UTAUT - Unified Theory of Acceptance and Use of Technology
UTAUT2 - Unified Theory of Acceptance and Use of Technology 2

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1. Introduction

This master's thesis will explore the ongoing shift towards the electrification of the transport sector, with a focus on the adoption and diffusion of wireless charging and electric taxis in urban environments.

1.1 Background

According to NASA (2024), excessive use of fossil fuels leads to emissions of greenhouse gases, which results in global warming, one of the most significant challenges our planet is currently facing. The transport sector contributed to approximately 25% of Europe's total CO_2 in 2019, of which road transportation was responsible for 71.7% (European Parliament, 2023). Consequently, numerous nations intensified their policies on the electrification of road transportation by implementing initiatives to promote the widespread use of EVs (electric vehicles) and the expansion of necessary charging infrastructure (Dimitriadou et al., 2023). The European Environment Agency established an initiative called "Fit for 55", with a set target of reducing CO_2 emissions for cars by 55% in 2030, relative to the year 2021, and being 100% CO_2 emission-free for new vans and cars by 2035 (European Environment Agency, 2023; European Commission, 2023). Canada announced in 2021 their federal target of achieving 100% sales of zero-emission light-duty vehicles from 2035 to 2040 (Dimitriadou et al., 2023). Additionally, the United States of America set a target in 2022 of achieving 50% in EV sales and establishing 500,000 public charging stations by 2030, facilitated by new incentives and subsidies (Dimitriadou et al., 2023).

A strategy involving EVs could be a major part of coping with these challenges, as they do not rely on fossil fuels and use significantly less oil (Longo et al., 2018). The benefits of electric cars compared to internal combustion engine (ICE) vehicles include reduced emissions, lower operational costs, and improved user experiences with quieter rides (Ahmad et al., 2018; Zamanov, 2023; Energy5, 2023a, 2023b). While the higher initial cost of EVs poses a challenge, government incentives and increasing consumer acceptance promise a sustainable solution for future urban transport (Wolbertus, 2020). Ideally, all EV charging should come from renewable energy sources, but even if this is not the case, EVs still offer three times better energy efficiency than diesel vehicles (Prohaska et al., 2016).

The evolution of urban mobility is rapidly moving towards more sustainable and technologically advanced solutions, with EVs leading this transformation (McKinsey & Company, 2021). Electric taxis play a crucial role in sustainable urban mobility, highlighting the increasing need for charging infrastructure (Oliveira, 2020). The exploration of technologies like fast and wireless charging is essential to meet this need (Ahmad et al., 2018). Wireless charging offers a seamless and convenient experience by eliminating the need for physical cables (Ahmad et al., 2018). When integrated into public and private parking spaces, it can provide continuous top-up charges without driver intervention, enhancing the practicality of EVs and promoting greater reliance on electric transportation (Ulrich, 2020).

Therefore, the investigation and development of these technologies are crucial not only for improving user experience but also for supporting the broader infrastructure and ecosystem necessary for a successful transition to electric mobility (Ahmad et al., 2018). This transition is of the utmost importance for reducing carbon emissions and achieving global sustainability goals in transportation (Longo et al., 2018).

1.2 Project Background

The "Wireless Charging for Taxi - in Gothenburg Green City Zone" project represents a significant leap in innovative and sustainable urban transportation solutions. The Gothenburg Green City Zone is a dynamic testing ground for zero-emission transport solutions. The aim is to ensure that all transport within selected areas is 100% emission-free by 2030. The region will become the first to develop zero-emission, scalable transport solutions at the system level (Smart City Sweden, 2022). The initiative is a technological experiment and a step towards redefining urban mobility in Gothenburg. The project launched with twenty Volvo XC40 EVs and was designed to test the viability of 43 kW wireless charging technology in a real-world urban setting. A diverse group of key players has been brought together, each contributing their unique expertise and resources towards the common goal of redefining urban mobility.

Organisation	Role in the Project
Volvo Cars	Leading automotive manufacturer. Supplied the project with twenty Volvo XC40 EVs.
InductEV	Specializes in developing wireless charging solutions. Provided the cutting-edge technology necessary for the project.
CabOnline	Largest taxi operator in the Nordic countries. Plays a crucial role by integrating EVs into its taxi fleet.
Göteborg Energi	Key energy provider in the region. Supports the project by ensuring the wireless charging stations are powered by sustainable energy sources.
Vattenfall	Ensures that the automated payment solution, InCharge, operates seamlessly for wireless charging during the trial period.
Business Region Göteborg	Facilitates the project's integration within the city. Works to align the project with Gothenburg's broader environmental and urban development objectives, contributing to the city's Green City Zone initiatives.

Table 1. Overview of stakeholders in the project

During the project's first year, a lot of comprehensive data was collected from the deployed EV fleet (Eriksson, 2023). This included data regarding driver experiences, vehicle performance, charging efficiency, and the integration of wireless charging into the daily operations of taxi services. The overall feedback from the drivers was generally positive, though some did not use the wireless charging due to it not fitting with their operational needs. The usage of wireless charging stations contributed to around 12% of the total fleet energy supply, and this figure is expected to rise with more charging stations. The fleet drove over 1 million kilometres within the first year, giving the project a rich data set for analysis. The project has also identified some operational limitations, particularly a need for more strategically located charging stations to meet the full demand of the fleet (Eriksson, 2023).

The “wireless charging for taxi” project stands at the intersection of technological innovation, environmental sustainability, and urban planning. It represents a holistic approach to dealing with the challenges of modern urban transportation. It might show how future cities can integrate advanced technologies to achieve a sustainable world.

1.3 Problem formulation and relevance of research questions

The transport sector significantly contributes to greenhouse gas emissions, with road transportation being a major source (Longo et al., 2018; European Parliament, 2023). Transitioning to sustainable transportation modes, such as EVs, is essential to address these environmental challenges (Ibham Veza et al., 2023). Electric taxis, in particular, offer substantial benefits in urban environments due to their high utilization rates and operational intensity, which can significantly reduce emissions (Zou et al., 2016).

Wireless charging technology presents a promising opportunity for quick and convenient charging for electric taxis, yet it faces several barriers to its widespread adoption (Oliveira et al., 2020). Some of the barriers include technical limitations, economic factors, user acceptance issues, lower power output compared to conductive charging, high initial investment cost, and the necessity of behavioural adjustments, especially for taxi operators accustomed to rapid refuelling methods (Marinescu, 2021; Jang, Jeong, & Lee, 2016). These challenges are further compounded by taxi fleets' specific operational and unique infrastructure requirements (Oliveira et al., 2020). The perspective of electric taxi fleets is different from those of using personal EVs due to the taxis being operated more extensively and the need to cope with real-time demands with limited planning possibilities (Shen, Wang, & Zhang, 2021). Personal EVs do not require continuous operation with frequently fast charging possibilities to the same extent as taxis (Oliveira et al., 2020). The seamless and convenient charging experience offered by wireless charging could revolutionise how electric taxi fleets operate, underscoring the need for specialised charging solutions, which could address the unique requirements of electric taxis. Thereby, the potential for wireless charging is highly significant for electric taxi fleets (Jang, Jeong, & Lee, 2016).

Research on high-capacity wireless charging for EV taxi fleets is sparse, with no studies focusing on the high power of 43 kW. While studies have investigated wireless charging for EVs and its user acceptance (Fett et al., 2018) and the potential of electrifying the taxi industry (Zou et al., 2016). Only one study has been found that addresses the barriers to wireless charging for electric taxis (Oliveira et al., 2020), however, this was done with a comparatively low wireless charging capacity of 7 kW, this gap in research highlights the urgent need for this study, which aims to describe the barriers and analyse their impact on the adoption and diffusion of wireless charging technology for electric taxis.

As stated above, wireless charging and electric taxis faces multifaceted challenges for its widespread adoption (Oliveira et al., 2020). These obstacles, if not addressed, will hinder the growth of electric taxi fleets, resulting in fewer EVs on the roads and subsequently worsening environmental conditions (Oliveira et al., 2020). This brings us to this study’s research questions below.

First research question: How do the challenges faced by electric taxi fleets in the past compare to the current challenges these fleets face with integrated 43kW wireless charging?
The first research question seeks to compare established barriers with current challenges at the 43kW level.

Second research question: How do these barriers affect the adoption and diffusion of electric taxis and wireless charging?
The second research question explores the impact of the barriers identified in the first research question on the adoption and diffusion of wireless charging and electric taxis. It employs various theoretical frameworks to enhance the understanding of user behaviour and acceptance of wireless charging and electric taxis. The frameworks help clarify potential users' perceived benefits and potential drawbacks, which can either accelerate or hinder widespread adoption.

1.4 Purpose

The purpose of this thesis is to describe the barriers and analyse their impact on the adoption and diffusion of wireless charging and electric taxis.

1.5 Delimitations

This thesis focuses on the barriers to wireless charging and electric taxis and how these barriers affect the adoption and diffusion of 43 kW wireless charging and electric taxis within Gothenburg's Green City Zone. It analyses the experiences of taxi drivers and key stakeholders and data previously collected in the project. It excludes comparative analyses of wireless charging outside the taxi sector. This approach ensures a concentrated exploration of wireless charging and electric taxis' role in advancing sustainable urban mobility.

2 Methodology

This chapter describes the methodology used in this study and outlines the approach to data collection and analysis. The methodology chapter covers the selection of appropriate research methods, data collection techniques and analytical procedures. In addition, the measures taken to ensure the quality and ethical standards of the research are dealt with. By clearly defining the methodological framework, this chapter provides a basis for understanding how the study's findings were derived and ensures the reliability and validity of the findings.

2.1 The research design

The research design explains the strategy one uses to carry out well-structured work (De Vaus, 2001). This must be done coherently and logically, thus ensuring that the study is carried out efficiently. The research design can be interpreted as a plan for collecting, measuring, and analysing the collected data (De Vaus, 2001). This study has been conducted according to the following design:

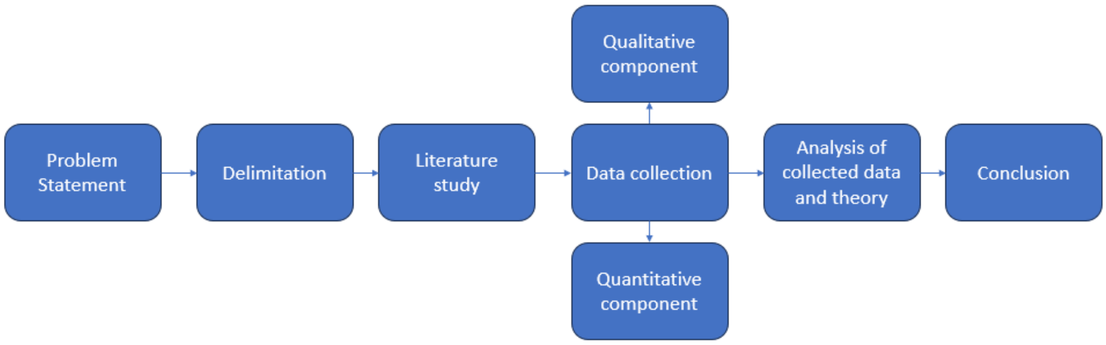

Figure 1. Illustrative mapping of steps taken in the methodology with arrows showing the direction and chronology (own illustration)

- Problem Statement: The problem statement is established primarily to understand why this study is important.
- Delimitation: Delimitations are developed to obtain a reasonable focus area for the study.
- Literature study: Relevant theory is analysed to find methods and create strategies for carrying out the study.
- Data collection: The data collection uses quantitative and qualitative methods to obtain a good basis for analysis.
    - Quantitative component: To analyse usage data and preferences.
    - Qualitative component: To explore taxi drivers' and stakeholders' perceptions, experiences, and suggestions for improvement.
- Analysis of collected data and theory: Analysis of collected data and theory contributes to a good overview of the current situation.
- Conclusion: The theory and collected data have been compared and presented at the end of the work.

This study applies a funnel-based analytical approach to systematically identify and explore the barriers to implementing as well as using wireless charging and electric taxis. This method structures the analysis from the broad context of charging infrastructure and EVs to the more specific aspects of wireless taxi charging. The funnel structure is designed by the authors to logically present the barriers to adopting wireless charging and electric taxis and explain how the different barriers are interconnected.

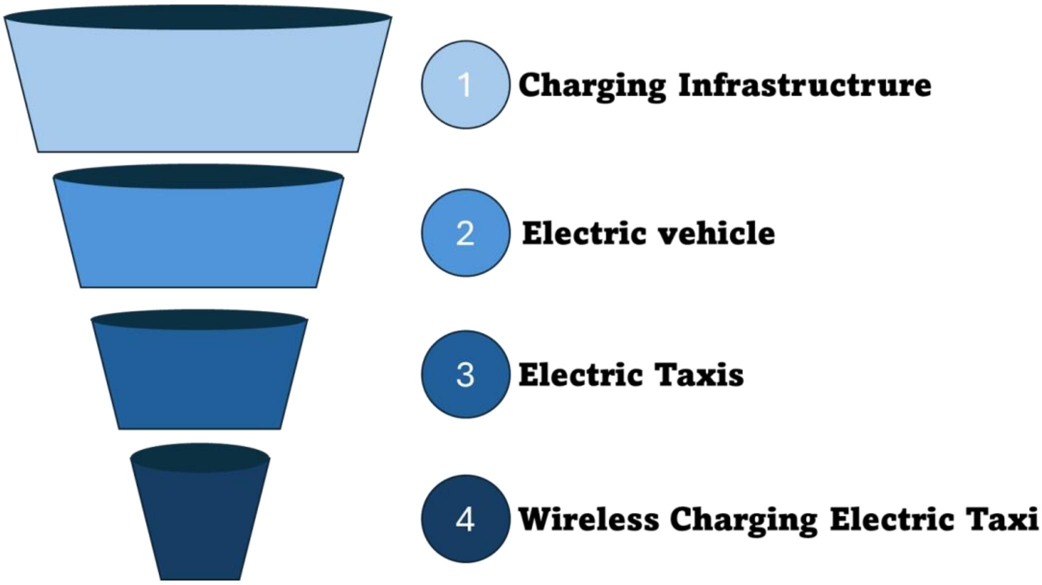

Figure 2. Illustrative funnel over potential barriers (own illustration)

The barriers identified at each level are interconnected. The barriers identified in the broadest part of the funnel, charging infrastructure, can intensify the challenges in narrower categories. For instance, inadequate charging infrastructure hinders the adoption of EVs in general, which in turn contributes to challenges for electric taxis. These challenges then affect the barriers of the narrowest part of the funnel, wireless charging electric taxis.

Conversely, successfully implementing innovations, such as wireless charging for electric taxis, can help solve broader challenges. For example, efficient wireless charging solutions could mitigate some infrastructure demands, streamline the use of EVs, and encourage broader adoption of electric taxis by demonstrating practicality and convenience. Addressing barriers at a broader level can mitigate issues at that level and help facilitate the resolution of challenges in narrower layers, while innovations in narrower layers can help solve broader issues. This holistic approach underscores the necessity for integrated solutions that improve the entire ecosystem.

2.2 Selection Methods

In the three research approaches, deductive, inductive, and abductive, the decision was made to employ the abductive approach with a mixed method (Bell et al., 2019). Abductive reasoning usually starts with an incomplete set of observations and then proceeds to the likeliest possible explanation for the set (Bell et al., 2019). It allows for the formulation and refinement of hypotheses as new data become available, accommodating the dynamic nature of technological and operational challenges (Bell et al., 2019).

This report uses the abductive approach to analyse and formulate hypotheses about the barriers electric taxi fleets face with 43kW wireless charging. A mixed method was used as it enabled the research to be approached conceptually and analytically to help understand how, why, and for whom the wireless charging and electric taxis will be appropriate (Bell et al., 2019).

2.2.1 Qualitative Method

Qualitative data can be obtained through interviews and observations without formal numbers or measurements (Bell et al., 2019). An example of this could be describing something as hot instead of saying the exact temperature (Locharoenrat, 2017). This data type focuses on understanding individuals' or groups' characteristics and subjective experiences (Bell et al., 2019). Rather than quantifying responses, qualitative data might describe the nuances of respondents´ attitudes, feelings, and behaviours (Bell et al., 2019).

This report used the qualitative method to interview the taxi drivers and key project stakeholders. The interviews aimed to capture the respondents' experiences, opinions, and insights to provide a more detailed understanding. By performing these interviews, this study gathered valuable qualitative data that might not be easily quantifiable but is important for a deeper analysis and interpretation of the project's impact and outcomes.

2.2.2 Quantitative Method

Quantitative data involves studies using statistical analyses, calculations, and measurements to obtain results (Locharoenrat, 2017). This type of data focuses on objectivity with numerical values, which allows for the analysis of patterns, correlations, and trends with the data gathered (Bell et al., 2019). Using mathematical and statistical techniques, quantitative research provides a clear and concise way to represent and interpret data (Bell et al., 2019). Quantitative methods enable researchers to obtain results that are both replicable and generalisable across larger populations (Locharoenrat, 2017).

In this report, the quantitative method has been used to analyse charging behaviour from previous data collected during the project's first year. Also, to map demographics and other objective parameters, such as the capability of charging at the drivers' residences. Systematic collection and evaluation of numerical data provide a robust framework for understanding user behaviours and trends. This method ensures that the findings are grounded in objective measurements, enhancing the reliability and validity of the research outcomes.

2.3 Data collection

There are two different categories of sources, -these are primary sources and secondary sources.

The most common primary sources are interviews, observations, and surveys. Secondary sources are different forms of documents, such as previous research, government publications, and information from personal registers. Neither primary nor secondary sources are 100% reliable, but one must review the sources and use one's judgement to ensure they are of high quality (Kumar, 2009).

2.3.1 Interviews

Interviews are a standard method of obtaining information from other people. An interview is any human-to-human interaction between two or more individuals with a specific purpose (Kumar, 2009). Interviews can be very good for discovering and gaining in-depth knowledge in a specific area (Kumar, 2009). An interview can be conducted in several different ways, such as structured and unstructured interviews, with various levels of flexibility and specificity (Kumar, 2009). The following interviewing methods were used in the study: Unstructured interviews, semi-structured interviews, and exploratory interviews.

Unstructured interview

The unstructured interview gives an almost complete freedom to decide upon content and structure. When conducting an unstructured interview, one may formulate questions and raise issues at the spur of the moment, depending on what occurs in the context of the discussion (Kumar, 2009). In this study, unstructured interviews were used in meetings, conversations, and interviews with members and key stakeholders within the project to get a good grasp of the project, its current status, and wireless charging product information.

Semi-structured interview

The semi-structured interview is positioned on the spectrum between the structured and the unstructured interview. The method employs a blend of prepared closed- and open-ended questions, often accompanied by follow-up questions to understand why and how (Adams, 2015). This study used semi-structured interviews with taxi drivers to provide comparable qualitative data (Adams, 2015). Total population sampling is a research technique that involves collecting data from every member of a population when it is small and manageable, ensuring highly accurate and comprehensive results (Creswell & Creswell, 2018). The researchers used total population sampling because there are limited taxi drivers with wireless charging capabilities. Drivers from all 20 cars were interviewed.

Exploratory interview

In research, the formulation of a specific problem is essential. When the motivation, incentives, or triggers of an individual involved in the situation or problem are unknown, exploratory research can be undertaken (Adams et al., 2007). The exploratory interview can thus be used to acquire a basic understanding of the topic by communicating with various stakeholders. The method is frequently used in the social sciences to study human perception. It has been used in various studies across different fields of science, such as business or demographic studies (Setyawan et al., 2018; Ghosh & Kshitij, 2016). This study used exploratory interviews with the various stakeholders to understand the topic.

2.3.2 Previous Research

A review of previous research has been carried out to build the study's theoretical framework. The theory is essential as it must be compared with the collected empirical data. The literature study comes from a compilation of books and scientific articles related to the subject areas. To ensure that the literature is credible, it has been reviewed, and discussed with opponents and a supervisor of the master thesis, to assess the relevancy of the literature.

2.3.3 Document Review

Document review is the process of examining and analysing documents to assess their relevance, accuracy, and compliance with specific criteria or standards (Patel & Davidson, 2003). Documents appear in many forms, such as written, statistical, image, and audio. In the past, all documents were written, but with technological developments, digital documents have also become prevalent (Patel & Davidson, 2003). This study used digital documents in the form of project-specific data collected throughout the project to analyse usage data and driver preferences.

2.4 Credibility of the study

This section of the report highlights the steps taken to ensure good validity and reliability, ensuring high research quality.

2.4.1 Validity

When conducting research, it is essential to ensure the validity of the methodologies chosen because they are directly connected to the relevancy and credibility of the research result (Bell et al., 2019). The different types of validity include face, concurrent, and construct validity, which cover both convergent and discriminant validity.

To implement this, the authors combined quantitative measurements (factual data) with qualitative insights from interviews with experienced project members. This dual approach of quantitative and qualitative gatherings will provide more detailed data and strengthen this research’s validity (Bell et al., 2019).

2.4.2 Reliability

According to Skärvad & Lundahl (2016), high reliability is achieved if a study is conducted in a way that is not influenced by the researcher's execution or the circumstances of the investigation. Reliability refers to the consistency of measurements; good reliability ensures that two different researchers will obtain the same results if they perform the same study in the same way (Yin, 2007). Bell et al. (2019) describes three main aspects of reliability, including stability, internal consistency, and inter-rater reliability, to ensure agreement among researchers, each covering various perspectives of consistency.

To achieve high reliability, the researchers used a strategy that includes measurements taken at different times to test the stability. They will also ensure that the used indicators constantly measure the same concept for internal reliability and with consensus among multiple observers for inter-rater reliability (Yin, 2007). Furthermore, by consulting with various experts in the field to enrich the authors' understanding of the subject and to confirm the results, good reliability will be reached for this study (Patel & Davidson, 2003).

2.5 Ethics

It is important to be ethically correct during research to ensure that the author's relationship to the task is not subjective or corrupt (ALLEA, 2018). One should follow the European codex for research integrity to achieve good research practice. Within the code, several basic principles are addressed to achieve this. These principles are then divided into four categories and described as below (ALLEA, 2018).

