THERE IS A NEW ROAD IN TOWN

AN EXPLORATIVE STUDY OF COMMERCIALIZATION OF ELECTRIC ROAD SYSTEMS IN URBAN ENVIRONMENTS

Oscar Jakobsson and Anton Lindström

LUNDS UNIVERSITET
Lunds Tekniska Högskola

Anton Lindström, Oscar Jakobsson
June 2021
MIOM05 Degree Project in Production Management
Division of Production Management
Lund University, Faculty of Engineering LTH

ABSTRACT

This master thesis explores the commercialization of electric road systems in urban environments, using a combined methods approach, in contrast to previous studies that have focused on long haul transportation. First, through interviews and document gathering, a stakeholder map was constructed, and the incentives of the identified stakeholders were analyzed. The thesis found disagreements between the stakeholders regarding the division of ownership and responsibility. Also, largescale cooperation between stakeholders was found to be crucial for large scale deployment. Second, using data from the interviews and insights from the stakeholder analysis, an interesting case was found. In collaboration with the Stockholm public transport authority, electrifying bus line 4 in Stockholm using Elonroad electric road systems was investigated. The case showed that switching from combustion engines to electric road systems would be financially viable as well as provide environmental benefits. In the case, buses in public transport are shown to be a promising pilot to test the electric road system and show that it can be profitable in practice. The case also illustrates how finding a suitable first user can enable commercializing of systemic innovation.

This master thesis was written under the guidance of the Division of Production Management at Lund University, Faculty of Engineering, and the electric road supplier Elonroad.

Keywords: Iterative research, Electric Road Systems, ERS, Electrification, Commercialization, Stakeholder analysis, Case study, Investment Decision, Investment modelling

PREFACE

This thesis marks the end of our five-year long journey at LTH to receive our M.Sc. in Industrial Engineering and Management, and with that our time in Lund. The thesis was conducted in collaboration with Elonroad, who helped with defining the problem, providing us with data, and guiding us throughout the project. The case study was done in collaboration with Elonroad and the Public Transport Administration at Region Stockholm.

While writing this thesis we have receive help and support from multiple different people that we would like to thank. First, we would like to express our gratitude towards our mentor Izabelle Bäckström at the Department of Production Management, who has supported and guided us throughout this entire process. Second, we would like to thank our mentor Karin Ebbinghaus at Elonroad, who has provided many valuable insights and further engaged us in the world of electric roads. Third, we would like to thank Malin Lindberg, Maria Övergaard, and Kenneth Domeij from the Public Transport Administration at Region Stockholm, who showed great interest and put a lot of time and effort into our case study.

Finally, we would like to thank all the experts from the different stakeholder groups that participated in our interview study. This thesis would not have been possible without your answers and insights - thank you!

Lund, May 2021

Oscar Jakobsson and Anton Lindström

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

List of tables

List of figures

1 INTRODUCTION

This chapter serves the purpose to introduce the subject and scope of the thesis. It introduces electric roads and Elonroad, as well as presents the research question, problem discussion and necessary delimitations.

1.1 Background

Electric vehicles (EVs) are becoming increasingly more relied on as a promise for a fossil-free future. However, high purchasing costs, limited battery range, and cumbersome charging has limited the adaptation, especially commercially (Bateman *et al.*, 2018). One emerging field, aspiring to give the electrification process of road transport an extra gear, is electric road systems (ERS). ERS allows electric vehicles to charge their batteries while driving, through the ERS charging infrastructure connected to the road. These emerging technologies have great potential to decrease dependence on fossil fuel, lower the emission of greenhouse gases & reduce pollution (RISE, no date). ERS theoretically enables infinite range and possibilities to drastically reduce battery sizes in EVs (Elonroad, no date).

Large scale deployment of ERS is a large undertaking that requires long-term collaboration between various stakeholders. For instance, ERS with dynamic charging introduces a new demand on the power grid and will create new load profiles, increasing grid demand (von Bonin *et al.*, 2020). Simultaneously, ERS systems can introduce a potential for battery-powered EVs to become energy storage units, providing demand-side management assistance to the power grid (von Bonin *et al.*, 2020; Elonroad, no date).