Reliability: This is to guarantee the quality of research. This is done through the choice of method, analysis, resources, and research design.

Honesty: One must think about carrying out the research objectively and fairly.

Respect: During research, one must respect one's colleagues, the environment, culture, participants in the research, and society.

Responsibility: One should be responsible for the entire research process, from the idea to the publication, and also for any consequences that may arise

During the study, it is also important to remember not to violate any form of confidentiality and to ensure that no individual is harmed (Kumar, 2009). Participating individuals will be informed that the information given out may be used in the study. If used, it will be checked with the individual that what is written down in the study matches the information given. It will also be checked that the information does not violate any form of confidentiality.

3 Theory

This section explores the multifaceted challenges and theory related to the adoption of wireless charging and electric taxis, covering barriers, user acceptance models, diffusion of innovation, motivational values, and change management strategies.

3.1 Charging Infrastructure and Electric Vehicle Deployment

3.1.1 Charging infrastructure

The EV industry has been steadily growing since the early 21st century (Deb et al., 2018), and the development of charging infrastructure is essential to cope with this trend (Chen et al., 2020). Despite the rapid growth in the popularity of EVs, barriers to overcome are present: limited driving range per charge, long charging times, and the limited availability of charging infrastructure (Zhang et al., 2018). Since the battery capacity for EVs has improved, faster charging technology is required to keep the charging time comparatively low, facilitating long-distance travel (Tu et al., 2019). Several fast charging standards were introduced in 2017, one of which is called CHAdeMO, which makes it possible for EVs to charge upwards of 200kW (Chen et al., 2020). More recent developments of premium cars show the capability of charging upwards of 350kW (Mateen et al., 2023). Often, the battery itself limits the charging capacity and not the infrastructural charging system to prevent battery damage (Zhang et al., 2017).

According to Zhang et al. (2018), determining the optimal locations for charging points is complex due to its multifaceted nature, with several economic aspects to consider. Some of the direct factors that influence the profit of charging infrastructure include the cost of charging stations, ground rent, maintenance cost, electricity price, charging price, and charging demand (Zhang et al., 2018). Indirect factors are also present, including psychological factors, the behaviour of EV owners, charging infrastructure technologies, EV technologies, and battery technologies (Zhang et al., 2018). The challenge of choosing the location of a charging point can be further explained by the many existing restrictions, for instance, the preservation of historic areas, visual clutter, and regulatory constraints, despite encouragement from public policies (Bonges & Lusk, 2016).

The widespread adoption of EVs increases the electricity demand and has a wide variety of adverse impacts on the power grid, especially during peak hours (Shareef et al., 2016). The adverse impacts include voltage instability, heightened peak demand, power quality issues, increased power loss, and transformer heating (Shareef et al., 2016). Shareef et al. (2016) concluded that a full EV penetration with uncoordinated charging exceeds the existing generation of capacity on average load days. As a result, at least 93% of the charging EVs need to be shifted to off-peak hours if no new power generation is added to the power grid (Shareef et al., 2016).

3.1.2 Electric Vehicle

In recent decades, technological advances, such as improvements in battery technology, have contributed to a revival of interest in electric cars (Williams et al., 2024). Even though the battery capacity and charging speed have improved, batteries still add considerable weight and constitute a significant proportion of the total cost of EVs (Deyang et al., 2016; Nykvist et al., 2019; Compostella et al., 2020). Improvements in battery technology are crucial for electric cars as they lead to cost reductions and increased range (Williams et al., 2024). Modern lithium-ion batteries charge faster and last longer, reducing concerns previously associated with electric driving (Williams et al., 2024). These technological advancements increase the utility and availability of cars, broadening the market (Williams et al., 2024). More and more people are becoming aware of the environmental impact of fossil fuels, creating an increased demand for cleaner alternatives such as electric cars (Wellings et al., 2021). At the same time, governments worldwide are introducing stricter emissions regulations to combat climate change, benefiting the EV market (European Commission, 2024). Electric cars offer a quieter, smoother, and often more responsive driving experience compared to ICE vehicles (Labeye et al., 2016). The immediate availability of torque and the lack of gearboxes in many electric cars make for a smooth and enjoyable drive (Labeye et al., 2016). This improved driving experience might attract consumers who value comfort and technology (Labeye et al., 2016). However, despite falling prices, electric cars are still, on average, more expensive than their petrol and diesel-powered counterparts (Danielis et al., 2018). The higher cost can be a major obstacle for many consumers, especially in segments where cost consciousness is particularly important (Giansoldati et al., 2020). Many potential electric car buyers worry about not being able to find charging stations, especially during longer journeys, limiting their willingness to switch to electric options (Thøgersen & Ebsen, 2019). Furthermore, although charging technology is improving, it still takes longer to charge an electric car compared to the time it takes to fill a tank of petrol or diesel (Giansoldati et al., 2020). This time difference can put off people who are used to the speed and convenience of traditional fueling (Giansoldati et al., 2020). Electric cars can experience reduced performance in cold or very hot weather, affecting the battery's charging capacity and range (Krishna, 2021). Consumers in areas with extreme climate conditions may be hesitant to adopt EVs due to these limitations, which may involve greater disruption and increased uncertainty compared to conventional cars (Krishna, 2021). Some consumers may hesitate to invest in electric cars due to uncertainty surrounding the new technology's reliability and long-term value (Krishna, 2021). Concerns about new technology include issues around battery life, maintenance costs, and the car's resale value (Krishna, 2021). This hesitancy may slow adoption among those who would otherwise consider switching to an electric car (Krishna, 2021).

3.1.3 Electric Taxis

Taxis play an important part in flexible transportation, particularly represented in bigger cities (Tseng et al., 2019). Taxis are responsible for a significant part of the emissions in cities, for instance, in Tokyo, where taxis only make up 2% of all vehicles but still contribute to 20% of the total carbon dioxide emission (Lu et al., 2012). Taxis are often operated as private businesses, and transitioning from ICE to electric-powered is thus critically dependent on the taxi drivers' desire for the transition (Tseng et al., 2019). Taxis require a longer driving range than personal cars since they normally travel approximately 300 kilometres daily (Tseng et al., 2019). The daily driving distance for taxis often exceeds what a fully charged battery can support (Lu et al., 2012). Rao, Cai, and Xu (2018) did a study in Shenzen, China, using real-world data, and the result revealed that more than 80% of the taxis charged three or more times per day and that the maximum amount of charging sessions was five times per day. The patterns of the charging duration showed that 80% of the drivers spent less than one hour per session, and less than 4% of the drivers charged under 10 minutes. Another finding in the study was that the drivers charged at specific times and with specific durations rather than visiting the charging stations randomly (Rao, Cai, and Xu, 2018).

Kim, Lee, and Kim (2017) did an environmental analysis and feasibility study on electric taxis in Seoul, South Korea. The result of the study showed financial feasibility, and the environmental analysis revealed that electric taxis could significantly reduce air pollution and emissions. The authors concluded that the implementation potential is high but found some opportunities for improvement. These improvements include developing the dispatch management system to address the limited driving range for electric taxis compared to ICE vehicle taxis to prevent electric taxis from getting the demand of long-distance customers. Additionally, it is important to strategically position charging points along key routes and in high-demand areas (Kim, Lee, and Kim, 2017).

The perspective of electric taxi fleets is different from those of using personal EVs due to the taxis being operated more extensively and the need to cope with real-time demands with limited planning possibilities (Shen, Wang, & Zhang, 2021). Salanova and Romeu (2018) did a comprehensive mathematical model primarily focusing on the Barcelona taxi market to evaluate and optimise taxi operations. The authors concluded that depending on how the taxis operate, a different setup of charging infrastructure is optimal and categorised the different operating types into hailing, dispatching and taxi queuing. Hailing, significantly affected by real-time demand by picking up passengers on the streets, required a dynamic operational model and the priority of charging infrastructure was to be accessible and conveniently located. The optimal placement for this operating model was found to be in busy commercial areas, airports and other transportation hubs to facilitate quick charging between customer trips (Salanova & Romeu, 2018). Dispatching, planned routes from the central system or applications had a more predictable schedule and routes, enabling drivers to plan for charging stops during their daily operations. The optimal charging infrastructure for this operation style was found to be located along their planned routes, for instance, at the start or end of frequent routes (Salanova & Romeu, 2018). The last operating setup involves physical queuing at taxi stands, where they have a consistent location to wait for customers. The ideal charging points for this type of operation are to be placed at these stops or in near proximity, to accommodate charging while waiting or queuing for customers (Salanova & Romeu, 2018).

To avoid loss of income, chargers should be readily available to enable the downtime to be used for recharging the battery (Bauer et al., 2019). The location of charging points is not always positioned on the drivers' route, resulting in inevitable detours to be able to charge, especially in larger cities and taxis equipped with small-range batteries (Yang et al., 2018). However, waiting times combined with breaks are commonly not enough time to cover the necessary charging time, forcing taxi drivers to dismiss customer trips to drive and charge instead (Asamer et al., 2016).

3.1.4 Wireless Charging electric taxis

According to Müllerleile et al. (2016), EVs offer a promising solution to environmental challenges, but an inadequate charging infrastructure contributes to range anxiety, which restricts its adoption. Finding innovative solutions for the charging infrastructure is crucial for accelerating EV adoption, and wireless charging stands out as a promising alternative (Müllerleile et al., 2016). Wireless charging offers an improved user experience with contact-free charging and improved infrastructure functionality by reducing maintenance costs, mitigating weather-related issues, and enabling underground installation to eliminate visual clutter (Müllerleile et al., 2016).

Ulrich (2020) introduces a project in Oslo, Norway, aiming to implement a wireless charging infrastructure suitable for taxis, buses and delivery trucks. The idea of the project is not to charge a whole battery cycle but rather use the charging technology to replenish some energy whenever an opportunity arises, for instance, when waiting in a taxi queue (Ulrich, 2020). Because the system is placed below the surface, the mechanical wear is low and has a high resistance to bad weather and vandalism, with the advantage of not being required to step out of the vehicle and face the weather to charge (Fett et al., 2018).

According to Dimitriadou et al. (2023), conductive charging can deliver significantly higher power levels than wireless charging, especially with DC fast chargers, due to the physical connection, which enables higher power transfer efficiency. Wireless charging also has lower energy efficiency, which might be an issue for acceptance, especially for those who use EVs frequently and thus have more experience (Fett et al., 2018).

According to Palani et al. (2023), the wireless charging system for the EV industry is still in its introductory stage. The cost of buying an EV with wireless charging capability by mounting a receiver on the car is still very high. It is currently a significant constraint, but it will, with time, be more affordable because of economies of scale (Palani et al., 2023). However, high initial costs for establishing this technology can still be a significant barrier for taxi companies and municipalities (Oliveira et al., 2020). Moreover, economic inefficiencies arising from potential overcapacity or underutilisation of the charging infrastructure can further complicate economic calculations, leading to a reluctance to invest in these technologies (Oliveira et al., 2020).

From a behavioural and perceptual perspective, the industry faces challenges such as resistance from drivers and taxi companies accustomed to conventional fuels and charging methods (Oliveira et al., 2020). This resistance to change is often grounded in habits and fear of the unknown (Oliveira et al., 2020). Reliability and convenience issues with new technology may also deter drivers from switching to electric taxis (Oliveira et al., 2020). In addition, a lack of awareness or misinformation about the benefits and operational methods of wireless charging systems can hinder the adoption of this technology (Oliveira et al., 2020). However, the result of the survey performed by Fett et al. (2018) on user acceptance of wireless charging suggests a high acceptance level for wireless charging, particularly among car-sharing applications and commercial fleets.

Regarding operational challenges, the alignment between the transmitter and the receiver coils must be precisely aligned, which means that the vehicle must remain stationary for some time (Ahmad et al., 2018). Birell et al. (2015) studied the importance of vehicle alignment when charging wirelessly. The result showed that only 5% of the vehicles were within the misalignment tolerances of ±10 cm from the vehicle centre point to the centre of the receiver (Birell et al., 2015). Furthermore, there are logistical issues with deploying and maintaining a widespread network of wireless chargers, especially in high-traffic urban environments (Oliveira et al., 2020). Technical challenges in integrating wireless charging technology with existing vehicles and electrical systems can also be significant, as existing vehicles and infrastructures are not always compatible with innovations (Oliveira et al., 2020). These problems require complex solutions and significant resources to overcome (Oliveira et al., 2020).

The potential environmental impacts of deploying wireless infrastructure at scale, including resource use and electronic waste issues, are of great importance (Oliveira et al., 2020). The efficiency of wireless charging systems and their impact on electricity demand and load management must also be carefully considered (Oliveira et al., 2020). These systems must be designed to be sustainable not only economically but also to minimise their environmental footprint and promote a more sustainable use of resources (Oliveira et al., 2020).

3.2 Technology Acceptance Model

The technology acceptance model (TAM) is a technical model initially introduced by Davis (1989). TAM was designed to evaluate the various factors affecting the acceptance of new technologies. The model emphasises two primary dimensions: Perceived Usefulness (PU) and Perceived Ease of Use (PEoU). Firstly, people tend to use an application to the extent they believe it can be helpful or make them perform better on a specific task, Davis (1989) refers to this as PU. Secondly, even if the user considers the application useful, potential users might think it is too difficult or complex to use. Thus, the benefits of usage are outweighed by the perceived required effort to use the application, which refers to the PEoU (Davis, 1989). TAM has been used in previous research to evaluate the likelihood of a technology's success based on consumers' perceptions of its PU and PEoU. It has been found that the ideas of PU and PEoU have the greatest influence on a technology's effective adoption and seamless transition (Bach et al., 2016). According to Bach et al. (2016), these concepts can significantly influence how users perceive a specific feature or the system as a whole. Additionally, the authors suggest that gaining insights into users' interactions with technology can be highly beneficial for identifying the strengths and weaknesses of its intended use case. TAM is the best model or framework to employ in usability studies and has received the greatest attention from the information system community in studies where the concepts of PU and PEoU have been the main focus (Bach et al., 2016).

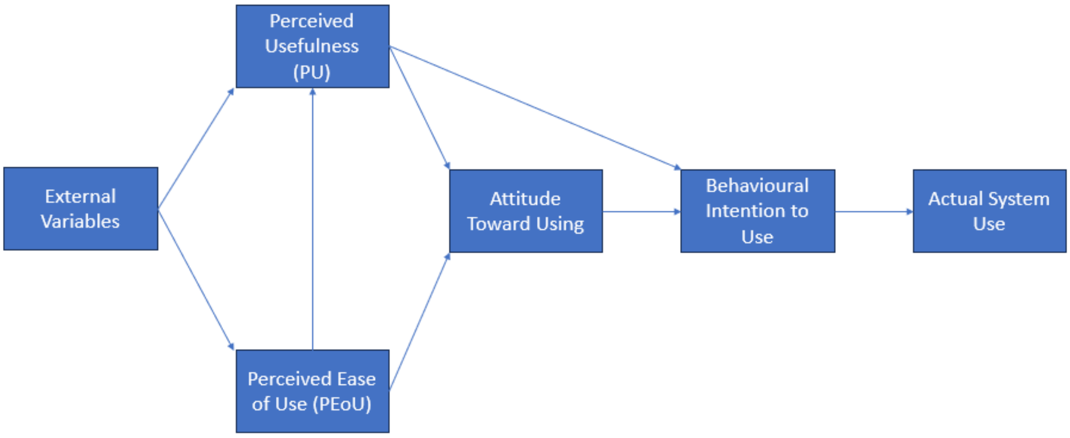

Figure 3: TAM and its concepts according to (Davis et al., 1989)

The behavioural intention to use the application will be determined by the PU and the attitude toward using the application. Furthermore, the attitude toward using the application is jointly determined by the PU and the PEoU. Effort saved due to improvements in the PEoU can also enable a person to accomplish more work for the same effort, giving PEoU a direct effect on PU. PEoU is also theorised to be determined by external variables (Davis et al., 1989).

3.2.1 Unified Theory of Acceptance and Use of Technology

Unified Theory of Acceptance and Use of Technology (UTAUT) is a framework that has been widely used since its development in 2003 (Venkatesh et al., 2003). The framework combines insights from various earlier theories to comprehensively understand and predict how people adopt and use technology. The framework considers theories such as the technology acceptance model, social cognitive theory, theory of planned behaviour, motivational model, and innovation diffusion theory. UTAUT aims to explain the factors that influence people's decision to use technology. It focuses on the expectations of the technology's performance, PEoU, and the conditions that support its use, all from a user perspective. The framework also considers the user's experience, age, and gender, whether the usage is voluntary, and how this influences the adaptation of technology (Venkatesh et al., 2003).

The probability of a successful adoption of technology is highly dependent on the following constructs:
Performance expectancy (PE) is most strongly associated with technology acceptance and usage and refers to how much an individual believes using a particular system will enhance their performance at work (Venkatesh et al., 2003). This effect will be the strongest for younger men (Venkatesh et al., 2003). Effort expectancy (EE) looks into how the PEoU affects the adoption of the technology, as customers are more likely to accept technologies that they find easier to use (Venkatesh et al., 2003). The effect of this construct significantly decreased after a period of technology usage (Venkatesh et al., 2003). This construct is defined as the ease associated with the use of technology, and this effect is strongest in younger women (Venkatesh et al., 2003). Social influence

(SI) can have a significant impact on whether an individual adopts or rejects a technology, especially in the early stages of the innovation diffusion process (Venkatesh et al., 2003; Rogers, 2003). Although the results of this concept have been inconsistent, this can be explained by the fact that when the use of the technology is mandated, social influence is a significant construct (Venkatesh et al., 2003; Zhou, Lu & Wang, 2010; Chauhan & Jaiswal, 2016). Social influence is the degree to which an individual perceives that others believe he or she should use the new system and is most significant in older women (Venkatesh et al., 2003).

Facilitating condition (FC) is defined as the degree of ease associated with the use of the system (Venkatesh et al., 2003). The FC can be the availability of resources, support, or infrastructure that is essential to the adoption of the technology (Venkatesh et al., 2003). The model suggests that the FC have a direct effect on use behaviour (Venkatesh et al., 2003). These predictors are affected by gender, age, experience, and voluntariness of use in the following ways: Gender affects PE, EE, and SI. Age affects PE, EE, SI, and FC. Experience affects EE, SI, and FC. Voluntariness of use only affects SI (Venkatesh et al., 2003).

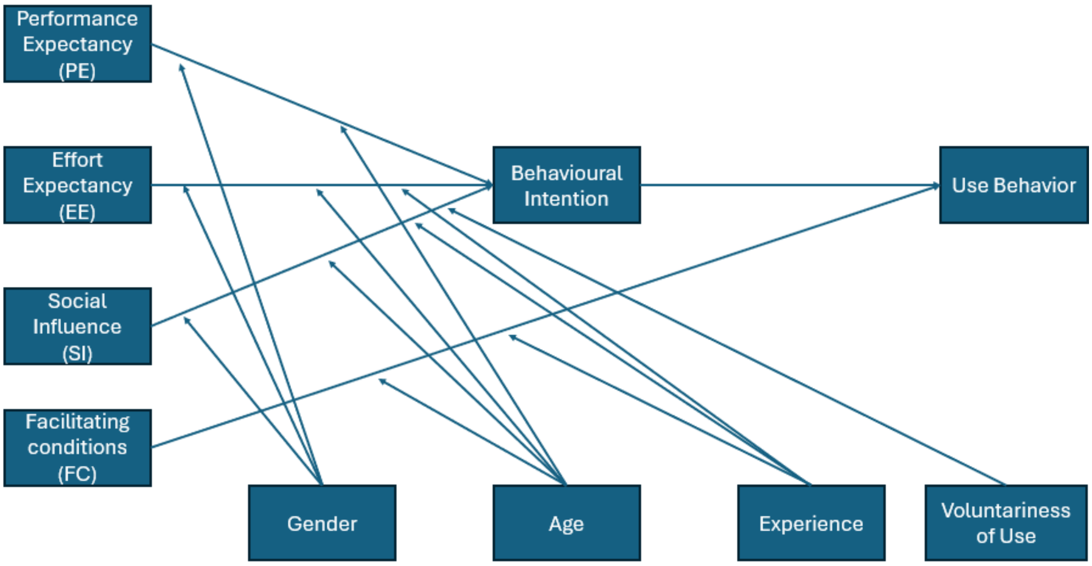

Figure 4. Visual representation of the UTAUT model (Venkatesh et al., 2003)

3.2.2 Unified Theory of Acceptance and Use of Technology 2

In 2012, the unified theory of acceptance and use of technology 2 (UTAUT2) was developed in response to the recognition that UTAUT did not fully capture the consumer side of technology adoption and use. This model better reflects the consumer context of technology adoption. It still retains the old predictors of UTAUT but added the following: Hedonic Motivation (HM), Price Value (PV), and Habit (HT) (Venkatesh et al., 2012).

The hedonic motivation (HM) is the pleasure or the excitement that the individual feels when using the technology. From the consumer's perspective, this can be a significant driver of technology (Venkatesh et al., 2012). Price Value (PV) highlights cost as a major factor when it comes to the adoption of technology. It allows the model to consider the perceived benefits of the technology and compare it to its monetary cost (Venkatesh et al., 2012). Habit (HT) highlights the role of past behaviour and routine in the use of technologies. It describes how people naturally carry out certain actions since they have previously learned them (Venkatesh et al., 2012).

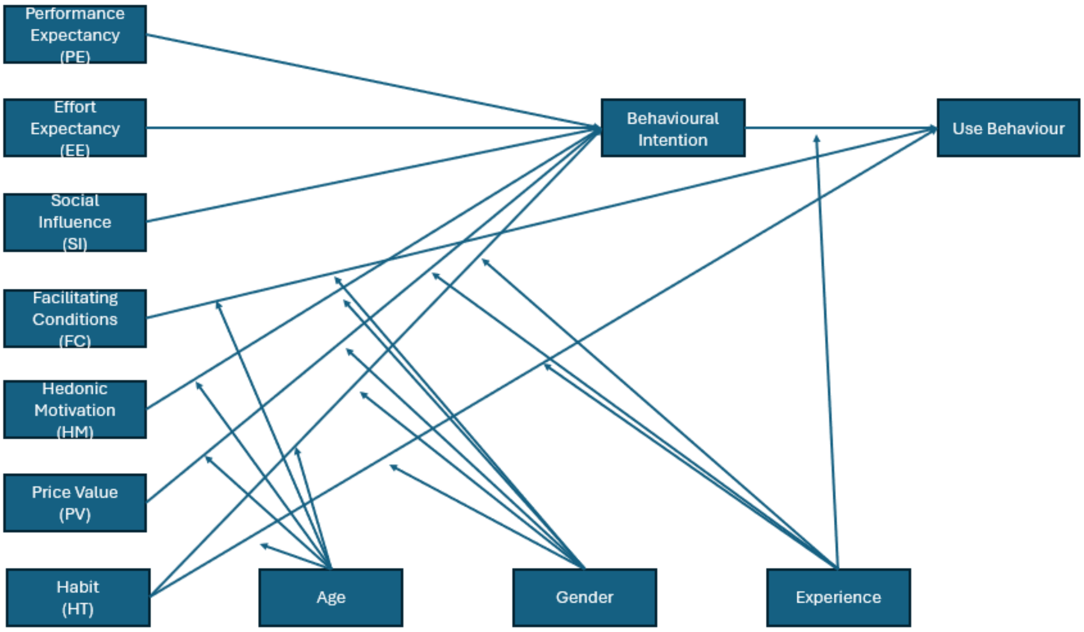

Figure 5. Visual representation of the UTAUT2 model (Venkatesh et al., 2012)

The additional constructs are affected as such: Age affects FC, HM, PV, and HT. Gender affects FC, HM, PV, and HT. Experience affects PV and behavioural intention (Venkatesh et al., 2012).

3.3 Diffusion of Innovations

How innovations, ideas, and new technologies diffuse throughout society has been studied for a long time in various disciplines (Goss, 1979; Rogers, 1962). In 1962, Everett M. Rogers developed a theory that investigates why, how, and how fast innovations get spread around society. According to Rogers, innovation is a very complex process as he presents the following elements: Innovation itself, communication channels, time, and the social system. Furthermore, the theory presented by Rogers also breaks down the innovation-decision process as well as the characteristics of the innovations that affect their adoption. Lastly, it also classifies people in a social system according to their innovativeness. This classification ranges from innovators to laggards (Rogers, 1962).

3.3.1 Key elements of the Diffusion of Innovation

The following are the key elements of the diffusion of innovation according to Everett Rogers in the 5th edition of Diffusion of Innovations published in 2003.

Innovation, the first element in Rogers' theory of diffusion of innovation, is defined as a new idea, practice, or object perceived as such by an individual or other unit of adoption. The characteristics of innovation could greatly influence its adoption. These characteristics can be divided into the following parts:

Relative advantage is how much better an innovation appears to be than any other alternative available for its potential adopter in terms of economic status, convenience, satisfaction, and social prestige. Trialability refers to the extent to which the innovation can be tested directly on a small-scale basis. For instance, mobile apps may have free trials that allow users to try out their features before purchasing them, thus fostering wider adoption, and reducing risks associated with them. Observability is the degree to which the innovation itself or its outcomes can be observed by others who are potentially willing to adopt it. If prospective adopters know nothing about the innovation and do not see it being used by anybody else, they will not easily take it up themselves. Compatibility is the degree of consistency between any existing value, previous experiences, and user needs in which innovation is perceived. Innovations are linked to other innovations based on their values as well as the experience potential adopters might have had with them. This is why some innovations might be assessed by possible adopters within technology clusters rather than singularly. Complexity is the degree to which one considers an innovation being difficult to understand or use. Complex and hard-to-use products are less likely to be adopted.

The second element in Rogers diffusion of innovation theory is the communication channels. This refers to the means through which information about innovation is transmitted to potential users. This component emphasizes how crucial both interpersonal networks and mass media are for the diffusion of innovations. How effective these channels are has a big impact on how fast the innovations diffuse into society.

The third element is time, and according to Rogers, time is a critical factor in the diffusion process. The time element of the diffusion of technologies can be described as three sub-elements. The innovation-decision process is the first sub-element and can be described as the time it takes an individual or another unit to move from the first knowledge of an innovation to a decision. The relative speed of adoption is the second sub-element and points to how quickly the innovation is taken up by members of a social system and adopted after its introduction. Finally, there is the rate of adoption across the social system. This sub-element looks at the pattern and speed at which different segments of the social system embrace innovation. This rate of adoption can often be depicted as an S-Curve with a slow start, rapid acceleration, and a plateau as the innovation reaches saturation.

The fourth element, social system elements, describes the role of social structures in the diffusion of innovation. It consists of the network of people and groups involved in the adoption process and considers their norms, values, and practices.

3.3.2 The Innovation-Decision Process

Rogers (2003) described the innovation-decision process as “an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation”. This process introduces the following steps: Stage (1) Knowledge, Stage (2) persuasion, Stage (3) Decision, Stage (4) Implementation, and Stage (5) Confirmation. These steps typically follow each other in sequence (Rogers, 2003).

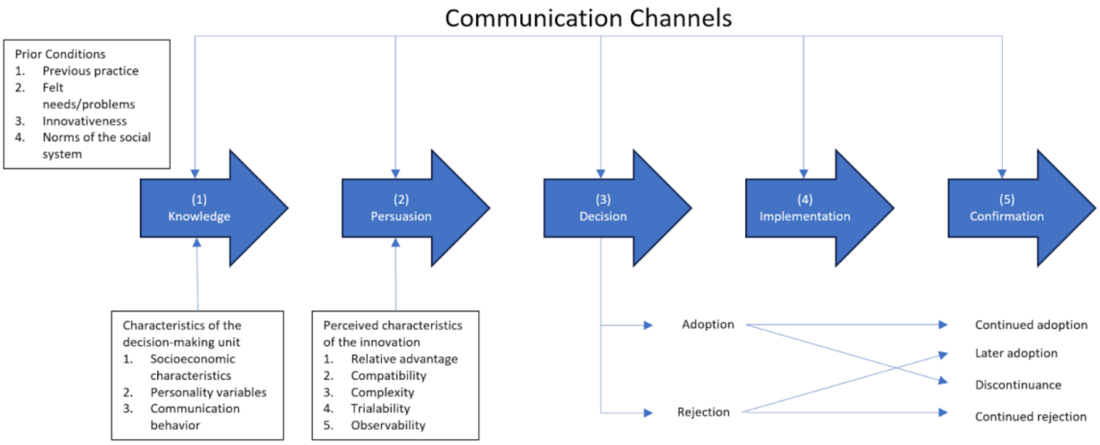

Figure 6. A Model of Five Stages in the Innovation-Decision Process (Rogers, 2003)

The Knowledge stage (1) is where an individual becomes aware of the fact that the innovation exists and starts to seek information about the innovation to answer questions such as “What”, “How”, and “Why” (Rogers, 2003). These questions form the following three different types of knowledge:

Awareness-knowledge - This is the knowledge to which the individual learns that innovation exists.
How-to-knowledge - This is the knowledge to which the individual learns how to use the innovation correctly.
Principles-knowledge - This is the knowledge to which the individual understands how and why the innovation works.

The Persuasion stage (2) is where the individual discovers the potential value of adopting the innovation and explores its potential capabilities. In this stage, the innovation must be perceived as useful by the individual. However, social reinforcement from others, such as friends or colleagues, also affects the individual's perspective of the innovation. It is also important to note that this attitude towards innovation does not always lead directly to adoption or rejection (Rogers, 2003).

The Decision stage (3) determines whether the innovation will be adopted or rejected. If the innovation has a trial function, it is generally adopted more quickly as the PEoU is positively impacted (Socia, 2011). Even though this stage formally determines whether an innovation will be adopted or rejected, the decision can occur at any point in the innovation-decision process (Rogers, 2003).

The Implementation stage (4) is where the innovation is implemented. However, even if the innovation is implemented, there can still be a degree of uncertainty at this stage. Moreover, reinvention usually occurs in the implementation stage, where the innovation is changed or modified by the user. The implementation stage is the last stage positioned within the innovation-decision process.

The Confirmation stage (5) is where the innovation decision has already been made. However, at this stage, the decision can still be reversed. Thus, the individual begins to look for support regarding their choice to adopt. In this stage, discontinuance can also occur in two different ways. Firstly, replacement discontinuance is when the innovation is rejected to adopt a better innovation, thereby replacing the first. Secondly, disenchantment discontinuance occurs when the individual rejects the innovation because they are not satisfied with its performance (Rogers, 2003).

3.3.3 Adopter Categories

To comprehend the innovation diffusion process it is important to understand the diversity among the potential adopters (Rogers, 2003; Socia, 2011). Rogers (2003) develops generalisations and categorises adopters into five different groups based on the innovativeness of the individual. The innovativeness is explained by the degree to which an individual adopts new ideas in regard to other members of a system by laying off standard deviations (sd) from the average time of adoption (See Figure 7). These five groups are as follows: Innovators, Early adopters, Early Majority, Late majority, and Laggards (Rogers, 2003).

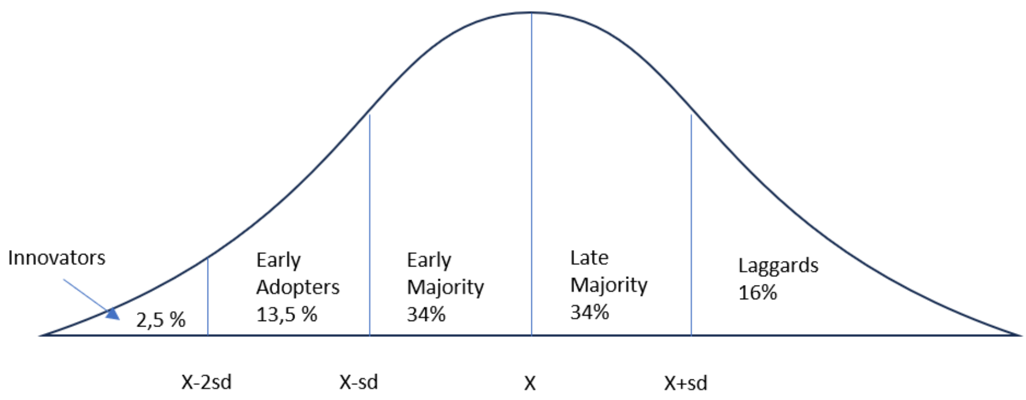

Figure 7. Adopter Categorization on the Basis of Innovativeness (Rogers, 2003)

Innovators: Venturesome

The innovators are defined as venturesome as they are the group which are most likely to try and experience new ideas (Rogers, 2003). Thus, they are also prepared to manage a high level of uncertainty about the innovation. The primary motivation for innovators is the desire to be at the forefront of technology or new ideas. They are driven by the thirst to explore new concepts and be pioneers in their social or professional circles. The innovators are less affected by peer opinions and are more influenced by their own personal interests and the potential they see in the innovation. These individuals must also be willing to accept an occasional setback when a new idea proves unsuccessful. This category of individuals is not respected by the other members of the local system. However, they do hold a gatekeeping role in the flow of new ideas into the system (Rogers, 2003).

Early Adopters: Respect

Early adopters are more integrated into the local system than innovators (Rogers, 2003). This category is defined as opinion leaders, thus having a lot of influence regarding the adoption of innovations. These individuals are the ones that potential adopters look to for opinions about their potential adoption. The early adopters are motivated by a desire to maintain their status as opinion leaders and influencers within their respective communities. They are defined as respected role models for others and seek out innovations that offer both a competitive edge and stability. Thus, they have less tolerance for uncertainty and failure than the innovator (Rogers, 2003).

Early Majority: Deliberate
New ideas are adopted by the early majority of a system just ahead of the average member (Rogers, 2003). The early majority, like the early adopters, have good interaction with other members of the social system however, they do not have the leadership role that the early adopters have. The primary motivation for this category is pragmatism. They need to see that the innovation has been tested and is worthy of adoption by one of their more adventurous peers, often the early adopters (Rogers, 2003).

Late Majority: Skeptical
New ideas are adopted by the late majority of a system right after the average member (Rogers, 2003). This category is defined as sceptical about the innovation and its outcomes. The late majority often does not adopt before most others in their systems have done so. The motivation for this category is economic necessity and peer pressure. They only adopt once they feel that it is a necessity to maintain social and functional parity with their peers. The late majority needs to feel assured of the innovations' success and does not tolerate uncertainty or failure (Rogers, 2003).

Laggards: Traditional
The laggards, who possess almost no opinion leadership, adopt new ideas last (Rogers, 2003). The laggards have a very traditional view and are even more sceptical about new ideas and innovations than the late majority. This category is motivated by a strong resistance to change and a preference for the familiar. The adoption only reaches the laggards once it has become so far integrated into society that it is no longer seen as new. These individuals desire stability, reliance on past experiences, and is sceptical toward the benefits of innovations (Rogers, 2003).

3.4 Hedonic, instrumental & symbolic values

Vandecasteele and Geuens (2010) identified three primary motivational aspects of consumer innovativeness, including instrumental (practicality and functionality), hedonic values (pursuit of pleasure or avoidance of discomfort), and symbolic (expression of personal identity or social status). These three dimensions can help understand the reasons why a consumer is drawn to innovations. Consumers will primarily focus on the practicality of a product if they have instrumental motives to adopt the product. Instrumental attributes are defined as functionality obtained from the functions performed by new technologies (Dittmar,1992; Vossetal., 2003). Similarly, individuals inclined towards hedonic innovation probably prioritise the emotional experience, such as joy or pleasure derived from new technologies (Dittmar,1992; Roehrich,2004; Vossetal.,2003). Symbolic innovativeness emphasises the symbolic relating to the sense of self or social identity, reflected in acquiring new technologies (Dittmar, 1992; Roehrich, 2004). Car ownership is commonly associated with instrumental, hedonic, and symbolic attributes (Heffner et al., 2006; Bergstadetal., 2011; Steg, 2005).

3.5 ADKAR Model

The ADKAR Model, developed by Jeff Hiatt (2006), is a framework for managing and facilitating change focusing on the individual. The theory behind the model is that organisational transformation is not solely based on structural adjustment but rather on the collective output of behavioural change among individuals. The framework further describes that meaningful and lasting organisational transformation can only be obtained through the personal development of its members. The model is designed as a sequential process, creating the acronym ADKAR, Awareness, Desire, Knowledge, Ability, and Reinforcement, with each component representing requirements for an individual to navigate through behavioural change successfully (Hiatt, 2006).

Awareness
The first step in enabling change is to understand its nature, why it should be implemented, and the risk of not changing. This includes investigating what internal and external drivers are present and what the individual's benefit could be (Hiatt, 2006).

The communication of the organisation's needs with clear reasoning as to why a change is necessary is highly important (Hiatt, 2006). If not communicated adequately, the risk of questioning the decision increases, and the concerned parties might think they've done wrong before, which is not necessarily true. At the same time, some managers argue that their employees are compensated for performing a job and questioning or understanding the reason behind this falls outside the employee's responsibility. Organisations' optimal degree of control is different and highly dependent on the circumstances. For instance, the degree of control is and should be high in military applications or firefighting scenarios. Trusting the chain of command without questioning is vital since time efficiency is of the essence. In a more innovative setting or high-performing workplace, control is less prioritised, and fully understanding the change for improvement is a prerequisite. The information age allows anyone to educate themselves, and it is easier than ever to construct own opinions. Thus, the risk of resistance increases if the change is not thoroughly motivated. Implementing a change for the general public is the greatest challenge since the amount of control and communication is highly limited. A good example with no direct control over the audience is Graz, Austria, where a campaign was launched to increase awareness of car emissions. City officials introduced a special sticker for vehicles with low emissions, which entitled them to reduced parking fees and thereby incentivised purchases of these cars. Beyond the financial benefit of the parking discount, lower-emission cars were easily recognised, which fostered public awareness about emissions and highlighted which cars could be bought to contribute to environmental solutions (Hiatt, 2006).

Hiatt (2006) identifies several factors that influence the process of creating awareness of a change for an individual. Acceptance of the need for change is highly dependent on how the individual views the current situation. Those attached to the current way may reject or doubt the reasons for change, underscoring the importance of an individual's mindset on both the recognition of the need for change and the approach to problem-solving. While some individuals may anticipate changes in advance, others might find themselves caught off guard, struggling to adapt to new realities. The effectiveness of communicating the change is of high importance and is affected by the trustworthiness of the messenger and the historical success of change implementation. Another considerable challenge when raising awareness about the necessity of change is misinformed rumours or entirely false information. In many cases, the challenge is not only rooted in giving out correct information but also in rectifying misconceptions that are already present. Furthermore, is the reason behind a change and where it comes from of high importance with regards to the level of acceptance and recognition it receives. It is easier to raise awareness for change when externally observable factors drive it. Changes based on internal factors or controversial reasons face more obstacles in gaining recognition (Hiatt, 2006).

Desire

To foster the willingness to participate and support the change, consider personal choice with unique intrinsic motivators to match the nature of the change (Hiatt, 2006).

According to Hiatt (2006), desire represents motivation for choosing to participate and support the change. It is different from the first step, awareness because regardless of how aware someone is of a problem, it is ultimately their choice to act. Creating awareness is a prerequisite for people to start evaluating the change, but desire is, by definition, not under someone else's direct control. For instance, employees of an organisation can be aware of changes in protocols, procedures or new technologies, but they cannot force them to be supportive of the change. A regular mistake managers make is to assume that creating awareness of a change automatically generates a desire. To effectively create desire, it is important to consider the nature of the change and how it will benefit the individual personally. The individual's view of the organisation and how the environment that is fostering the change is designed, together with the individual's own circumstances. Furthermore, it is important to figure out what drives the individual, such as their belief in their ability to successfully implement the change (Hiatt, 2006).

Knowledge

Training and education are needed to know the necessary information about implementing the change, including processes, techniques, and behavioural aspects (Hiatt, 2006).

Knowledge is the next step for realising the change after the person has the awareness and desire to participate in and support the change (Hiatt, 2006). Depending on the type of change, some people may already have enough knowledge from experiences or education, whereas others may not. The probability of implementing a change successfully is directly affected by the possible gap between the current knowledge and the required knowledge. Another aspect is the individual's capacity to learn. Some of us can easily pick up new information, while others require more effort and time. The individual's ability to attain knowledge is also highly dependent on the type of knowledge; some find memorising information to be easy, while others find difficulties in learning technical skills, and vice versa. Some learn more easily from a textbook, whereas others prefer practical examples by instructors, which presents the third important factor for the knowledge step, to have the necessary resources available to provide education and training, which varies a lot between organisations. Some knowledge is hard to get access to, especially recent advances in research. The accessibility to knowledge is also dependent on geographical location; some areas of the world have limited educational institutions and experts in the field, or there is simply no internet connectivity. Knowledge is an essential step towards change, both for the individual and the organisation as a whole. The understanding of how to change can, in some cases, be a simple process, whereas it may require a transformation for others. One assumption often made for this step in the ADKAR model is that knowledge automatically leads to ability, which is wrong. Knowing how to do something is not necessarily the same thing as being able to do something (Hiatt, 2006).

Several factors determine an individual's ability to acquire new knowledge to implement a change. These factors include the individual's current knowledge, their ability to acquire new information, the resources available for training and education, the presence of the required knowledge, and the availability to access it (Hiatt, 2006).

Ability

The required skills are to implement the change and turn the knowledge into action. It is the ability of a group or a person to realise the change at the required performance level (Hiatt, 2006).

According to Boca (2013), the ability element of the ADKAR model is the difference between the theory attained and the necessary practice to implement the change. To ensure the change is implemented effectively, the individual needs to know how to change and be given enough time with adequate practice. Apart from the time and practice aspect, support plays a vital role in coaching and feedback to fulfil the ability element (Boca, 2013).

Reinforcement

The internal and external factors that sustain change over time involve recognition with rewards or celebrations and positive feedback (Hiatt, 2006).

Reinforcement is an essential component to consider to avoid falling back into old habits and ways of thinking after the change has been implemented (Hiatt, 2006). Reinforcement or corrective actions are necessary to ensure that individuals do not revert to old ways (Hiatt, 2006). Reinforcement can be utilised in various ways, with positive feedback, measuring performance, simple recognition, or internal reinforcement based on satisfaction with the achievement of the work the individual has put in (Hiatt, 2006). If the reinforcement seems ineffective in coping with the change in the individual's habits or ways of thinking, corrective actions may sometimes be necessary (Boca, 2013; Paramitha et al., 2020).

Summary of Theory

The theory section begins by discussing the need for a robust charging infrastructure to support the growing electric car industry. The theory addresses challenges such as limited range, long charging times and lack of charging stations. Furthermore, it also explains how improvements in battery technology have increased the range of electric cars and lowered costs. Despite these advances, issues such as high prices, limited infrastructure, longer charging times and performance in extreme weather conditions remain, preventing wider adoption. For electric taxis, the need for frequent charging and strategic placement of charging stations was highlighted. Additionally, the potential of wireless charging is discussed, offering contactless convenience but facing a wide variety of challenges. Addressing these challenges is critical to promoting wider adoption. To analyse the challenges or barriers to wireless charging and electric taxis, technology acceptance models are presented. The TAM model is introduced to evaluate the various factors affecting the acceptance of new technologies. The model suggests that the usage of the wireless charging and electric taxis will be determined by the behavioural intention to use the application, looking at factors such as external variables, PU, PEoU, attitude toward using, behavioural intention to use, and actual system use. Partly built upon insights from the TAM model is the UTAUT framework, which combines insights from previous research to provide a comprehensive understanding of how people adopt and use technology. The framework presents constructs on which the likelihood of successful adoption of a technology is highly dependent. Connected to these constructs are demographics, which enables an analysis of how the chosen demographics experience the constructs. In 2012, UTAUT2 was developed in response to the recognition that UTAUT did not fully capture the consumer side of the adoption and use of technology. The new model retains the old factors but adds more to gain a more representative view of the consumer side. The focus is shifted to the diffusion of innovations to understand how innovations, ideas, and new technologies diffuse throughout society. Presented in this chapter are the key elements of the diffusion of innovation, which are the innovation itself, communication channels, time, and social structures. A part of the diffusion of innovation is the innovation-decision process. This is explained as an information-seeking and information-processing activity where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation. In the innovation-decision process, the following stages are introduced: knowledge stage, persuasion stage, decision stage, implementation stage, and confirmation stage. In the diffusion process, individuals can be divided into five different groups based on the innovativeness of the individual. Innovativeness is explained by the degree to which an individual adopts new ideas in regards to other members of a system. The groups are innovators, early adopters, early majority, late majority, and laggards. Additionally, the three primary motivational aspects of consumer innovativeness are explored: hedonic, instrumental, and symbolic values. Lastly, the ADKAR model is presented as a framework for managing and facilitating change with a focus on the individual. The model is designed as a sequential process creating the acronym ADKAR: Awareness, Desire, Knowledge, Ability, and Reinforcement, with each component representing requirements for an individual to navigate through behavioural change successfully, which is important to consider when adopting new technology.