1.1.1 The Electric Road Industry

Currently, a few different players are researching and developing their electric roads business. Elonroad, Elways, Siemens, Alstom & Electreon are examples of companies developing different types of electric road systems, ranging from conductive to inductive charging and from overhead lines to solutions placed on top of the road (Alstom, 2017; Electreon, no date; Elways, no date; Siemens, no date).

The size and dynamics of the emerging electric road industry is so far unclear. No player has taken a dominant position and the potential market size is difficult to estimate due to the width of the applications and the number of competing technologies.

1.1.2 Elonroad

Elonroad is an ERS supplier founded by Dan Zethraeus. With great visions of how the future of infrastructure will look, Elonroad set out on a mission to create their own ERS which is using conductive charging. The solution consists of a charging module that is mounted underneath the vehicle and a rail that is mounted on top of the road. When driving over the rail the conductor is lowered down to the rail and the vehicle's batteries are charged. Elonroad conductive solution has high efficiency, exceeding 97%, and can handle an effect of up to 300kW (Elonroad, no date). The system also contains an advanced data link that collects and analyzes data. This enables multiple functions, such as detecting who is using the road and when, and the possibility of charging specific users for their usage. For safety, the road is powered in short segments, meaning that only the part that a vehicle is driving over is powered (Elonroad, no date).

The commercial side of Elonroad's business is in the development process. There is a need to analyze potential applications, markets, and business cases to define the next commercial step more concretely for their ERS. Elonroad wants to map the opportunities that best will take the company to the next stage where they can profit from their technology and scale up to eventually reach their vision, to electrify the entire transport sector and make fossil fuel a thing of the past.

So far, Elonroad has deployed their ERS in Lund, Sweden, as a pilot. Roughly, the next steps for Elonroad are to move on into serving closed-loop systems such as harbors and then taking on large-scale infrastructure projects such as cities and highways. There is currently no Swedish or European standard for ERSs, (Almestrand Linné, Sundström and Hjalmarson, 2020) and one of Elonroad's end goals is to become the standard.

1.2 Purpose

The purpose of this thesis is to examine how electric road systems could be commercialized in urban environments, focusing on Sweden. This purpose is twofold. First, it is to analyze the current stakeholder environment surrounding ERS, aiming to understand the different roles and intensions. Second, it is to study a case of potential commercialization of ERS in urban environments, to bring new insights and knowledge into the processes and decisions associated with the commercialization.

1.2.1 Research Questions

The main research question addressed in this thesis is: **How can ERS suppliers commercialize their products in an urban environment?**

The main question will be divided into 2 sub-questions:

RQ1: Who are the stakeholders, and what drives them, in the deployment of urban ERS?
RQ2: How should an ERS supplier construct their ERS offer, regarding whom to target and how?

This study intends to contribute to the specific field of ERS, as well as to the theory related to commercialization of systemic innovation, through the combination of the research questions. Answering RQ1 provides an integral screening for finding ways to answer RQ2, interlinking the two research questions.

1.3 Problem discussion

While looking for commercialization opportunities, Elonroad found urban areas to be an interesting market. Little to no research has yet been done on the usability and financial viability of ERS in urban areas and Elonroad wanted to further investigate the viability of deploying their technology to this market. Looking at ERS with a more general lens, the technology is in the phase of commercialization. There is no existing market, it is a complete innovation. This study is exploratory in nature as the problem at hand has not been studied very clearly.

On the topic of commercialization of systemic innovation, an umbrella which ERS belongs under, a gap in theory has been identified. In order to commercialize systemic innovation, theory suggests finding suitable business-cases is a way to start. However, there is a lack of examples of these types of cases and situations where systemic innovations have successfully been commercialized. One problem with finding this type of case is that commercialization of systemic innovation suffers from the chicken and egg dilemma. Multiple parties want to use the innovation, in this case the ERS, but not until it is widely available and used. This thesis intends to tackle this problem and contribute by helping to fill this gap.

1.4 Delimitations

Investigating commercialization of ERS in urban areas can be a very large exercise without delimitations. To reduce the problem, and keep the ultimate results feasible for Elonroad, this thesis will only focus on the Swedish market.

Another delimitation is that this thesis primarily focuses on the commercial side, not the technical. Technical aspects will be discussed, but it is assumed that the technology works as intended.

1.5 Target group

The primary target group is the management team at Elonroad, aiming to use this thesis as a compass moving forward into commercialization. The thesis also targets groups interested in the electrification of society, for instance the Public Transport Administration, the Energy Authority and other ERS suppliers.

1.6 Thesis outline

Chapter 1 Introduction

The introducing chapter includes the background, purpose, and scope of the thesis. The main research question is presented and divided into two sub-questions, RQ1 and RQ2. The chapter also discusses the problem at hand, as well as the delimitation of this thesis.

Chapter 2 Methodology

The second chapter presents the methodological framework used in this thesis, as well as the decisions made regarding research strategy, research design, data collection and data analysis. The chapter also illustrates the work process, and the trustworthiness is discussed.

Chapter 3 Theory

The chapter presents the theoretical and academic foundation that this thesis is built upon. The first section contains the topics of stakeholder theory and stakeholder mapping. The second part contains the area of commercialization in general and commercialization of systemic innovation specifically.

Chapter 4 Findings

The chapter presents the results that were gathered throughout the interview study and the literature review. The chapter presents the different stakeholder groups that were identified as well as the selection of stakeholder groups that were interviewed. The interviewees' opinions on the most discussed and relevant topics are also presented.

Chapter 5 Stakeholder analysis

This first analysis chapter analyses the information presented in chapter 4, Findings. First the stakeholders' incentives and ambition are analyzed and discussed, then the interdependence between the stakeholders is analyzed. Lastly the two most crucial questions, ownership and how the first business case could be designed are analyzed and discussed.

Chapter 6 Case study line 4

This chapter presents the background, process and results of the case study done on bus line 4 in Stockholm. The financial and environmental impact of the case are discussed.

Chapter 7 Commercialization analysis

This second analysis chapter analyzes the aspects of commercialization, using the answers from RQ1 and the case study to analyze and discuss primarily RQ2.

Chapter 8 Conclusions

This section concludes the thesis by summarizing the results as well as presenting more concise answers to the research questions. It also reflects upon the thesis in general and ends with suggestions about relevant further research.

2 METHODOLOGY

This chapter serves the purpose of presenting the methods used in the thesis. It introduces the strategy and design of the research, as well as the design and methodology of the data collection. Finally, it discusses the validity and academic quality of the thesis.

2.1 Research strategy

2.1.1 Qualitative vs. quantitative approach

There are many different approaches to data analysis that can be used in research. Denscombe (2014) states that in practice most options can be divided into either quantitative or qualitative research. This thesis is mainly of qualitative nature but has quantitative parts.

Bansal, Smith and Vaara (2018) state that qualitative studies deduce new knowledge that can lay the ground for new theory or new directions for existing theory. Qualitative studies use words and/or visual images as units of analysis (Denscombe, 2014). Qualitative research is often associated with data analysis during the data collection, whilst quantitative research is more associated with analyzing the data after collecting it (Denscombe, 2014).

Quantitative research primarily uses numbers as units of analysis (Denscombe, 2014). Quantitative research also tends to be associated with large-scale studies as the reliability greatly scales with the sample size, while qualitative research often includes a limited number of data sources and is often associated with small-scale studies, (Denscombe, 2014).

The study presented in this thesis is mainly qualitative in nature. It seeks to create understanding about the process of commercialization of ERS systems in urban environments. The market and the product are new, lacking sufficient numerical data and benchmarks, making qualitative study methods more feasible. However, a part of this study involved financial modelling of an investment decision, which is done quantitatively. This study is exploratory in nature as the problem at hand has not been studied very clearly. Data was analyzed throughout the gathering process, as well as after the collection was finished in an iterative manor.