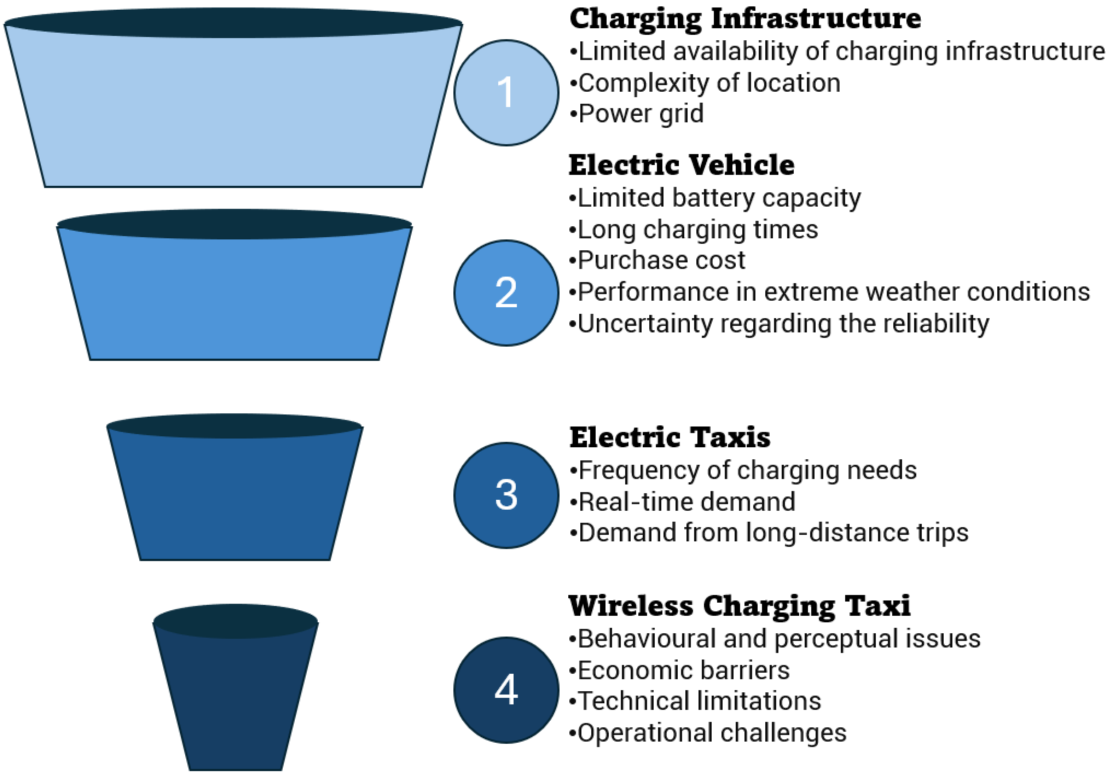

Figure 8. Illustrative funnel presenting identified barriers from previous literature (own illustration).

4 Empirical findings

This section presents the empirical findings from interviews conducted with taxi drivers using wireless charging technology, insights from the Gothenburg Green City Zone project, and data collected throughout the project's lifetime.

4.1 Demographics of Wireless Charging Taxi Drivers

This section presents the demographic characteristics of the study sample. The data is summarized in four key areas: age distribution, gender distribution, housing situation, and education level.

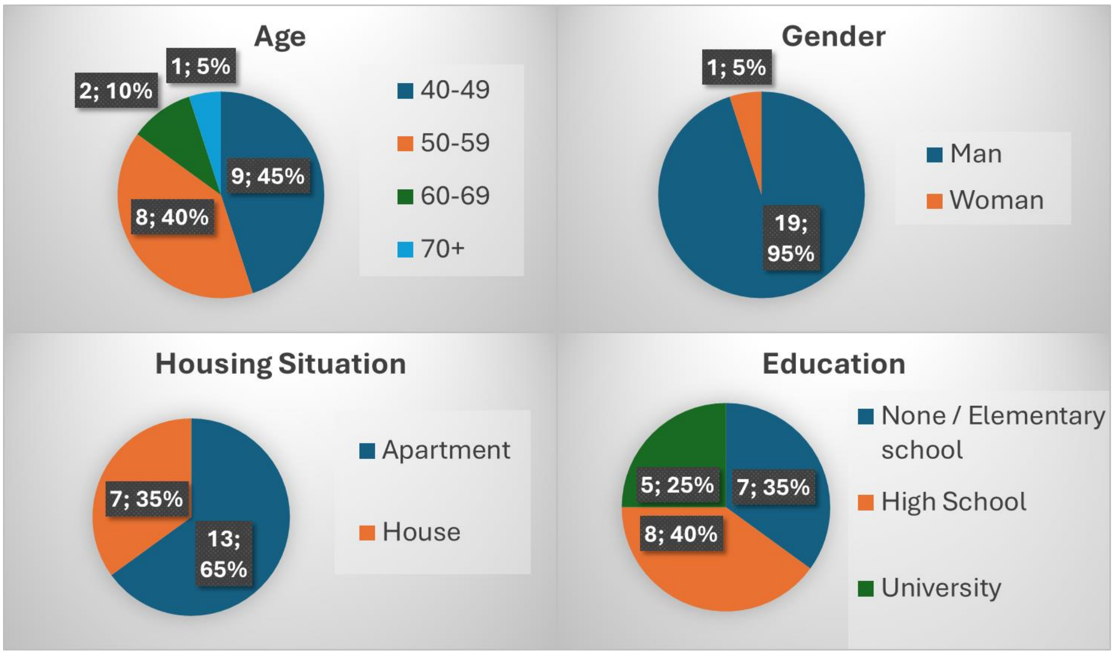

Figure 9. Demographics of the interviewees

The age distribution of the participants reveals that the largest age group is 40-49 years, comprising 45% (9 individuals) of the sample. This is followed by the 50-59 years age group, representing 40% (8 individuals). Participants aged 60-69 years account for 10% (2 individuals), and those aged 70 and above constitute the smallest group at 5% (1 individual). The gender distribution is predominantly male, with men making up 95% (19 individuals) of the sample, while women represent only 5% (1 individual. Regarding housing situation, 65% (13 individuals) live in apartments, whereas 35% (7 individuals) live in houses. The educational background of the respondents is varied, 35% (7 individuals) has completed elementary school or has no educational background at all, 40% (8 individuals) has completed high school and 25% (5 individuals) has a university degree. These demographic insights provide an understanding of the variety of the sample.

4.2 Interviews with Wireless Charging Taxi Drivers

What type of power source did your previous vehicle have?

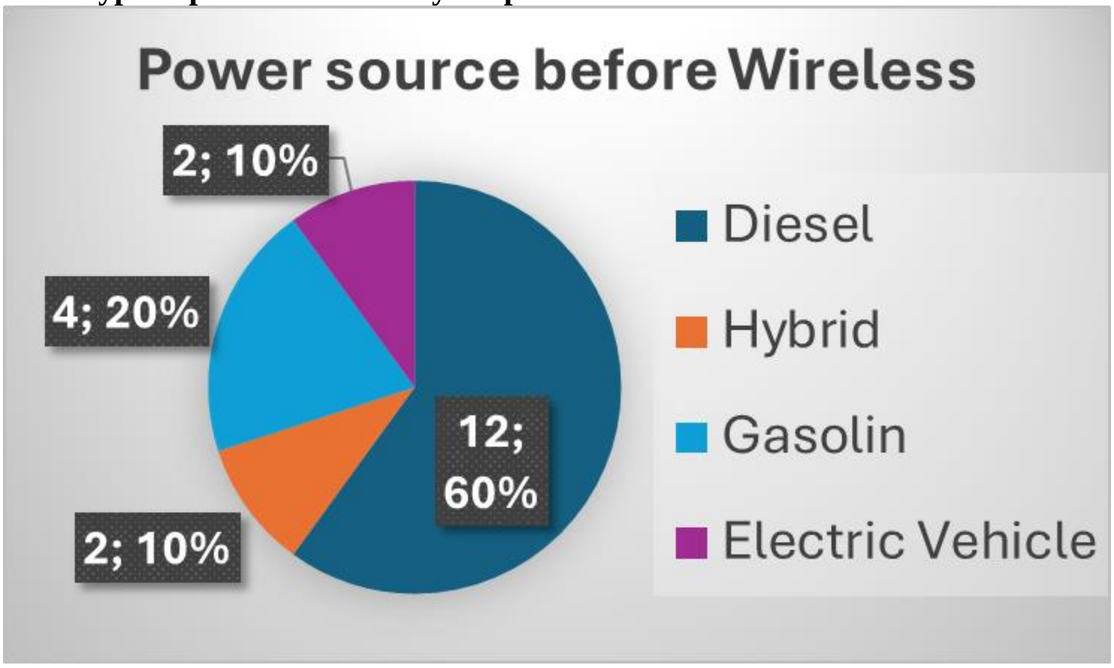

Figure 10. Previous Power Source of the Respondent's Vehicle

The previous power source of the respondents' vehicle is different for the sample. 60% (12 individuals) of the sample drove a diesel-powered car before, 20% (4 individuals) drove a gasoline car before, 10% (2 individuals) drove a hybrid car before and 10% (2 individuals) drove an EV before.

How many kilometres do you typically drive per day?

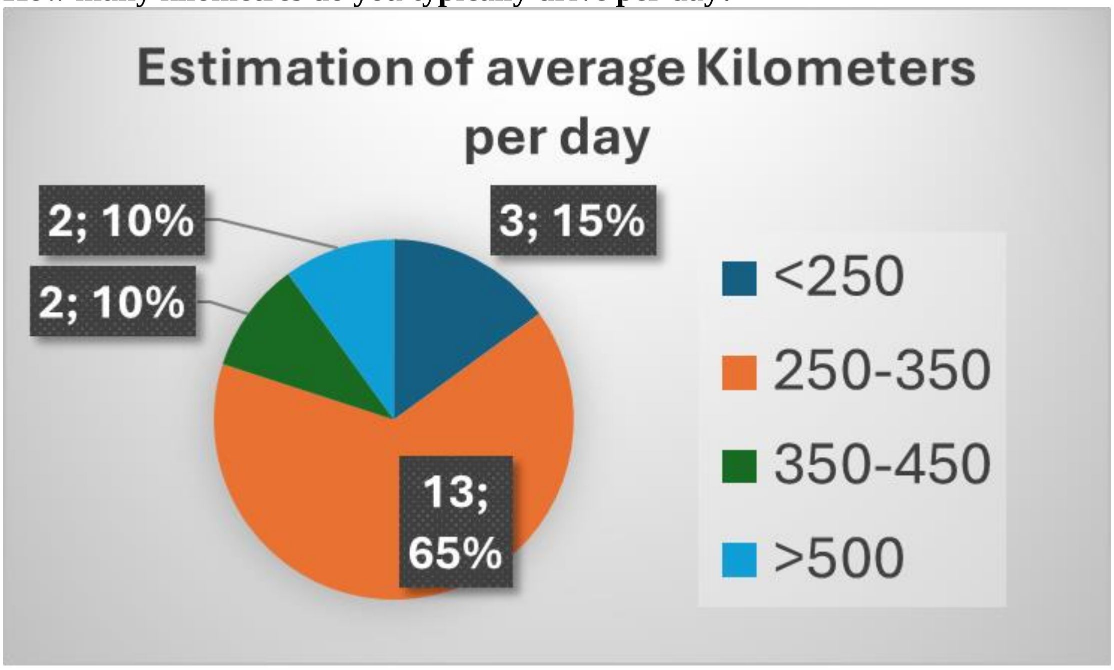

Figure 11. Estimated average kilometres travelled per day for the respondents

15% (3 individuals) estimated their daily distance driven to be less than 250km. The majority, 65% (13 individuals) estimated their daily distance driven between 250-350 km. 10% (2 individuals) estimated their daily distance driven to between 350 to 450 km and 10% (2 individuals) estimated their daily distance driven to more than 500 km.

How often do you use the wireless chargers?

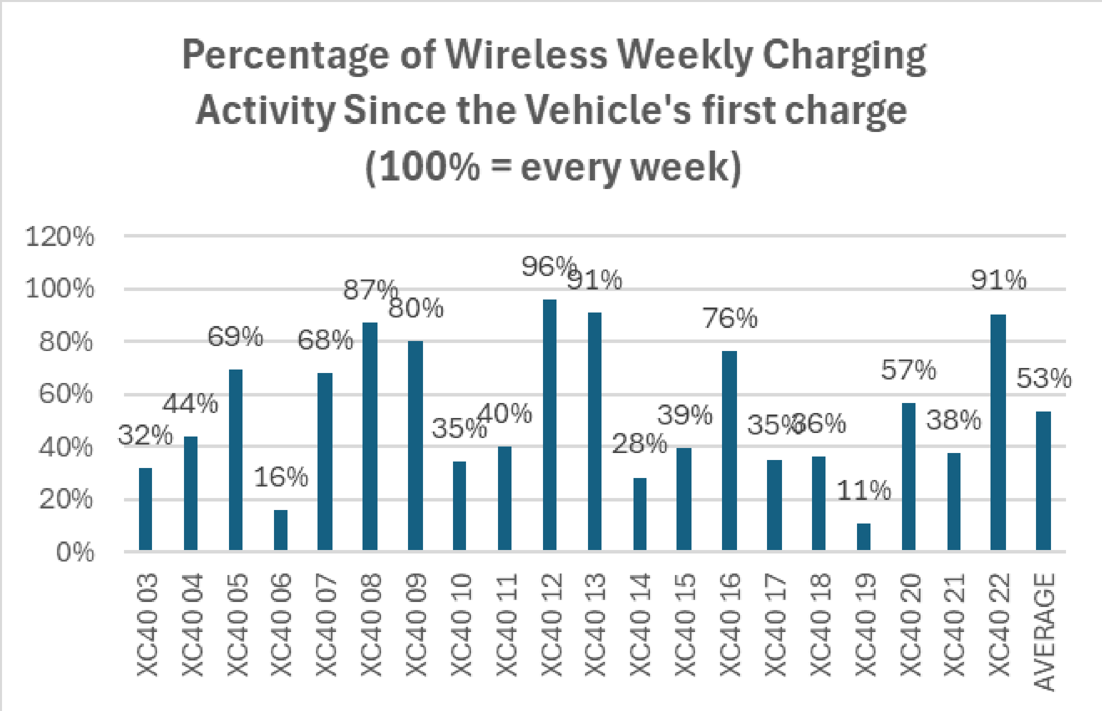

Figure 12. Percentage of Wireless Weekly Charging Activity Since the Vehicle's first charge
(100% = charging every week)

The graph above shows the continuity of the vehicle's charging pattern, which has been expressed as weekly charging activity since its first wireless charging session. For instance, "*XC40 12*" charged at least once per week 96% of the weeks since the vehicle started charging. Some discrepancies were found between the answers in the interviews and the quantitative data, but overall, the results were truthful. One respondent claimed to charge their vehicle two to three times per week but actually charged it less than 30% of the weeks during the vehicle's active time. However, this graph does not account for the number or duration of charging sessions. A respondent could have charged much more in some weeks and not at all in others. This is because, regardless of the frequency or duration of charging sessions within a week, it is counted as one week of charging activity.

Where do you usually charge – at home, at public stations, or somewhere else?
All interviewees prefer to charge their vehicles at home if the opportunity exists, emphasizing the convenience and accessibility of home charging. When additional charging is needed or when home charging is not sufficient, public charging stations are used to either supplement the battery level or compensate for the lack of charging at home. Thus, home charging is the primary option, while public stations serve as complementary solutions to meet the various charging needs of electric car owners. Furthermore, interviewees with access to home charging show a lower frequency of charging, usually only once or at most twice per day at public charging stations. On the other hand, drivers without access to home charging, charging sometimes takes place up to four times per day at public charging stations.

"I usually charge at home, and then I charge once if needed at a public station just to be sure that I can get through the day."

"Depending upon how much energy I have left, I either go to a fast charger in the morning and get full battery before the day begins, or I go on with my day and hope that I get the time to charge in-between customers."

Do you prefer to charge overnight at home or at public stations?
All the respondents stated that they prefer to charge at home overnight if they have that possibility.

Are you the owner of the taxi, or is it owned by the company?

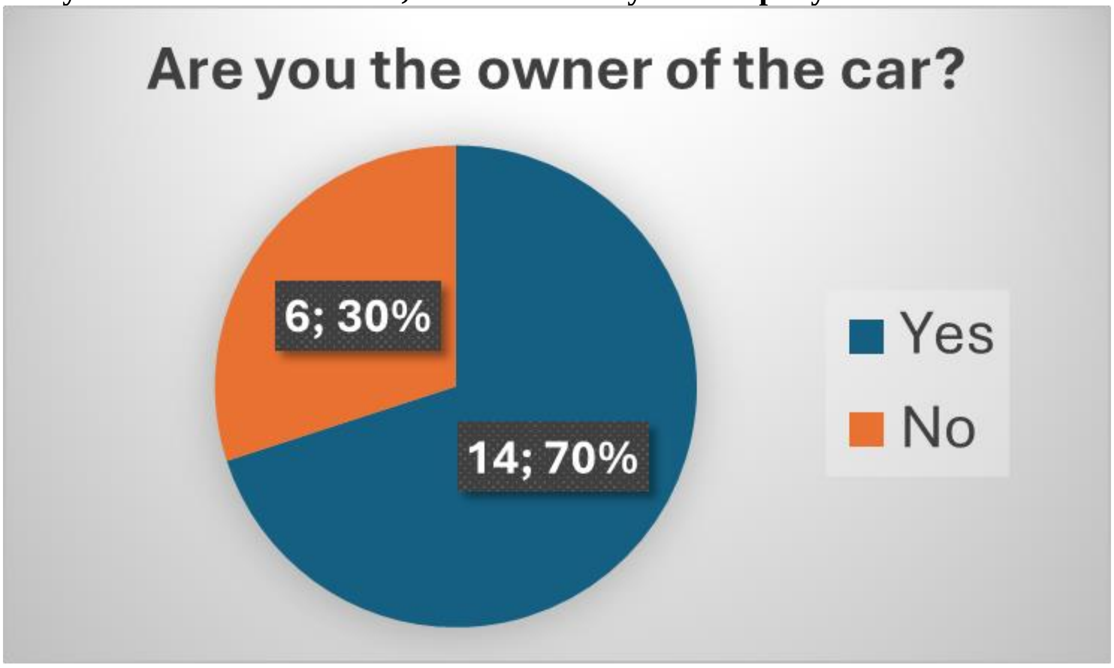

Figure 13. Overview of ownership of the vehicle

70% (14 individuals) stated that they were the owners of the car they were driving and 30% (6 individuals) stated that they did not own their car they were driving.

Who bears the cost of operations – you as the driver or the taxi company?
In the interviews, it emerged that all the drivers who did not own the taxi did not bear the cost of charging or purchasing the car. During the discussion, several of the interviewees expressed a general opinion that the purchase cost of electric cars is too high compared to ICE vehicles. Despite this perception, they noted that the price they were offered for this specific vehicle was very good, as they received a discount in the context of the wireless charging project.

"If it wasn't for the discount from this project, I wouldn't have bought an electric car. The price was just too high for me otherwise."

Would you use wireless charging more if the power was higher? Would 75 kW be sufficient?

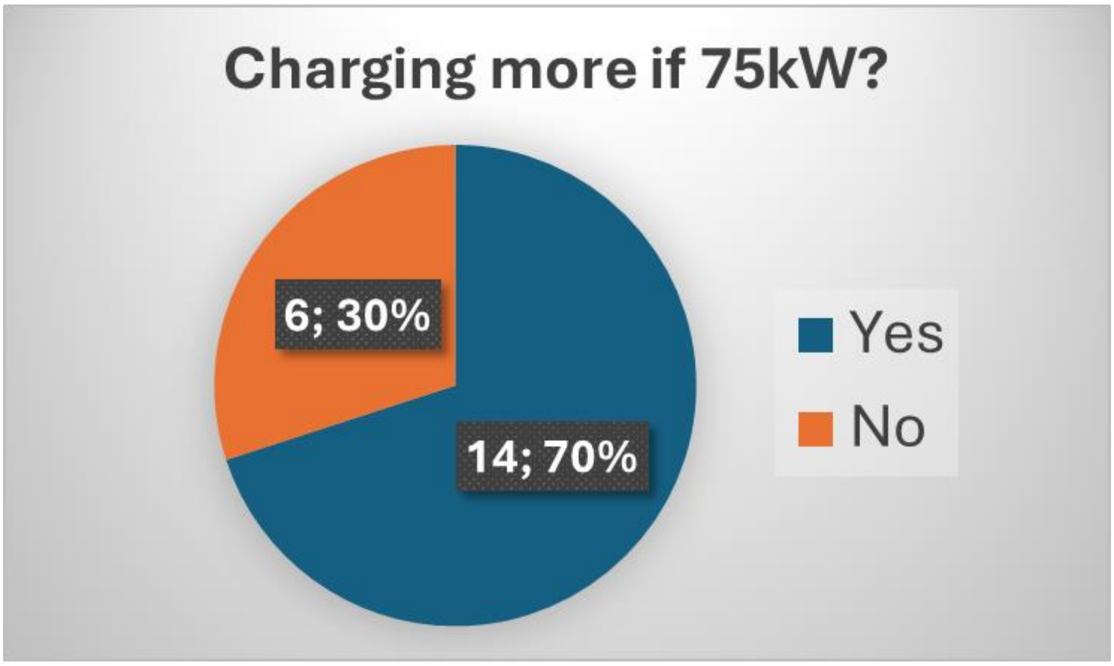

Figure 14. Charging power acceptance of 75 kW

70% (14 individuals) stated that they would use the wireless charging stations more if the charging power was increased to 75 kW. 30% (6 individuals) stated that they would not charge more if the power was increased to 75 kW. Almost all the respondents pointed out that it took a lot of time to charge wirelessly, not being as quick as fast chargers. A few of them who did not think 75kW would be sufficient thought 100 kW would be enough, practically cutting the current charging time in half.

What is most important to you, the availability of charging stations, the speed of charging, or the cost of charging?

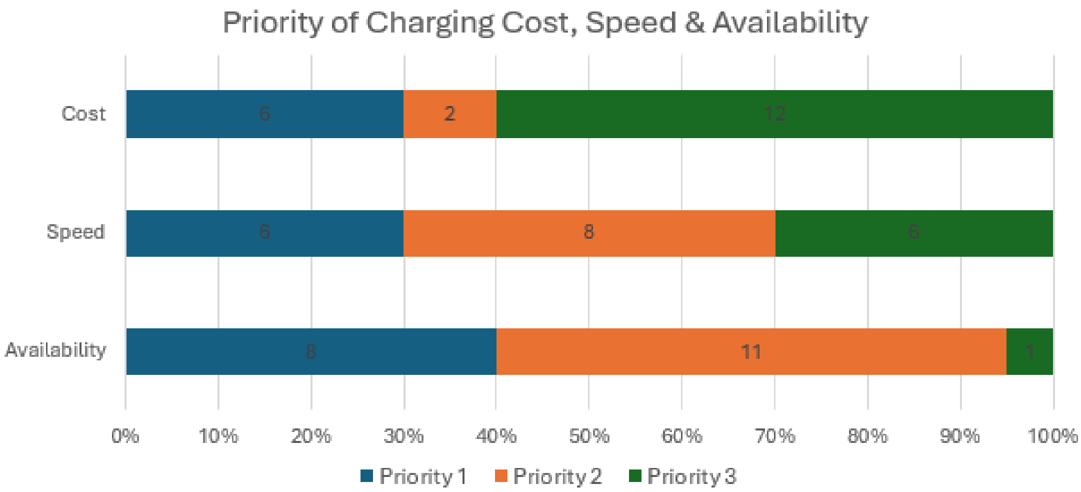

Figure 15. Priority of cost, speed, and availability of charging stations

Six respondents prioritised cost as the most important factor, two ranked it as the second most important, and 12 placed it last. Six respondents considered charging power the most important factor, eight ranked it second, and six placed it last. Eight respondents prioritised availability as the most important factor, 11 ranked it second, and one placed it last.

Some interviewees thought that the availability of charging stations is an important factor, especially in the areas where they usually have their regular routes. For some, this was the most important factor, and it was only picked once as the last priority as it directly affected their daily logistics route. The charging power was the second most prioritised. Some interviewees argued that high power charging stations enables the drivers to streamline their use of the car, thus reducing waiting times and increasing overall convenience. The cost aspect was also central for many of the interviewees, and some interviewees argued that the high charging costs could undermine the fuel cost benefits of choosing an electric car, making the pricing structure of charging a deciding factor.

"Availability of charging stations is critical for my routes, it's the most important factor for me. High charging costs are a concern, but they won't deter me if the station locations fit well with my daily logistics."

Despite higher costs, some drivers participating in the experimental project express a certain level of acceptance towards the expenses associated with wireless charging. One driver articulated their viewpoint by stating the following.

"After all, we entered into an agreement when we bought the cars and it suits me, I don't care if it gets a little more expensive, I take it as a break."

This reflects a tolerance for the additional cost in exchange for the benefits provided by the project, such as convenience and the opportunity to support new technology. Respondents said that if the charging station was closer to the driver's home, the charging power would not matter as much. There was an understanding that drivers who had no home charging possibilities would be more inclined to use fast chargers at the start and end of their driving shift. Many interviewees expressed a need for conveniently placed fast chargers, especially during peak hours.

“When driving a taxi during peak hours, faster chargers at convenient places are of high importance since losing time when charging results in fewer customer rides.”

"If the charging station is close to my home, I don't worry too much about how fast it charges. But without home charging, I rely on fast chargers at the start and end of my shifts, especially during peak hours when time is money.”

Some respondents stated that at the beginning of the project, it was much harder to find charging stations but that it has become gradually easier, some with the explanation that it is because of better awareness of where to find them and some said that it was because of the increase in charging points. Also, since not all drivers are owning the vehicle, some respondents stated that if they were owners and paid for the charge, they would think more about the cost.

How do you balance these factors in your daily work?

Many of the interviewees mentioned that they use some kind of strategic planning to balance the factors of availability, effect, and costs. Some of the respondents answered that they are charging while they are waiting for customers. Since it is often a physical or digital queue for getting the passengers, they could get notified beforehand and decide on how long they might be able to charge. The reality of their daily work can often lead to spontaneous charging decisions. One driver described the reactive nature of their charging habits as below.

"I drive so much that as soon as I get a chance, wherever I am, I charge the car."

However, the drivers often plan their routes based on where they know available charging stations with enough power and low enough costs are placed, taking all of the factors into account. One driver illustrated a proactive approach to integrating charging into daily work routines.

"I do my morning shift and then I plan so that I end up at Sahlgrenska and stand and charge, I don't get upset that it takes an hour to charge because then I eat breakfast and take a walk while it charges, then I get the next trip and depending on where the next trip goes, I either go back and charge wirelessly. If it's a long trip outside of Gothenburg, I charge where it's available."

This strategy demonstrates how drivers can effectively manage their time and resources by aligning charging times with breaks or less busy periods, turning a potential inconvenience into an opportunity for personal downtime or preparation for the next segment of their shift. A few of the interviewees tend to prioritise different factors according to specific needs that they have at a specific time. For example, on days with high activity and lots of driving, speed of charging takes precedence, while cost is a more prioritised factor during less intensive periods. Some emphasised that the balance between the factors often involves compromises. Choosing the most available charging station may not always mean the fastest charging or the cheapest costs. The choices are adjusted based on a trade-off between the factors, depending on their immediate needs and financial considerations.

"On busy days, I prioritise charging speed to keep moving, but on slower days, cost becomes more important. It's always a balance, and sometimes you compromise on speed or cost based on what's available."

Furthermore, a few interviewees said they made great use of technology, such as apps, to determine the lowest cost and charging times. However, they mentioned that not all knew how to do this.

How many times a day do you charge, how long, and at what speed?

Most interviewees charge their vehicles at least once per day, with some needing to charge two to three times depending on their daily mileage, work patterns, and, especially, if they have overnight charging possibilities. The charging sessions varied among respondents, ranging from one to three times in a full working shift for 30-45 minutes each. Some mentioned shorter sessions of around 10-20 minutes for fast charging. A few interviewees mentioned that the charging time is adjusted according to needs and available charging options during the day.

“Charging time can vary; I might do a quick 10-20 minute fast charge, or a longer session if I'm using a slower station. It really depends on what my day looks like and what options are available."

Furthermore, the speed of charging also varied. Some preferred fast charging (150kW) to minimise interruptions in the working day, while others used wireless charging (50kW) or slow charging (11kW) when time allowed. The choice of charging speed reflected a balance between the need for rapid battery replenishment and available charging options at different locations.

What do you mostly use for fast charging (150 kW), slow charging (11 kW), or wireless charging (50 kW)? Why?
Most of the interviewees prefer fast charging (150kW). According to them, it is mainly due to its efficiency and timesaving. For those who have tightly scheduled working days or need to quickly top up the battery to continue their daily routes, fast charging offers a practical solution. According to the interviewees, the choice is motivated by the need to minimise downtime and maximise the time they can be active on the roads.

"Personally, I lean towards fast charging because it's all about efficiency and saving time for me. But I know some folks prefer slower charging, maybe to save costs or to be gentler on the battery. It's all about finding what works best for your own needs."

For those interviewed who have access to overnight charging at home or at work or those who can plan their drives so that longer charging stops are feasible, slow charging (11kW) is sometimes preferred. According to the interviewees, this choice is guided by the lower cost compared to fast charging and the less stress on the battery. Some interviewees say that they appreciate the convenience of not having to deal with cables. When it comes to charging wireless (50kW), some interviewees also perceive the 50 kW as sufficient for daily use, especially when they enter the workday with a fully charged vehicle and just have to charge small amounts to have enough power for the whole day. When discussing their charging routine, a few interviewees highlighted their reliance on the various charging options and their specific use.

"I charge at home every night, wirelessly in Gothenburg for comfort, and complement with fast charging to top up the battery when needed."

What do you prefer in terms of capacity for slow and fast charging? Please share your experiences with 11 kW, 50 kW, and 150 kW chargers.
Slow charging is appreciated by those who prioritise cost efficiency and battery health over speed. Many interviewees appreciate the possibility of being able to charge overnight at home or for longer periods when the car is not in use. The charging time is longer; however, it is not seen as an obstacle for those who have adapted their use to this format. Some expressed appreciation for the 50kW option, which balances speed and convenience. Some expressed appreciation for the 50kW option, which balances speed and convenience. Although it does not offer the same speed as dedicated fast chargers, users appreciate the convenience and less wear and tear on the battery compared to higher capacity. However, the answers differed, with some emphasising that the time it takes to charge a car at 50kW is too significant compared to what they are used to with ICE vehicles.

“I find the 50kW option appealing as it strikes a balance between speed and convenience. While it may not be as fast as dedicated fast chargers, the convenience and reduced wear on the battery usually make it a favourable choice for me."

"50kW takes a very long time to recharge the battery compared to refuelling in seven minutes with a petrol or diesel car."

"For me, fast charging is essential because it saves time and keeps me on the road. Despite the potential higher cost and impact on the battery, I prioritise the convenience of quickly topping up my battery to maintain productivity throughout the day."

Moreover, the responses show a clear preference for different charging types based on individual circumstances and needs. While some value cost efficiency and battery health by using slow chargers, others prefer the time efficiency that fast chargers offer and 50kW seems to offer a compromise for those seeking a balance between these factors.

Do you have access to home charging, and how does this affect your choice of charging locations during work?

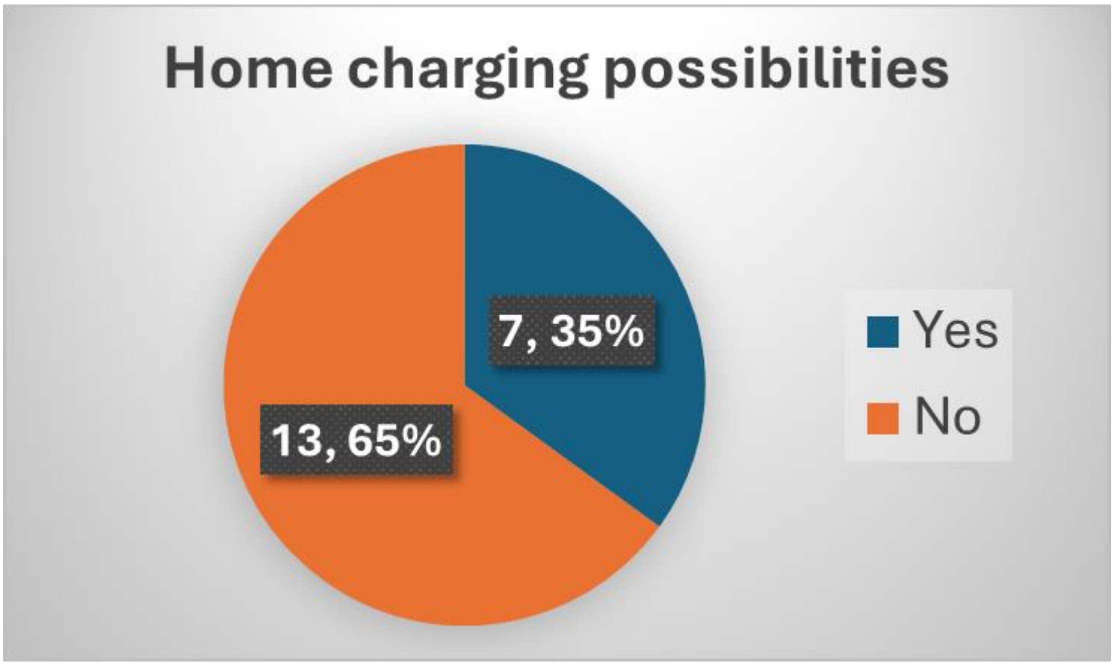

Figure 16. Percentage of interviewees able to charge at home.

35% (7 individuals) stated that they had home charging access, and 65% (13 individuals) stated that they did not. A minority of drivers have access to home charging. These individuals tend to start the day with a fully charged car and thus feel less need to use fast-charging (150 kW) public stations during the working day. Home charging is seen as a convenience that offers both financial and operational benefits. One driver clearly articulated the advantages of this setup.

"I always have a full battery in the morning when I start the session. This practice not only ensures that I am prepared for the day's demands but also reduces the urgency to find public charging stations."

"When I didn't have access to home charging, I had to rely on public stations. I had to plan my routes meticulously, prioritizing locations where I could charge. But when I got access to a charger at home, it was different. Now, I have more flexibility and

can use public stations mainly for longer trips or special situations. It's clear that having home charging changes how I plan my days."

Where in the city are the most convenient places to charge?
Many interviewees stated that charging stations along their normal routes were particularly valuable. This was motivated by the fact that they can charge the car in sudden downtimes, which minimises any interruptions to their workflow. Furthermore, charging stations in or near their residential areas are particularly important for those who do not have access to home charging.

Where would additional charging stations be most beneficial for you?
Many interviewees expressed a need for more charging stations in the city centre and business districts where most of the taxi business is concentrated. According to them, this would allow drivers to recharge between trips without leaving areas with high demand for taxi services. Yet, the practical placement of these charging stations is crucial. One driver highlighted a common misplacement issue that could act as a significant barrier.

"If you are going to put out more charging stations, then keep in mind that it is no idea to have a charging station in a hotel for example, it is madness! Because I mean if you come in there and stand in line, how long do you stand there waiting for a customer, you don't even have time to get 5%."

A popular response was the airport “Landvetter”. The respondents further explained that optimal charging points are not necessary on the same street as the customers are picked up, but in the nearby area. According to some interviewees, being able to charge at the airport would mean that drivers can maximise their working hours by avoiding long journeys to distant charging stations. Additional charging stations in these residential areas would be very valuable for drivers living in areas where the charging infrastructure is limited.

“It would facilitate the start and end of the working day for those who do not have the opportunity to charge at home. “

Specific suburban areas such as “Angered”, “Bergsjön”, “Gamlestaden”, “Kortedala”, and “Hammarkullen” were highlighted as areas where the need for more charging stations is particularly acute due to a combination of high taxi traffic and a lack of current infrastructure.

How does the need to respond to customer demands in real-time affect your choice of different types of charging stations? For example, fast charging and slow charging, whether they are private or public?
Many drivers emphasised the importance of fast charging stations to minimise the time the car is stationary. Fast charging is essential to returning to work as quickly as possible, especially during peak periods when the demand for taxi services increases. This facilitates a quick response to customer inquiries without long interruptions.

"In the hustle of peak hours, fast charging can be a lifeline, it's all about minimising downtime to meet customer demands promptly"

The interviewees plan their charging stops strategically based on expected customer needs and traffic flows. They can use fast chargers at specific times of the day when a quick return to work is critical and rely on slow charging (if available) when customer demand is lower. The location of the charging station plays a big role. Stations near areas with high demand for taxi services or along regular routes are preferred.

“It's not just about speed, location matters too. Stations strategically placed along our routes or in high-demand areas keep us on the road and ready for customers."

This means that taxi drivers can charge their vehicles without deviating too much from their regular routes or areas where they are most likely to receive customer requests.

“When the pace slows down, I become open to slower options like wireless charging or overnight charging to keep our batteries healthy,"

This strikes a balance between maintaining battery health and ensuring availability for work. The choice between public and private charging stations is often influenced by cost, availability and charging time. Private stations may offer benefits such as better prices or reserved charging spots for taxi drivers, while public stations provide wider accessibility across the city. The taxi drivers' choice of charging stations was usually a dynamic process that balances the need for quick return to work with factors such as charging station location, cost, and the expected demand for taxi services. Being able to quickly respond to customer requirements is at the centre of their strategic considerations regarding charging.

Does your charging behaviour change between summer and winter or between good and bad weather conditions?

Many of the interviewees confirmed that their charging behaviour varies between summer and winter. During the winter, when energy consumption increases due to higher air density and energy demand increases for heating the compartment, drivers reported needing to charge more frequently to compensate for the reduced range.

"During those colder months, it's like a race against time, we've got to charge more often to make up for the shorter range caused by the lower temperatures."

Summer was considered less problematic, with a longer range and less frequent need for charging. Bad weather, such as rain, snow and ice, also affects the charging behaviour, especially for the wireless station since it is stated to be even harder than it currently is to align the vehicle on top of the charging pad when the markings are hard to see. The drivers indicated that the charging station located at Lindholmen was specifically hard to align since it was located in a curve. Some drivers also indicated that they preferred to use charging stations with sheltered areas during bad weather conditions to avoid discomfort.

"Trying to align your vehicle perfectly on that charging pad in the snow or rain can be a real challenge. But it does not matter to me, I prefer to seek out stations with sheltered areas during bad weather anyways."

“It can be a headache to align and connect to the wireless chargers, especially on Lindholmen with that curve, one time I tried 10 times before I was successful.”

In addition, the cold of winter can require longer charging times, which affects their workflow. To cope with these variations, the interviewees adapt their charging behaviour, plan their charging stops more carefully during the winter and consider potentially increased use of fast charging stations to minimize time loss. Some drivers also mentioned that they are more careful about maintaining a higher battery level during the winter to avoid the risk of being stranded due to unexpected battery losses, which is less of a concern during the summer months.

"Longer charging times in the cold can really throw a wrench into my schedule. That's why I plan my stops more carefully and might rely more on fast chargers to stay on track."

The responses show that taxi drivers' charging behaviour is significantly adjusted based on season and weather conditions, with particular attention to the challenges that cold and bad weather bring with it in terms of reduced battery performance and potential increase in demand for taxi services.

How do you feel about the cost of electricity at wireless chargers?
A significant proportion of those interviewed expressed concern about the cost of charging at wireless charging stations. They often compared the cost of wireless charging to traditional charging methods and emphasised the importance of keeping operating costs low to maintain taxi business profitability. Some drivers acknowledged that while the cost of wireless charging can be higher than alternative charging methods, this is sometimes outweighed by the convenience of wireless charging. This group felt that the extra cost could be justified by the benefits of not having to deal with cables and the easier charging process. Almost all drivers expressed a desire for lower costs for wireless charging. They called for more competitive pricing to make wireless charging more appealing and economically feasible as a primary charging method for taxis. According to the majority of interviewees, reducing the costs could increase the acceptance and use of wireless charging among taxi drivers. One of the interviewees explained the pricing question as such.

"The price is okay, it would have been smart to have the same price as I have with my home charger (around SEK 2-2.5), then I think more people would have charged. But that's not good for me, then I would have had to queue to charge. Therefore, it is a good and right price, however, there would be a higher utilisation if it was lower priced."

What do you think is an optimal charging time?
Many drivers expressed a desire for fast charging times, with an ideal span of 20 to 30 minutes. This time frame is seen as sufficient to effectively restore a large part of the battery capacity without causing excessive interruptions to the working day. At the same time, there is an awareness that charging too quickly can negatively affect the battery's health. Optimum charging time was therefore balanced, taking into account both the need to quickly return to work and to maintain battery life and performance over time. There was also a desire for flexibility in charging times based on different scenarios. For longer breaks or overnight, a longer charging time would be acceptable, while fast charging was preferred when time was a critical factor. The interviewees prefer a charging time that offers a practical balance between quickly restoring the

battery's capacity to continue the working day and preserving the battery's health in the long term. A charging time of 20 to 30 minutes is often cited as ideal, but there is an understanding that different situations may require different charging times.

"Around 20 minutes hit the mark – it's enough to get us back on the road without sacrificing too much time."

How important are environmental considerations in your choice of an electric vehicle over a traditional gasoline- or diesel-powered vehicle?

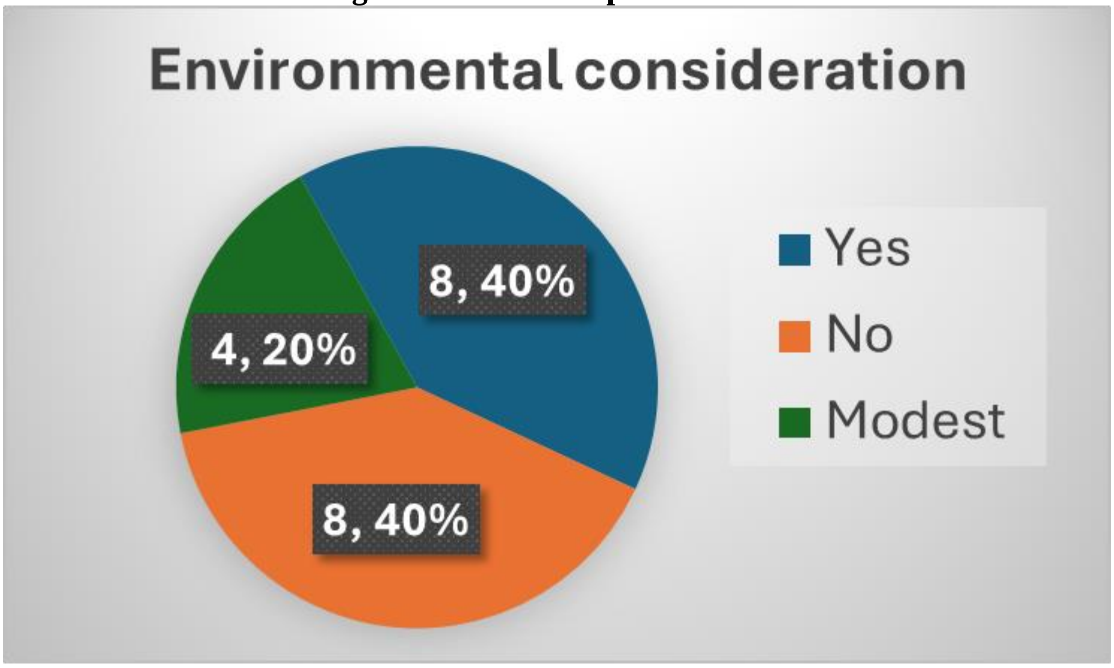

Figure 17. Percentage of interviewees considering the environment as a factor for transitioning to EVs

40% of the interviewees stated that they did not take the environmental aspect into consideration at all when they joined the project and bought the EV. 20% of the interviewees stated that they considered the environmental aspect of EVs but it was not significant in their decision to buy an EV. 40% of the interviewees emphasised that environmental considerations were a big part of their decision to choose an electric car and some believed that the higher initial cost was justified due to the reduced environmental impact. For some, the decision to drive an electric car is also linked to a professional image. One respondent stated that they of course thought about the environmental aspect when they purchased the car and further explained that they were proud of driving an EV.