2.1.2 Reasoning approach

Research strategy can also be described in terms of what reasoning principle is used. Two well-established principles are induction and deduction. Inductive reasoning evaluates or constructs arguments based on observations, moving from specific observation to general conclusion. Deductive reasoning evaluates or constructs arguments based on hypothesis, moving from general statements to specific conclusions (Gregory and Muntermann, 2011). Kovácks & Spens (2005) described inductive research as creating a theoretical framework based on empirical observation, while deductive research forms a hypothesis based on theory, which is later tested empirically.

There are also hybrid reasoning approaches. Abductive reasoning is a combination of inductive and deductive, commonly used in qualitative research settings (Starrin and Svensson, 1994; Gregory and Muntermann, 2011). Thompson (1956) started his paper by stating that "The unique contribution of science lies in its combination of deductive and inductive methods for the development of reliable knowledge", adding credibility to the high adoption of abductive reasoning. Thompson's paper is still relevant and used as reference, likely due to the old age and classical methods of the field. Abductive reasoning is based on finding the best explanation for given observations but is not necessarily deductively true. It involves iterative interaction between observations and ideas (Starrin and Svensson, 1994).

This study is of qualitative nature and abductive principles are prevalent. However, the RQ1 stakeholder analysis is constructed as a specific conclusion/application of general statements from the theory section, which could be described as a more deductive approach. Also, to maximize the academic contribution this study offers, generalizations have been formulated based on specific observation from the research into ERS, more inductive in its reasoning.

2.2 Research design

The research design used in this study is based on conducting semi-structured interviews, finding subjects through following a pre-set stakeholder model. However, the process was iterative, and the model was altered as more information and perspectives were gathered. In line with the standard proceedings of a qualitative approach, data was analyzed throughout the collection process, which called for alterations in the a priori knowledge-based stakeholder model.

The interview process provided data that was used to create a stakeholder map, as well as point out whom to initially target with an ERS offer. While conducting the data gathering through interviews, the need for a more in-depth analysis of a specific case for ERS use in urban environments became apparent. Following the abductive reasoning approach of this study described under 2.1.2, a prominent first customer was further analyzed, enabled by a collaboration with the organization in question. This helped answer RQ2 as well as added to the overall contribution of the thesis.

An insight found during the interview and stakeholder process was that it is difficult to analyze ownership from a top-down perspective. The initial approach taken was to discuss ownership in general during the interviews, which rendered answers that were difficult to either apply in a specific situation or generalize. It was deemed a better approach to have a more bottom-up approach, first finding a use case of interest and given the specific situation find the optimal owners.

Answering the first research question, the focus is on understanding the situation for ERS in general, not regarding Elonroad as a focal case-organization. However, answering the second question, a specific situation was studied, with Elonroad as the intended supplier of the ERS. A

Single-Case Design was chosen, testing the critical case of whether the ERS would be feasible for the most prominent user. Yin (2003) states that a Single-Case Design, studying one case instead of many, is rational when:

- The single case represents the *critical case* in testing a well-formulated theory,
- The single case represents an *extreme* or *unique* case,
- The single case is the *representative* or *typical* case,
- The single case is the *revelatory* case,
- The single case can be studied at two or more different points in time, *longitudinal.*

The case chosen can be considered *extreme* as well as *revelatory*, indicating that the single-case design is rational in this study. The case can be considered extreme because the route chosen is used by the same vehicles repeatedly in an extent that is difficult to find elsewhere, therefore it is extremely suitable for ERS deployment. Also, electrification using other methods is impractical due to space constraints. It is considered revelatory because if ERS is not feasible on the case route, it is hard to picture feasibility, considering only one user, anywhere else. The case will be introduced in 2.2.1.1 Case study settings and explained deeper under Chapter 6.

The intention of the case was to explore how an offer, from Elonroad, could be presented to the possible customer in detail, as total cost analysis and scenario-analysis are integral parts of investment decisions. It was also conducted to, in more detail, understand the dynamics in play when approaching a purchase/investment decision for the potential users of the technology. The next section will describe the concept of case studies as well as introduce the case studied in this thesis.