"Although I'm not an environmentalist, idling for 20 minutes while waiting for a customer would be embarrassing with a traditional car. Now, with an electric vehicle, I can wait as long as needed without any concerns about pollution or wasting fuel."

"The price of electric vehicles is higher, but for me, it is worth it because it helps the environment."

Can you compare your driving experience between an electric vehicle and a traditional vehicle?

An overwhelming majority of drivers reported a positive driving experience with electric cars compared to traditional vehicles. They especially appreciated the quietness and smooth ride, which made for a more pleasant and less stressful working day. moreover, many drivers emphasise the superior performance of electric cars, especially when it comes to acceleration. They described how electric cars offer an immediate response without delay, which they found beneficial in city traffic and when overtaking. Furthermore, a sense of pride could be seen from a few of the drivers, both to be a part of a pioneering project and drive electric cars, wearing it like a status symbol.

"Electric cars have totally changed the driving experience they're quiet, smooth, and have great acceleration, especially handy in city traffic."

“I am proud of my car, it’s good-looking and also good for the environment”

Economic aspects were also part of the comparison, with drivers citing lower running costs for electric cars due to less maintenance and lower energy costs compared to the cost of petrol or diesel. Despite the many benefits, a majority of drivers directly cited range anxiety as a challenge with electric cars. They pointed out that the need to plan runs and charging stops more carefully can be a disadvantage compared to traditional vehicles, especially during long working days or in areas with limited charging infrastructure.

"Driving an electric car is like driving with anxiety, similar to driving on an empty tank."

“One big drawback is the battery capacity, which only lasts 300 kilometres.”

Furthermore, some interviewees said that they used to take long-distance trips when driving a traditional ICE vehicle. However, now when driving an EV they stay away from taking on long-distance trips where they would have to stop and charge, partially because of the fact that they don't want to recharge with a customer in the car. But also because of the fact that they are not certain that the infrastructure is sufficient in the areas, they might have to travel to.

“Long trips were no issue with my old car, but now, I steer clear with my electric vehicle. Recharging with passengers onboard can be a little embarrassing, and I'm not always confident in the availability of charging spots in remote places.”

How has your charging behaviour changed since the start of the project?

Many drivers reported increased planning and awareness around charging. They have become more strategic in when and where they charge their vehicles to maximise efficiency and minimise time away from driving. This includes choosing the right charging station based on location, availability and charging time.

"Difficult to find charging stations, knowledge is too little about how to find easily, there are older people who do not have the opportunity to search for charging in the apps, gets dizzy."

Furthermore, the experience of driving an electric car for a longer period of time has helped drivers gain a better understanding of their vehicles' range and how various factors, such as temperature and driving style, affect it. This knowledge has enabled them to optimise their driving and charging strategy. The drivers have adapted to the electric cars' unique characteristics and limitations. For example, they have learned to manage range anxiety and integrate regular charging stops into their daily routines, which has reduced the stress of finding charging stations at the last minute. The availability of charging stations has increased a lot since the start of the project. For many, initial uncertainty and scepticism have been replaced with increased confidence in electric car technology and charging infrastructure.

"This was the first electric vehicle I had. I got stuck when I took a long drive at the beginning of the project, but over time, I have learned a lot. Now, I only go for short drives; finding charging spots used to be harder, but now it's much more accessible because we have charging stations everywhere. Before, you had to travel further to find a charging station. I'm better at mapping and planning based on price and functionality now compared to early in the project."

Do you think others feel the same way as you do? What do you think others think?
Many drivers believe that their colleagues share their views, especially when it comes to the positive aspects of driving an electric car, such as lower variable costs, less environmental impact, and an overall more pleasant driving experience. They point to a common appreciation within the taxi industry for the benefits that electric cars bring. At the same time, some drivers admit that there is variation in how quickly different drivers adopt electric cars. They suggest that some colleagues may be more sceptical of the change, either because of range anxiety, costs of initial investment, or concerns about the reliability of the car and charging infrastructure.

What have we missed with our questions?
Drivers emphasized the importance of maintaining effective communication and cooperation concerning the technical support and maintenance of their electric cars. They highlighted the necessity for a quick and efficient response to technical issues and maintenance requirements, noting that this rapid response is crucial for minimizing downtime and ensuring they can swiftly return to their work. The ability to address and resolve issues promptly is considered vital for the seamless operation of their vehicles and the overall efficiency of their daily routines.

Several drivers underscored the importance of the reliability of chargers. They emphasized that for them to be able to manage their EVs confidently, the chargers must function consistently and reliably. One driver mentioned a general apprehension about adopting new technology, expressing hesitation due to unfamiliarity. The project stakeholder for InductEV provided reassurance, stating that extensive testing has been done and there have been no reports of any major issues with the technology.

Finally, many drivers express frustration with the requirement for specific apps, tags or memberships to initiate charging sessions. This additional step is perceived as burdensome and inconvenient. In contrast, it is noted that wireless charging stations do not impose such requirements.

4.3 Insights of implementation of chargers in infrastructure

Various stakeholders in the project provided insights into implementing wireless charging stations within Gothenburg City's infrastructure. Initial observations pointed to Lindholmen as an attractive location for one of the two wireless charging stations since it is a hub for business travel and meetings, which motivated the placement of the taxi fleet. However, the recent pandemic a few years ago led to a transition towards digital instead of physical meetings, which drastically affected the demand for taxis.

After a review of the city's planning processes, with a stakeholder within the project from Business Region Gothenburg, the stakeholder concluded that building a public charging station with complex administrative structures and procedures was challenging. It is something many administrations take into consideration before getting approved to change the infrastructure. The Urban Environment Administration is responsible for the city's public space and overall accessibility. Some of its responsibilities are, for instance, counteracting congestion with congestion charges or deciding on where the use of studded tyres is forbidden. Another administration is the City Planning Administration, which controls all land in the municipal limit (both private and public) and has the mission to develop the city. The Gothenburg City Administration for Circulation and Water is responsible for the provision of sewage and clean water and has a say about everything below the surface. To top it all off, there are different organisations owning the power grid. In Gothenburg, a large proportion of the power grid is owned by Gothenburg Energy. Since it is almost always a monopoly, it is statutory for the owner of the power grid to accept any offer if expansion is necessary. However, how the investment cost is distributed is their choice, sometimes with significant investments that require extensive negotiations. It is required to get approved by all of the administrations above in order to start building a wireless charging station.

According to the stakeholder from Business Region Gothenburg, the availability of DC fast charging has increased significantly in the last few years, with an estimated ten times as many 150 kW chargers now compared to two years ago, enhancing support for the growing number of EVs.

The wireless charging infrastructure is not widespread and can not take advantage of economies of scale. Thus, currently, building the wireless charging option is, according to a stakeholder from Göteborg Energi, twice as expensive as the conductive charging alternatives. The price to charge at the wireless chargers is currently fixed and is 5 SEK per kWh, including VAT. As explained by the Göteborg Energi stakeholder, the idea is that the price of SEK 5/kWh for wireless charging should be competitive compared to other charging options (see Table 2).

"It was more than twice as expensive to build induction charging than to build the equivalent conductive charging…. If inductive charging becomes widespread, there is no indication that it will be a more expensive option from a life cycle perspective."

Furthermore, according to the same stakeholder from Göteborg Energi in terms of power draw, there is no discernible difference between the various charging technologies examined.

"The load on the electricity grid for the power output itself does not differ between the different charging technologies."

According to a project stakeholder at Volvo Cars, the development of the software for the cars proved to be the most time-consuming aspect of the project, alongside negotiations and coordination with the respective stakeholders. However, challenges emerged during implementation. Ground clearance issues arose from the placement of the receiver beneath the car, leading to reports of the receiver bumping on speed bumps and similar obstacles.

Moreover, integrating wireless charging receivers onto the vehicles and the corresponding software posed significant difficulties. The existing EV lacked compatibility with this technology, necessitating extensive modifications and adaptations to ensure seamless integration. Overcoming these hurdles demanded substantial time and resources, underscoring the complexity of the endeavour. The integration process outlined involved several key steps: mechanical mounting, electrical connection to the battery, software integration, ensuring functional safety, and establishing communication with the charging infrastructure.

According to stakeholders, the wireless charging system features an additive capacity by adding charging pads. A single charging pad can manage a charging output of 50-75 kW, while a bus with six receivers can achieve a total charging capacity of up to 300 kW. However, it is important to note a compatibility issue where the maximum charger output exceeds the intake capacity. While the charger can provide up to 75 kW, the cars in the project can only accept 43 kW, thus not fully utilising the charger's capabilities.

"The bottleneck is not the output of the wireless chargers but the input constraints of the cars"

Supplier (50kW charger)	Price (including VAT)
InCharge (Torpavallsgatan)	5.35 SEK/kWh
Northe (Torpavallsgatan)	5.95 SEK/kWh
E.On Drive (Torpavallsgatan)	7.35 SEK/kWh
Elton (Torpavallsgatan)	4.59 SEK/kWh + 2.5 SEK/min
EasyParkGo (Torpavallsgatan)	4.59 SEK/kWh + 2.5 SEK/min + 49 SEK/Mo.
EasyPark Small (Torpavallsgatan)	5.28 SEK/kWh + 2.5 SEK/min
E.On Drive (Bäckebol)	6.5 SEK/kWh
Virta (Bäckebol)	6.5 SEK/kWh
OKQ8 (Bäckebol)	6.5 SEK/kWh
Mer (Bäckebol)	7.5 SEK/kWh

Elton (Bäckebol)	7.53 SEK/kWh
Northe (Bäckebol)	7.70 SEK/kWh
Wireless charging (Lindholmen & Medicinaregatan)	5 SEK/kWh

Table 2. Overview of charging prices for 50 kW chargers (Extracted 6th of May, 2024)

Table 2 shows current prices for charging EVs at public 50 kW stations, the information was supplied by a project stakeholder from Göteborg Energi. The prices include VAT and refer to various suppliers and charging stations in the Gothenburg area, including Torpavallsgatan and Bäckebol. The table also includes prices for wireless charging at Lindholmen and Medicinaregatan.

5. Analysis

This chapter will analyse the evolution and current charging infrastructure challenges facing electric taxi fleets, particularly the integration of 43kW wireless charging. It will explore past barriers, their impact on current adoption rates, and the practical implications of these challenges through empirical evidence and theoretical frameworks.

5.1 Charging Infrastructure

According to the empirical data and previous research (Zhang et al., 2018), the availability of charging stations is insufficient and not optimally located to the taxi drivers' routes and needs. Moreover, all the respondents said they prefer to charge at home overnight if possible due to the convenience, lower cost, and reduced impact on battery health. Practically reducing the urgency of finding public charging stations at the start or end of their working shift. According to Venkatesh et al. (2003), FC refer to the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system. Thus, emphasising the importance of accessible resources and support in encouraging the adoption and effective utilisation of new technologies (Venkatesh et al., 2003). This corresponds to the importance of public charging infrastructure availability and home charging capability to support taxi drivers' adoption and effective use of EVs. Early in the project, charging stations were scarcer. However, drivers still need more charging stations that match high-traffic areas and regular routes, facilitating a smooth workday and minimising lost time. According to Davis et al. (1989), in TAM, PU and PEoU affect the behavioural intention to use the application, affecting the actual use of the system. The insufficiency of charging stations directly influences drivers' perceptions of their PEoU and usefulness for EVs, especially compared to ICE vehicles. According to Rogers (2003), the late majority will only adopt the technology when it has been approved by earlier adopters so that they can be assured of the innovation's success with minimal uncertainty. However, despite the recent increase, the availability of charging infrastructure still needs to be improved and can be seen as uncertain. Thus, increasing the availability of charging infrastructure will be crucial when addressing the late majority segment of diffusion**.**

The empirical data reveals that although the ability to plan their charging was initially limited, it improved over time as proficiency in utilising technology increased throughout the project duration. According to ADKAR (Hiatt, 2006), awareness is the first step towards change. Knowledge refers to individuals gaining the necessary information to understand how to use technology effectively and the ability to execute the change. This knowledge helps build their ability to implement change successfully. Knowing where to find suitable charging stations is a prerequisite for efficient planning for EV users. This knowledge depends on their awareness of existing charging stations, their knowledge of getting new information, such as using various apps, and their ability to execute their plan. Even though drivers have gotten better at utilising the conductive charging technology, they continue to express frustration over the requirement to use specific apps, tags, or memberships to initiate charging sessions. This ongoing issue can be analysed with the help of TAM, specifically focusing on the PEoU (Davis et al., 1989). Empirical data shows that wireless charging stations, in contrast, are praised for not having such requirements, offering a more seamless user experience. According to TAM, simplicity of usage enhances the PEoU, potentially increasing user satisfaction (Davis et al., 1989). Therefore, the likelihood of adopting wireless charging as a preferred option is higher due to its simple charging process. Wireless charging stations could significantly improve the overall user experience by reducing the barriers associated with the initiation process, fostering greater acceptance and integration of this technology among EV drivers.

The empirical evidence confirms the theoretical perspective on barriers to charging infrastructure but also adds insights into the practical and administrative challenges of implementation. A city like Gothenburg's complex administrative structure, with many public agencies and bureaucratic requirements, makes it challenging to build charging stations, which leads to delays and complicated negotiations. Previous research supports the complexity involved in selecting charging locations, hindering the effective deployment of charging infrastructure to meet the rising demand resulting from the increasing adoption of EVs (Zhang et al., 2018; Bonges and Lusk, 2016). Moreover, while there is no noticeable distinction between conductive and inductive charging technologies regarding their impact on the power grid, the widespread adoption of EVs escalates the electricity demand, leading to various adverse effects on the grid (Shareef et al., 2016).

5.2 Electric Vehicle

Empirical data highlights concern over EVs' insufficient driving range, which poses a significant barrier to their wider adoption, aligning with previous research (Lu et al., 2012; Williams et al., 2024). According to UTAUT and UTAUT2, PE and EE are directly linked to behavioural intention, which affects the use behaviour (Venkatesh et al., 2003; Venkatesh et al., 2012). Limited battery capacity negatively affects both PE and EE, which, in the end, hinders the adoption of electric taxis. Users expect their vehicles to perform reliably and efficiently throughout their daily journeys. Their willingness to adopt the technology is reduced when these expectations are unmet due to battery limitations. Furthermore, the effort required to plan charging stops and manage range anxiety can be perceived as unnecessarily inconvenience, increasing the technology's perceived complexity, and reducing its appeal compared to ICE vehicles. According to Rogers (2003), the early majority is sceptical and looks for clear benefits before adopting an innovation. They also prefer that the innovation is compatible with their existing routines. The early majority will be more inclined to transition to EVs if the battery capacity can meet their daily driving needs without frequent interruptions for charging since it may not be seen as a clear benefit for choosing an EV over an ICE vehicle. Transitioning to an EV may also be incompatible with their current refuelling habits. Addressing battery capacity and clear communication about these improvements will help convince this segment.

Previous research presents long charging times as a barrier to the adoption of EVs (Giansoldati et al., 2020). However, according to the empirical data, long charging times are not a significant barrier since the current power of conductive fast chargers is sufficient to recharge the batteries without creating major operational interruptions. According to TAM, PEoU and PU affect the attitude toward using the application; PU also directly influences the behavioural intention to use (Davis et al., 1989). Fast charging times can increase PU and PEoU since users will experience less downtime, making the EV more useful and easier to use, leading to a greater willingness to adopt EVs. However, empirical data highlights the conflicting nature of prioritising shorter charging times with higher effects and its impact on the battery health. According to the Diffusion of Innovations theory, developed by Rogers (2003), one of the key factors influencing the adoption of an innovation is its compatibility with existing values, past experiences, and needs of potential adopters (Rogers, 2003). Fast chargers improve the compatibility of the fast-paced modern culture, encouraging broader EV acceptance. While EVs still take longer to charge than traditional vehicles to refuel, the improved speed of conductive fast chargers reduces this time difference significantly. Thus, in this case, the relative advantage of the speed of traditional refuelling is often reduced to a negligible level over conductive fast charging. Rogers (2003) states that the early majority rely heavily on peer validation when adopting innovation. Therefore, the early majority will adopt EVs more extensively when they hear that fast-charging technology can meet their expectations for PEoU and compatibility with their busy lifestyles. Effective communication about the availability and performance of fast chargers can help this group overcome concerns about charging times, promoting broader adoption.

The empirical data confirm previous research that the higher purchase price of EVs is a barrier for many consumers (Giansoldati et al., 2020). According to TAM, PU is a determinant of an individual's intention to use a technology (Davis et al., 1989). Applying this from a financial perspective suggests that making EVs more cost-effective and demonstrating their long-term value would enhance their PU and, thus, their attractiveness. Applying the Diffusion of Innovations theory, the high initial cost of EVs may be seen as diminishing their relative advantage, affecting the PV, and potentially slowing their adoption despite their environmental benefits and advanced technology (Rogers, 2003; Venkatesh et al., 2012). Additionally Rogers (2003), states that the early majority adopt an innovation after a varying degree of time and rely on evidence of the innovation’s benefits and widespread acceptance by early adopters. The early majority will be more inclined to adopt EVs if the long-term value and cost-effectiveness are clearly demonstrated. However, empirical data shows that these other benefits still play a significant role when purchasing EVs. Our findings indicate that drivers value the driving experience, emphasising EVs' practical benefits and utility, aligning with instrumental values (Dittmar, 1992). Additionally, the data highlights the significance of environmental considerations, suggesting that the drivers derive emotional satisfaction from contributing to environmental conservation, reflecting hedonic values (Dittmar, 1992). Furthermore, the empirical data reveals that status also plays a role in EV adoption, with some consumers regarding the visual appeal of EVs as a status symbol, indicating a connection to symbolic values (Dittmar, 1992).

The empirical data show that performance in extreme weather conditions, especially during cold periods, is a significant barrier, aligning with previous research on the subject (Krishna 2021). According to the Diffusion of Innovation theory, compatibility with existing values, experiences, and needs is crucial for adopting new technology (Rogers, 2003). If EVs cannot effectively operate in cold climates, they lack compatibility with the needs of consumers in those areas, hindering their diffusion. Thus, identifying and addressing specific technological barriers that affect vehicle performance in extreme weather is essential to enhance compatibility and promote wider adoption of EVs. Furthermore, The empirical data portrays concerns about the reliability of EVs, aligning with previous research stating that reliability can be a significant factor affecting its adoption (Krishna 2021). In the empirical data, these concerns often stem from uncertainties around the longevity and performance of EV batteries, especially under varying operational and environmental conditions. According to UTAUT, concerns about reliability directly impact PE (Venkatesh et al., 2003). If there is doubt regarding the reliability and longevity of EVs, individuals may become sceptical about the technology's ability to meet their needs over time, which can significantly deter adoption. The late majority in the Diffusion of Innovation framework is often more sceptical and cautious about adopting new technologies and often waits until strong evidence of reliability and benefits is shown (Rogers, 2003). Thus, the late majority will adopt EVs to a higher degree when they see consistent, reliable performance regardless of weather conditions. Clear communication about technological advancements and widespread positive feedback from users in extreme climates will be crucial to convince this group.

Empirical data shows that the drivers expressed frustration with Volvo Service's communication and support regarding technical issues with their electric cars. According to Venkatesh et al. (2003), FC and EE are critical in determining how easily a technology is adopted and used. FC refer to the degree to which an individual believes that organisational and technical infrastructure exists to support the use of the system, while EE is the degree of ease associated with using the technology. The drivers' frustration with communication and technical support from Volvo Service suggests inadequate FC, possibly hindering EV adoption. Another factor concerns EE, which concerns technology's PEoU. Poor service communication may increase perceived effort in maintaining and troubleshooting EVs, potentially discouraging adoption due to perceived user unfriendliness and problematic experiences.

5.3 Electric Taxis

Previous research indicates that the frequency of charging needs presents a barrier to adopting electric taxis (Rao, Cai, and Xu, 2018). However, empirical data shows that drivers can address the potential barrier of frequent charging needs by ensuring their vehicles are charged before starting their work shifts. This proactive approach reduces the necessity for frequent charging throughout the day. The Habit construct in UTAUT2 suggests that when an activity using technology becomes routine, it leads to more natural and sustained use of the technology (Venkatesh et al., 2012). When drivers begin their day with a fully charged vehicle and it becomes habitual, operating electric taxis feel less cumbersome. Furthermore, previous research has identified the unique challenge of managing real-time customer demands with limited flexibility for planning (Shen, Wang, & Zhang, 2021). Empirical data shows electric taxi drivers can efficiently manage peak-hour demands by starting the day with a fully charged battery and the use of fast charging stations, this combination significantly reduces downtime, and enables quick service response. Applying the Complexity aspect of the Diffusion of Innovations theory, it is shown that these measures significantly reduce the perceived complexity involved in managing a vehicle's energy needs. This reduction in complexity can pave the way for their widespread adoption.

However, for individuals without access to home charging, commencing each workday by heading to a charging station at the start of a shift and waiting for a period to charge may still be considered an inconvenience. This applies to the EE aspect of the UTUAT framework (Venkatesh et al., 2003), the additional steps required for drivers to start their day at a charging station can increase the effort of using electric taxis. The perceived effort and additional time needed to prepare the vehicle for service could deter individuals who prefer more straightforward options.

The late majority tends to be more cautious and risk-averse, often adopting new technologies only when they become more user-friendly and less complex (Rogers, 2003). Thus, for electric taxis, reducing the complexity of ensuring that the vehicle starts the day with a full charge is crucial for this group. Making home charging feasible and convenient for all drivers directly addresses this concern, increasing the likelihood of adoption among the late majority. Simplifying the charging process and ensuring it fits seamlessly into taxi drivers' daily routines can significantly influence their decision to switch to EVs.

The empirical data supports the theories Kim, Lee, and Kim (2017) proposed, indicating that the demand from long-distance customers presents a barrier to the wider adoption of electric taxis. Applying the Diffusion of Innovation theory (Rogers, 2003), electric taxis must be compatible with long-distance travel demands to be widely accepted. The perceived complexity of managing an electric taxi for long distances can deter both drivers and customers from adopting this technology for their long-distance trips.

5.4 Wireless Charging Electrical Taxis

Oliveira et al. (2020) present behavioural and perceptual barriers to wireless charging technology, such as habits, reliability, and fear. Empirical data shows resistance from some drivers accustomed to traditional fuels and charging methods. The UTAUT2 framework supports this by acknowledging that habits are crucial in shaping individuals' attitudes and behaviours towards technology adoption (Venkatesh et al., 2012). In this case, the resistance from taxi drivers could highlight how deeply ingrained habits can act as barriers to adopting wireless charging for taxi drivers. Furthermore, empirical data suggests that the lack of reliability associated with wireless charging may also contribute to drivers' hesitance to use the technology. Applying to the PE aspect of UTAUT (Venkatesh et al., 2003), the lack of reliability directly undermines drivers' perceptions of wireless charging technology's effectiveness. If the technology does not consistently perform well, it fails to meet basic expectations, thereby decreasing its PU. Additionally, one driver has expressed a fear of the technology, further highlighting the complexity of concerns surrounding its adoption. In the context of social influence within UTAUT2, individuals' perceptions of the importance others place on using new technology play a crucial role (Venkatesh et al., 2012). In this context, even a single report of negative experiences can significantly sway the opinions of other potential users within the taxi driver community. If shared within the driver community, the fear expressed by one driver can create a ripple effect, leading others to doubt the safety and reliability of the technology, regardless of the actual incidence rate of such events. The late majority in Diffusion of Innovation (Rogers, 2003) will need to see widespread adoption and positive feedback from their peers before considering wireless charging. Ensuring consistent performance and addressing reliability concerns will be critical. Additionally, promoting the normalisation of wireless charging within the industry can help overcome habitual resistance and fear of new technology.

According to Oliveira et al. (2020), there are economic barriers connected to wireless charging technology for electric taxis. Several drivers expressed concern over the high cost of charging at the wireless charging stations, which initially appeared to be a significant barrier. However, the data shows that the price for charging at the wireless station of 5 SEK/kWh is competitive with the alternatives as can be seen in Table 2. Applying the PU aspect of TAM (Davis et al., 1989), despite competitive actual costs, the perception that wireless charging is more expensive can adversely affect its PU. If drivers perceive higher costs, they may fail to recognise the economic benefits or utility of transitioning to wireless charging, regardless of the actual costs. Furthermore, drivers emphasised the attractive purchase price of the cars, noting substantial discounts due to their participation in the project. For some, this incentive was pivotal in joining the project. This aligns with the Relative Advantage construct in the Diffusion of Innovation theory (Rogers, 2003). Here, the financial incentives give a notable edge to the project's cars over other vehicles, whether traditional EVs or ICE vehicles. This advantage is a compelling factor influencing the drivers' decision to adopt the new technology. By offering financial incentives, the project successfully attracted its first group of users, innovators, the earliest adopters of new technology. These innovators will play a vital role in the diffusion process (Rogers, 2003). Their initial adoption and subsequent feedback help pave the way for further adoption by demonstrating the technology's benefits and practical viability to later adopters (Rogers, 2003). However, without discounts, the high purchase costs for EVs with wireless charging capabilities can still be a significant barrier for taxi companies and municipalities (Oliveira et al., 2020).

According to empirical data, there were challenges with integrating wireless charging due to existing EV incompatibility. This finding aligns with the observations made by Oliveira et al. (2020), who outline technical limitations with wireless charging for electric taxis, specifically focusing on the charging power and integration complications with existing vehicles. The power of the wireless chargers was a perceived problem for drivers, particularly noticeable during peak hours when they constrain operational efficiency. As previously discussed in the analysis, a charging power resembling that of conductive fast chargers could mitigate other barriers, such as accommodating real-time customer demands. However, the real problem is not the output of the wireless chargers but the input capacity of the car. The EVs are limited to 43kW, but even if the receiving technology develops to 75kW, it would still remain a barrier when comparing it to conductive charging. This suggests that the PU of wireless charging, a key component of TAM (Davis et al., 1989), is significantly affected by the lower power compared to conductive fast chargers. Enhancing this aspect would improve drivers' perceptions of the technology's usefulness, encouraging broader adoption. Concurrently, UTAUT's concept of PE, which emphasises the expectation that technology will yield gains in job performance, aligns closely with this issue (Venkatesh et al., 2003). As the charging capabilities of wireless systems improve to match those of conductive chargers, it is anticipated that both the PU and PE will rise, leading to increased acceptance among drivers (Venkatesh et al., 2003; Davis et al., 1989). The early majority (Rogers, 2003) will be more inclined to adopt wireless charging technology if it is perceived as reliable and effective in maintaining operational efficiency, especially during peak hours. Addressing the capacity of the receiver and charger and showcasing successful performance improvements will be crucial for the widespread adoption of wireless charging for electric taxis.

Empirical data reveals issues for drivers aligning their cars correctly at wireless charging stations, this is consistent with previous research on the importance of very precise alignment between transmitter and receiver coils, as highlighted by Ahmad et al. (2018) and Birell et al. (2015). The EE dimension of UTAUT (Venkatesh et al., 2003), which measures the ease of using technology, directly relates to the difficulties drivers experience in aligning their cars correctly at wireless charging stations. The need for precise alignment increases the effort required to use the technology. This could negatively impact drivers' willingness to adopt and continue using wireless charging if the process is perceived as too cumbersome or demanding.

6. Conclusion

This thesis examines the challenges surrounding the integration of electric taxi fleets and wireless charging technology. Two main questions guide our analysis: First, how do the barriers faced by electric taxi fleets in the past compare to the current barriers these fleets face with integrated 43kW wireless charging? And second, how do these barriers affect the adoption and diffusion of electric taxis and wireless charging?

Limited availability of charging infrastructure hinders electric taxi adoption by reducing PEoU, PU, and FC. The adoption of electric taxis is going to be negatively affected until the infrastructure is reliable and widely available. Complex administrative structures and bureaucratic requirements hinder the deployment of charging infrastructure, causing delays, and complicating negotiations. Addressing these challenges is essential for meeting the rising demand due to increasing EV adoption. Furthermore, widespread EV adoption increases electricity demand, causing various adverse effects on the grid.

Limited battery capacity remains a barrier and hinders electric taxi adoption by decreasing PE and increasing EE. The adoption of electric taxis will likely be negatively affected since current battery capacities do not meet daily needs without major interruptions. Long charging times are not a significant barrier to electric taxi adoption as fast chargers effectively reduce downtime. The adoption of electric taxis is going to be positively affected since fast charging can accommodate the demands of their busy schedules. High purchase prices remain a barrier to electric taxi adoption by reducing PU. The adoption of electric taxis is going to be negatively affected until long-term value and cost-effectiveness are clearly demonstrated. Performance in extreme weather, particularly cold conditions, remains a barrier to electric taxi adoption. For electric taxis to be compatible with the needs of consumers in cold climates, addressing technological barriers affecting performance in these conditions is essential for wider adoption. Concerns about the reliability and longevity of EVs remain a barrier hindering adoption by decreasing PE. The adoption of electric taxis is going to be negatively affected until consistent, reliable performance is demonstrated. Additionally, inadequate communication and support from service providers can decrease FC and increase EE, further deterring adoption.

Frequent charging needs are not a significant barrier to adopting electric taxis. Drivers with home charging can reduce this barrier by charging vehicles before their shifts, simplifying daily operations. The adoption of electric taxis is going to be positively affected since habitual home charging can integrate EV use naturally into daily routines, increasing user acceptance. Managing real-time customer demands is not a significant barrier. Starting the day with a fully charged battery and using fast charging stations reduces downtime and complexity, mitigating the previous barrier and promoting adoption. However, for drivers without home charging, starting the day at a charging station increases the EE and perceived complexity. The adoption of EV taxis is going to be negatively affected since this can be perceived as a barrier. Making home charging feasible and convenient is crucial for adoption among the late majority. Demand from long-distance customers presents a barrier to the wider adoption of electric taxis. The perceived complexity of managing an electric taxi for long distances can deter both drivers and customers from adoption.

Behavioural and perceptual barriers, such as habits, reliability, and fear, hinder the adoption of wireless charging technology for electric taxis. The adoption will likely be negatively affected since ingrained habits, reliability concerns, and fear diminish PU, and PE, and spread negative perceptions within the community. Economic barriers to wireless charging technology, such as perceived high costs of charging and high purchase prices, hinder its adoption. Although the actual cost of charging wirelessly is competitive, the perception of higher expenses reduces PU. Financial incentives and discounts play a crucial role in attracting early adopters. However, without these incentives, the high purchase costs remain a significant barrier. Technical limitations such as incompatibility with existing EVs and charging power remain a barrier and hinder the adoption of wireless charging for electric taxis by decreasing PE and increasing EE. The adoption will likely be negatively affected until the technical limitations are fixed. Technical limitations and operational challenges, including incompatibility with existing EVs, lower charging effect, and alignment difficulties, hinder the adoption of wireless charging for electric taxis by decreasing PE and increasing EE. Addressing these limitations is crucial for its widespread adoption.

Addressing these interconnected barriers holistically is crucial for the broader adoption and integration of electric taxis and wireless charging into urban transportation systems.

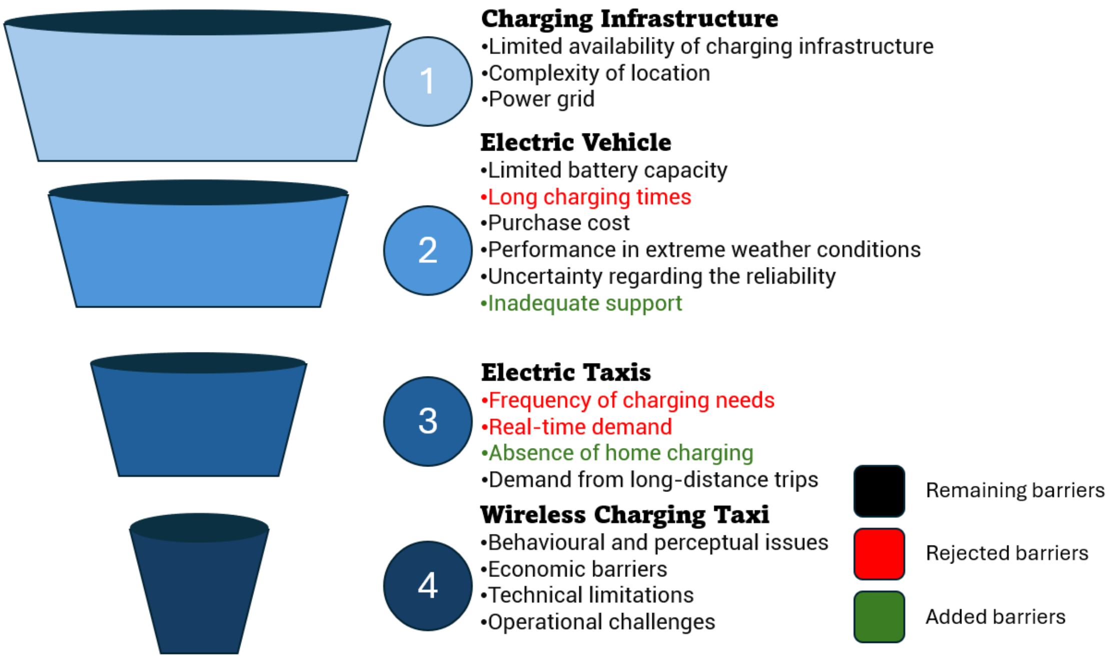

Figure 18. Illustrative funnel over remaining, rejected, and added barriers (own illustration)

6.1 Additional comments

Wireless charging was originally considered as a method of topping up batteries, for instance when waiting in a taxi queue and not for a whole battery cycle. However, in this project, drivers often used wireless charging stations similarly to how they used conductive charging stations and not as opportunistic chargers the way it was intended. The wireless charging technology offers a less cumbersome alternative to conductive charging, which often requires the use of apps, tags or memberships. Emphasis on the practical benefits of wireless charging, such as saving drivers from getting out of the car and plugging in a cable, especially during bad weather, and the environmental contribution it can bring are all factors that can help justify the higher initial purchase price of this technology. This simplicity may promote wider acceptance. All charging types have their advantages and disadvantages, and it is important to recognise the unique characteristics of each method in order to fully understand their specific contributions and use cases.

6.2 Further research

Further research is needed on the mass deployment of wireless chargers. This includes studying the scalability of wireless charging infrastructure and the economic feasibility for all stakeholders involved. Understanding these factors will be critical to planning and implementing the widespread deployment of wireless charging in urban environments.

Moreover, future research should explore the potential and challenges of wireless charging technology specifically tailored for self-parking cars and autonomous vehicles. These vehicles stand out as ideal wireless charging users, where they can benefit from wireless charging by automatically positioning themselves on charging pads. This minimises the need for human interaction and streamlines the charging process. If self-driving cars are part of the transport sector's future, wireless charging is likely the dominant method.

7 References

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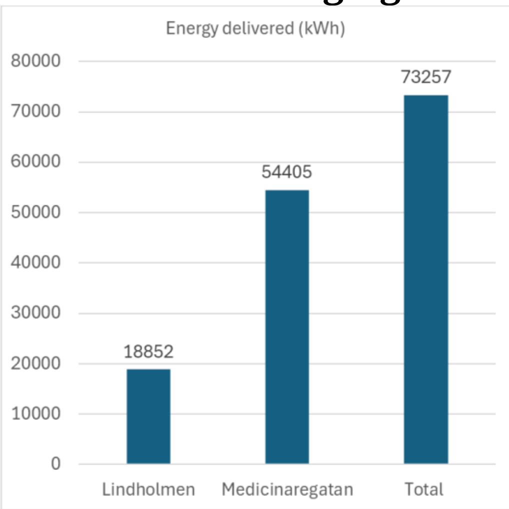
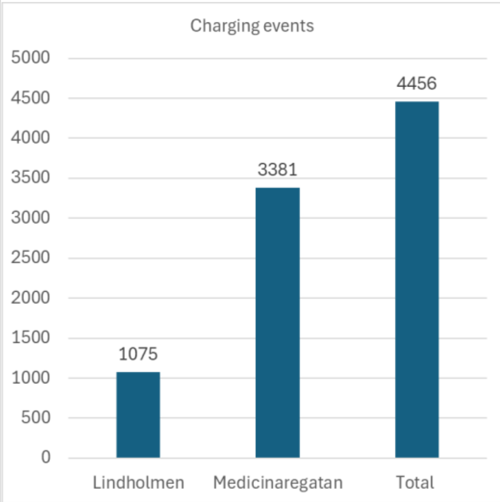
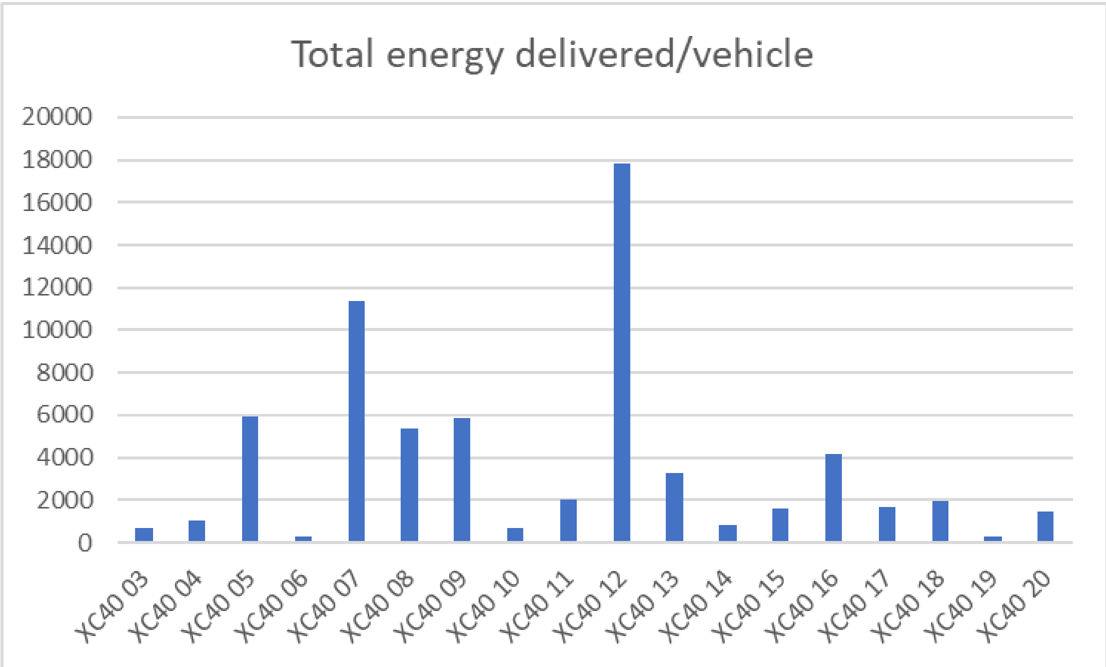
Attachment 1

Data on charging behaviour throughout the project

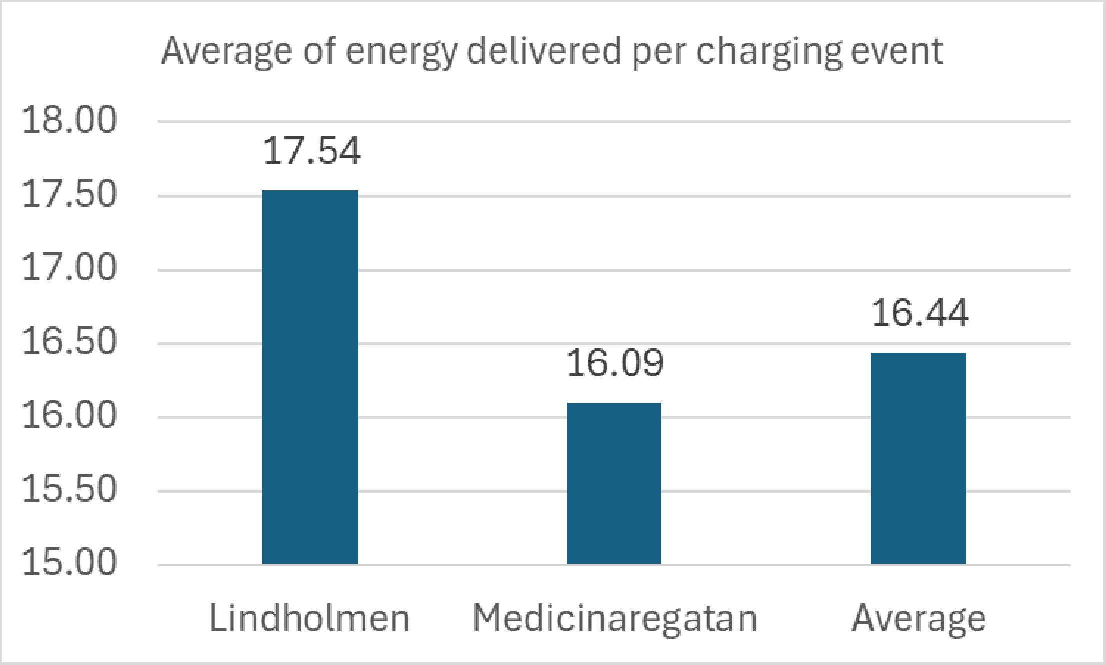




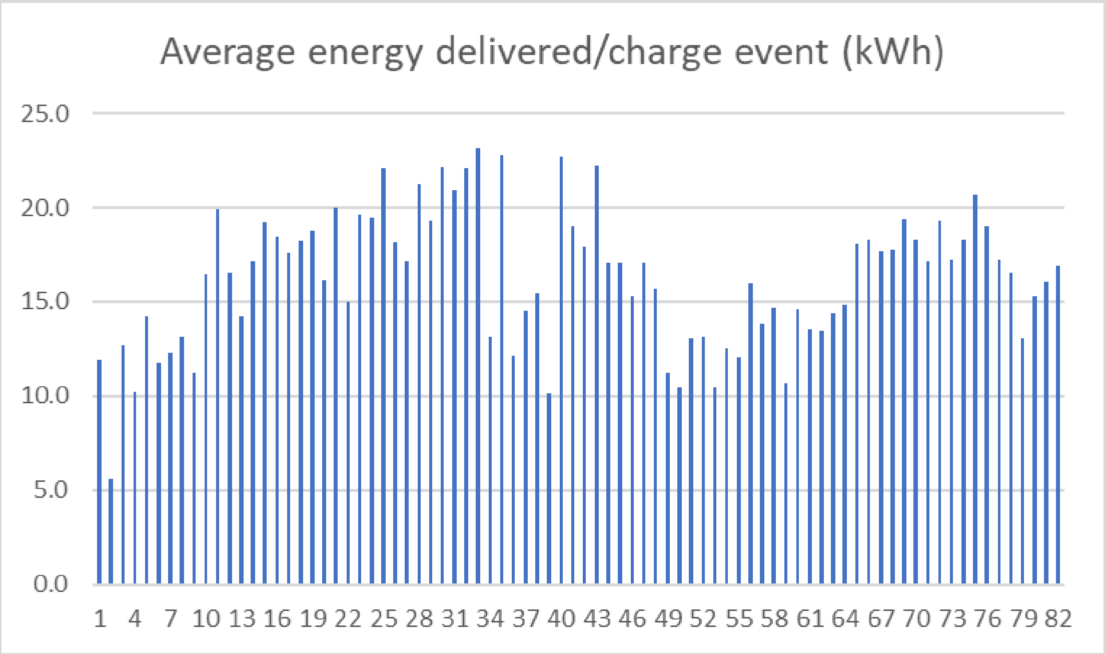
Attachment 1.1. The energy delivered per charging station and charging events per charging station