2.2.1 Case study

Case studies are common in several fields of research, and they can vary in size and definition. A case is a closed system with its own characteristics and specifications. The singular case often points towards a more general setting, the point of studying a case is often to highlight or study a more general phenomenon (Alvehus, 2019). Denscombe (2014) claims that studying cases is one of the most common methods to conduct small-scale research, often associated with mainly qualitative research, aiming to gain deeper understanding within a defined setting.

In this thesis, a case study was conducted to gain deeper understanding of how ERS can be commercialized. A significant contribution could be made by deep diving into the most prominent first commercial ERS application identified, and modelling the finances as well qualitatively discussing it. The case study aimed to assess the second research question: "How should an ERS supplier construct their ERS offer, regarding whom to target and how?". The case study specifically addresses the "how"-part of the question.

2.2.1.1 Case study settings

The case study chosen was the current decision on which types of buses should run on Public Transport Line 4 in Stockholm. The case was conducted in collaboration with Elonroad and the Transport Authority in Region Stockholm. The Transport Authority in Region Stockholm was chosen while investigating the first research question; finding and analyzing the stakeholders in the deployment of urban ERS. It became evident that public buses were the most prominent first users of ERS, a good place to start commercializing the technology. Line 4 was chosen in collaboration with the Transport Authority because the line currently has problems that ERS might solve as well as being of political interest due to popularity and visibility. The specifics of the case are discussed further under Chapter 6 Case Study Line 4.

As stated, case studies are analyzed in well-defined settings. Setting the boundaries for cases regarding ERS is difficult because there are very many different scenarios to consider. When financially modelling the consequences of putting ERS on a road, a parameter deeply affecting pay-back time is how much the system will be used. Ideally, a single owner/user/customer can use the system enough to make it financially feasible for them alone, without relying on other players using the road. However, when the ERS is in place it makes sense for the owner/user of the ERS to lease the road to other players, generating cashflow. This cashflow is hard to capture when conducting business cases for the first, singular, buyer/user since it requires cooperation from other players which makes things visionary/hypothetic. Therefore, it is important to clearly set the boundaries for which opportunities the quantitative financial analysis covers, and which ones it does not. The parts of a case situation not chosen to be quantitatively analyzed should be qualitatively discussed, to give a complete picture of the situation.

2.3 Data collection

Collecting data is important to create and develop knowledge about the problem formulated. Common ways to collect data are via interviews, observations, surveys and document gathering (Jacobsson and Skansholm, 2020). Since this study is mainly qualitative in nature, the data collection methods most fitting are interviews and document gathering via a literature review, which will be described further in this section. The following sections describes more about the methods used to collect data.

2.3.1 Literature review

A variety of different document types can be used to synthesize old and create new knowledge, for instance magazines, research papers and official documents (Jacobsson and Skansholm, 2020). In this study, this was done through a non-systematic literature review which will be described further down in this section. The literature review aims to provide a background of the theoretical concepts used in the analysis and to gather documents, one of the data collection methods described above.

The theoretical background was built on the literature review. In every academic report, essay, and thesis a theoretical background is required. Alvehus (2019) formulates that the idea of the theory section is to paint a picture of the current knowledge bank regarding the phenomenon the thesis will address, and to establish central terms and models/frameworks. He also states that the interpretation of the theory within the chosen field should be made clear and defined.
The theory section should be somewhat goal-oriented, focusing on what´s relevant for the problem at hand instead of addressing everything written on a subject (Alvehus, 2019). The

theory section should also be kept simple, at least not seek unnecessary complexity. Ekegren & Hinnfors (2006) state that simple and uncomplicated relations between thoughts and systems often is the key to success.

In preparing this thesis, a literature review was conducted to find general knowledge about stakeholder mapping and commercialization to understand the topics. In line with what Alvehus (2019) recommended, the literature review concentrated on the parts of the subjects more relevant to this study. The review was primarily based on information found via the databases LUBsearch, powered by EBSCO, and Google Scholar, as well as from public libraries in Sweden. All searches were documented using Google Spreadsheet.