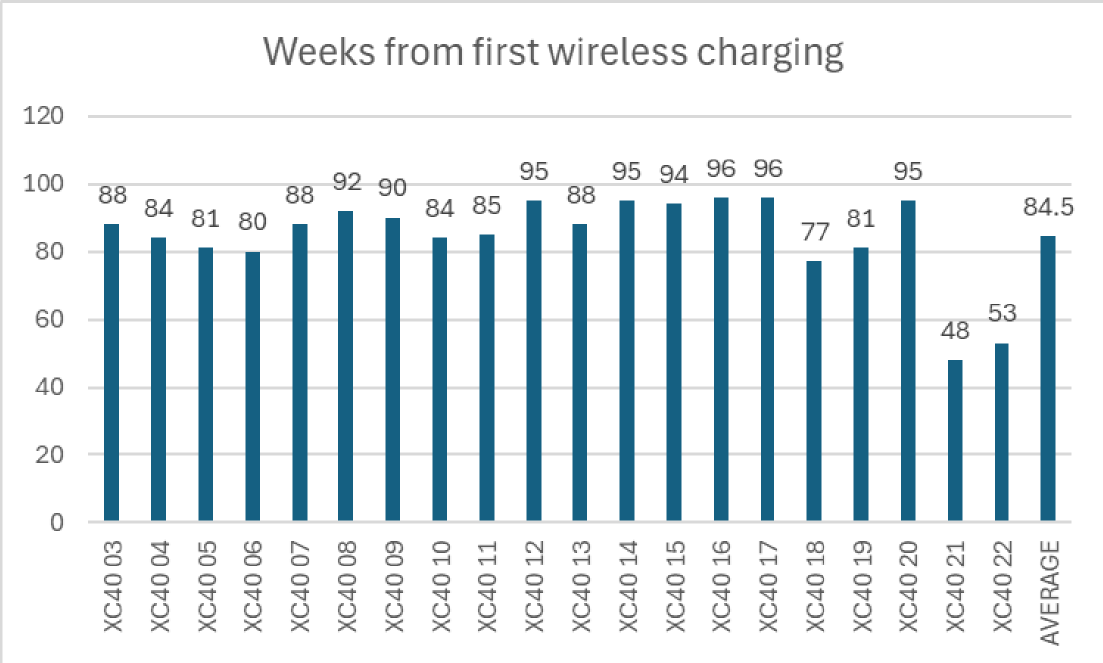
Attachment 1.2. Total energy delivered per vehicle



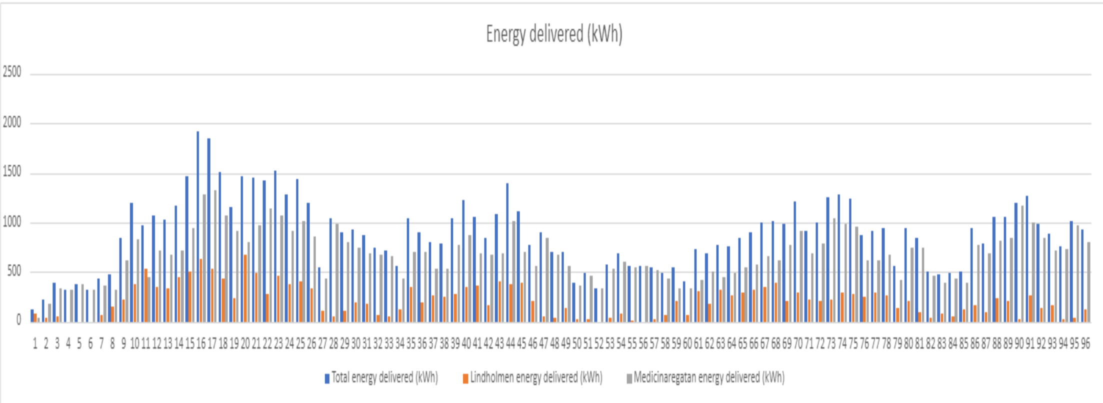
Attachment 1.3. Average of energy delivered per charging event (kWh)



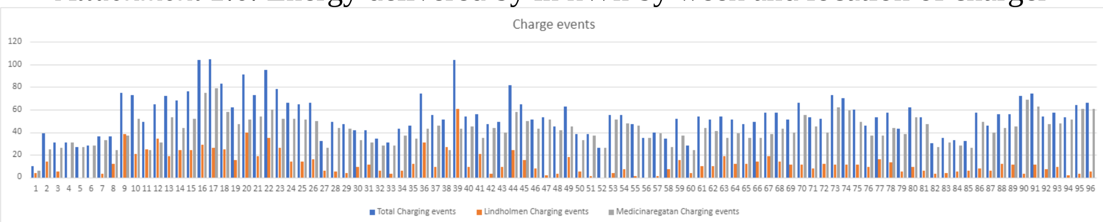
Attachment 1.4. Average energy delivered per charging event per week



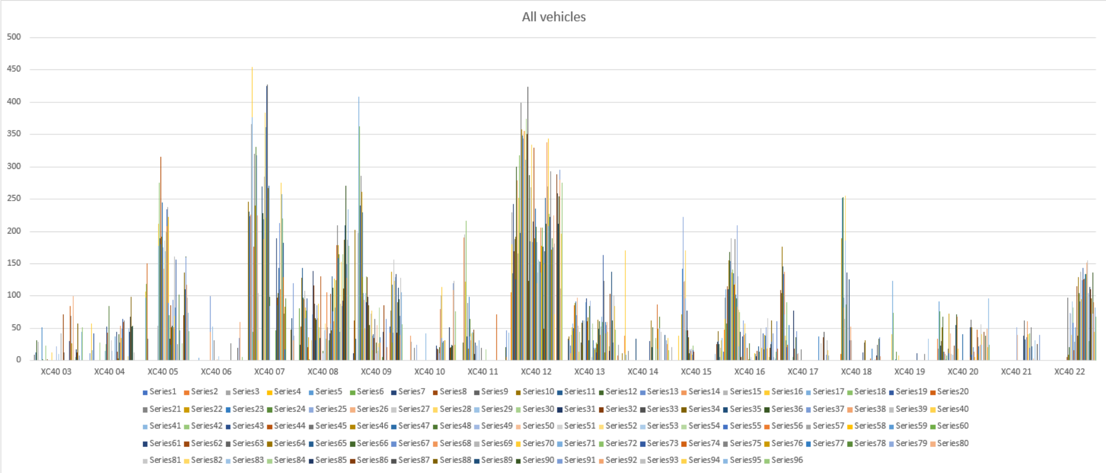
Attachment 1.5. Weeks from first wireless charging (96 weeks after the project started)



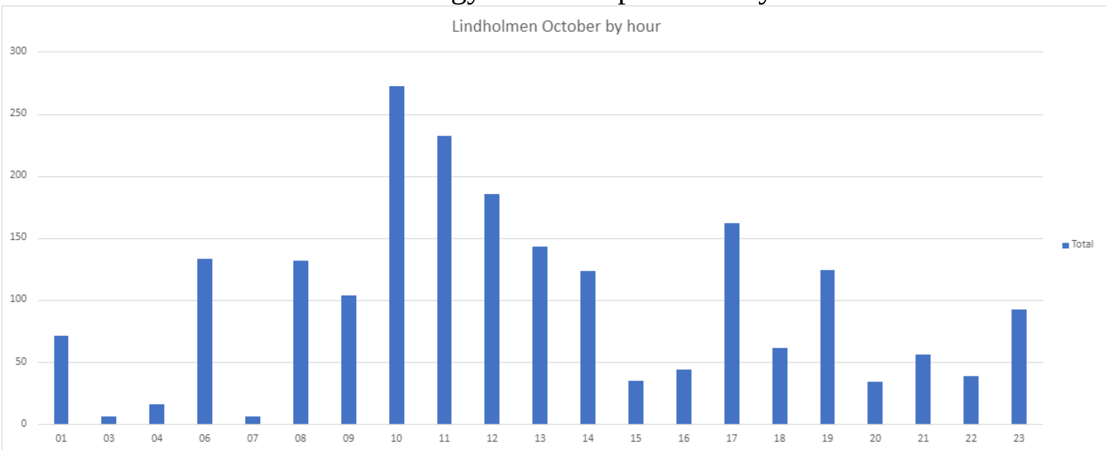
Attachment 1.6. Energy delivered by in kWh by week and location of charger



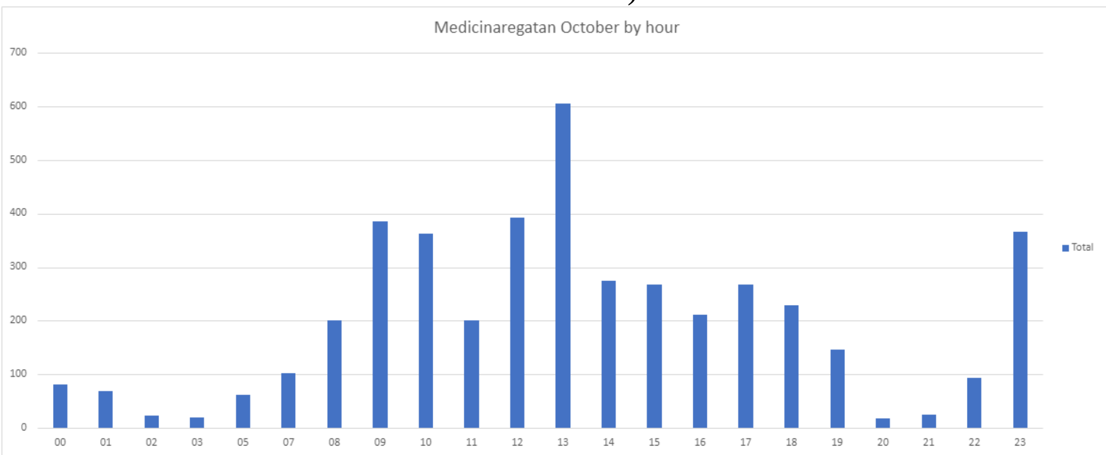
Attachment 1.7. Charge events by week and location of charger



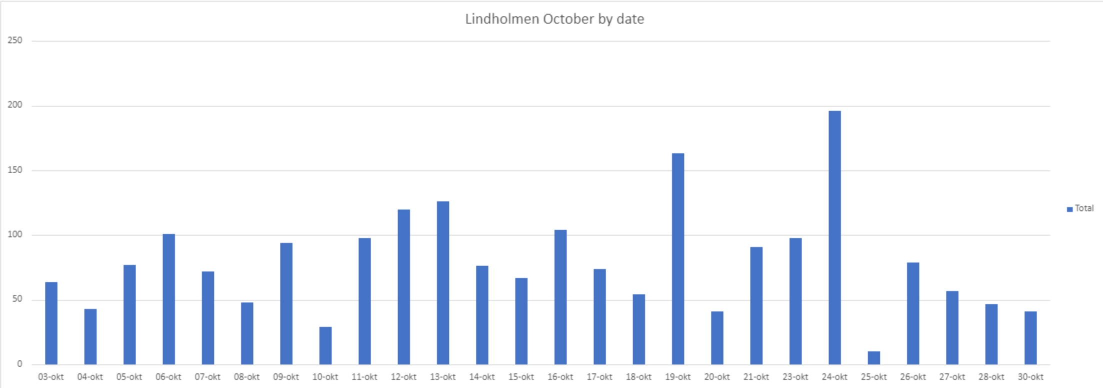
Attachment 1.7. Energy delivered per week by all vehicles



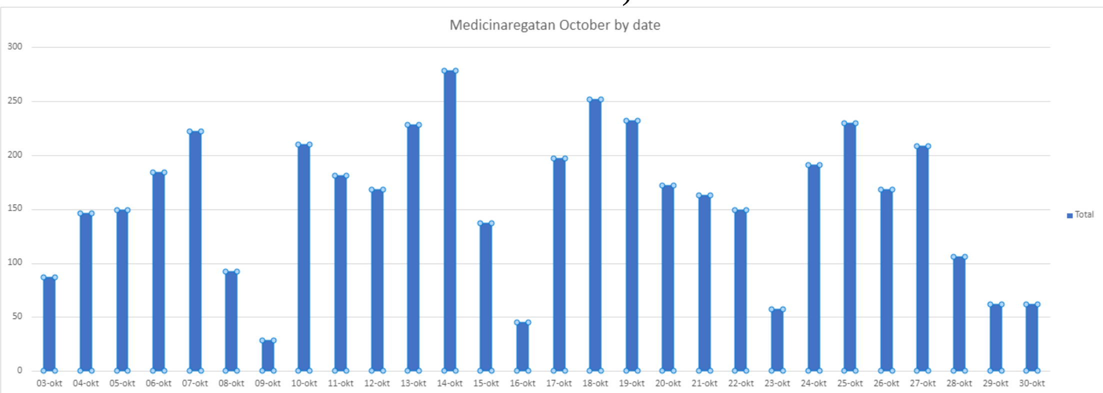
Attachment 1.8. Energy delivered by hour and charging location (*October*, Lindholmen)



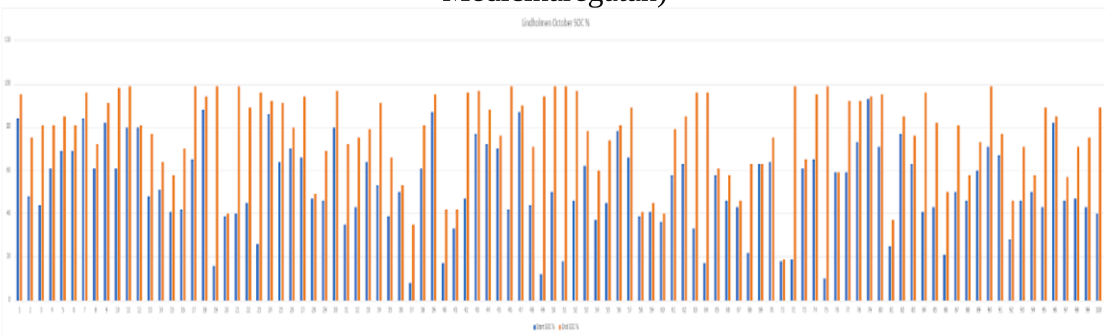
Attachment 1.9. Energy delivered by hour and charging location (October, Medicinaregatan)



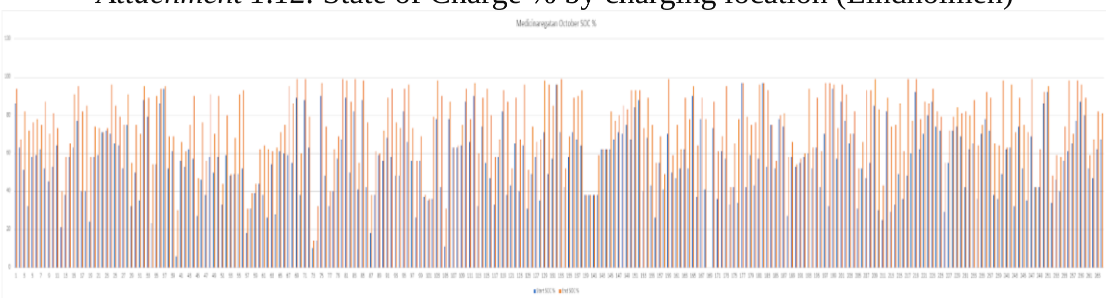
Attachment 1.10. Energy delivered by date and charging location (October, Lindholmen)



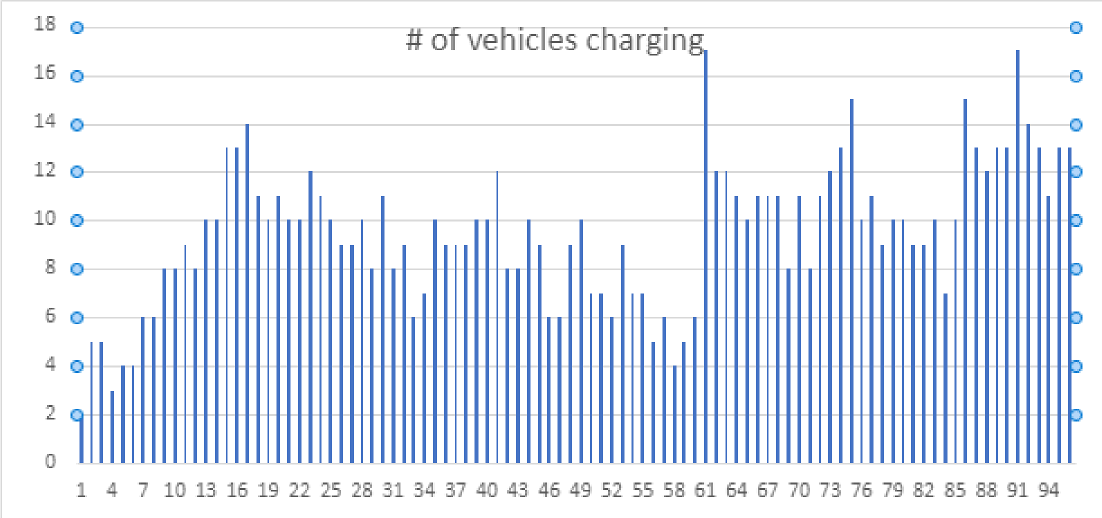
Attachment 1.11. Energy delivered by date and charging location (October, Medicinaregatan)



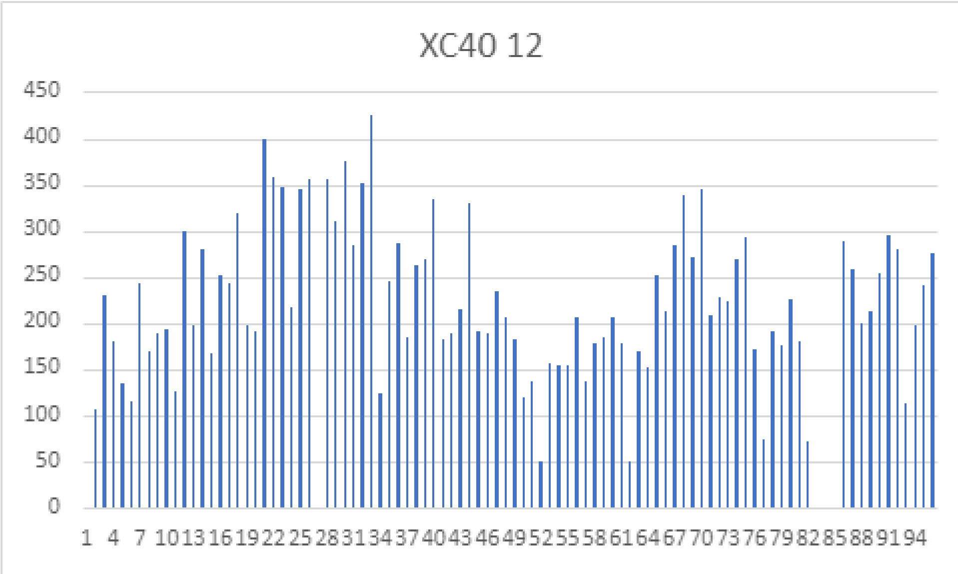
Attachment 1.12. State of Charge % by charging location (Lindholmen)



Attachment 1.13. State of Charge % by charging location (Medicinaregatan)



Attachment 1.14. Numbers of vehicles charging by week



Attachment 1.15. Energy delivered by week for the car that charges the most

Attachment 2

Interview guide for wireless charging taxi drivers

Introduction

Thank you for participating in our study on wireless charging for electric taxi fleets. Your insights are vital for understanding the challenges and preferences of taxi drivers using this technology.

This interview will cover your daily driving patterns, charging habits, and thoughts on wireless charging and electric taxis. All information will be kept confidential and anonymized.

We appreciate your time and participation. Please feel free to ask any questions during the interview.

Questions

1. Demographical description of wireless charging taxi drivers (Age, Gender, Housing Situation, Education)

2. What type of power source did your previous vehicle have?

3. How many kilometres do you typically drive per day?

4. How often do you use the wireless chargers?

5. Where do you usually charge – at home, at public stations, or somewhere else?

6. Do you prefer to charge overnight at home or at public stations?

7. Are you the owner of the taxi, or is it owned by the company?

8. Who bears the cost of operations – you as the driver or the taxi company?

9. Would you use wireless charging more if the power was higher? Would 75 kW be sufficient?

10. What is most important to you, the availability of charging stations, the speed of charging, or the cost of charging?

11. How do you balance these factors in your daily work?

12. How many times a day do you charge, how long, and at what speed?

13. What do you mostly use for fast charging (150 kW), slow charging (11 kW), or wireless charging (50 kW)? Why?

14. What do you prefer in terms of capacity for slow and fast charging? Please share your experiences with 11 kW, 50 kW, and 150 kW chargers.

15. Do you have access to home charging, and how does this affect your choice of charging locations during work?

16. Where in the city are the most convenient places to charge?

17. Where would additional charging stations be most beneficial for you?

18. How does the need to respond to customer demands in real-time affect your choice of different types of charging stations? For example, fast charging and slow charging, whether they are private or public?

19. Does your charging behaviour change between summer and winter or between good and bad weather conditions?

20. How do you feel about the cost of electricity at wireless chargers?

21. What do you think is an optimal charging time?

22. How important are environmental considerations in your choice of an electric vehicle over a traditional gasoline- or diesel-powered vehicle?

23. Can you compare your driving experience between an electric vehicle and a traditional vehicle?

24. How has your charging behaviour changed since the start of the project?

25. Do you think others feel the same way as you do? What do you think others think?

26. What have we missed with our questions?

Closing

Thank you for sharing your experiences and insights. Your input is very valuable to our research. If you have any additional thoughts or questions, please feel free to contact us.

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