2.3.2 Interviews

In this thesis, interviews were used as the main data collection method. Interviews is a common method for gathering data and can be used as the only method for collecting data or as a part of a combination approach (Jacobsson and Skansholm, 2020).

Denscombe (2014) divides interviews into three different categories, based on the structure. These are: Structured interviews, semi-structured interviews, and unstructured interviews. Structured interviews are heavily controlled by the interviewer and all interviewees are asked the same questions in the same order. The answer options are also limited by the interviewer which enables relatively easy analysis of the data. Semi-structured interviews also use the same questions for each interviewee but here the order of the question is flexible, and the interviewee is encouraged to develop ideas and speak widely on the questions asked (p. 175). Unstructured interviews are usually centered on the interviewees' thoughts, rather than on predetermined questions. The interviewer presents a theme or topic and then lets the interviewee discuss around it and present their views and ideas (Denscombe 2014, p. 175).

This study mostly followed a semi-structured format when conducting interviews. Alvehus (2019) states that in semi-structured interviews the respondents have a better chance to steer the interview/answers to what the respondents find most important. This can be beneficial when the study is more exploratory in nature.

2.3.2.1 Interview sampling strategy

When conducting interviews to collect qualitative data, devising a sample strategy to specify categories of people to be included in the sample is a must. The sampling can be random/convenience based or purposive. Purposive sampling strategies are non-random ways of making sure that certain categories within the given sample space are represented in the final sampling. Purposive sampling strategy is used when the researcher assumes that certain categories of individuals should be included in the sample, for instance based on important perspectives they hold. Purposive sampling is more common within qualitative research than random sampling strategies. (Devers and Frankel, 2000)
In this study, a purposive sampling strategy was followed. Other researchers have conducted stakeholder analysis of electric road systems in other settings, which can be used as a-priori-

knowledge base that allows a hypothetical categorization of stakeholder groups and thus categories to pick interviewees from. Based on research by Wang, Q., Berlin, D. and Meijer, S (2019) and by Tongur & Sundelin (2016) Table 2.1 was created.

This study pursued to find subjects covering all the different stakeholder groups. The sample size was based on the theory of information saturation, when no or little new information was to gain by further interviews no more interviews were booked. From the interviews it was evident that many shared the same general ideas, but each respective group brought different insights and perspective. Early on, two different subjects from the academia and authorities & government groups were interviewed, and the authors felt that the second interviews did not add much new data. Also, most stakeholders interviewed represented major stakeholders in their respective group and can be assumed to have a good overview of their whole stakeholder groups opinions and thoughts. Therefore, it was decided that one interview per stakeholder group was enough also considering the time each interview takes with planning, conducting, and transcribing. Note that for all but one interview, one individual was interviewed per interview. In total 14 persons from 12 different stakeholders were interviewed in this thesis and each interviewed lasted from 45 minutes to little over an hour. Apart from the formal interview process, continuous communication with Public Transport Administration and Elonroad was held.

One drawback with interviewing only one representative from each stakeholder from each stakeholder group is that the interviewee's personal and/or employers view on ERS may affect the results of the study. However, the stakeholders interviewed were all big players in their respective market and their opinion should reflect most of the market, thus limiting the risk of missing important insights.

Table 2.1. Identified stakeholder groups used to find and categorize interview subjectcs for interview study (adapted from (Wang, Berlin and Meijer, 2019))

Subsystem	Stakeholder group	Example stakeholder	Description
Operation	Operator	Elonroad	Operators of ERS, doing maintenance
Regulation	Authorities & Government	Region Stockholm Energimyndigheten Transportstyrelsen Trafikverket	Local and national authorities that for instance can ban or allow ERS
Energy	Electricity supplier Grid operator/owner	E.ON C.S. Skellefteå kraft Kraftringen Ellevio Svenska Kraftnät E.ON	Companies and organizations producing, transporting, and selling electricity.
Technology	ERS supplier	Elonroad Elways	The entities that develop and construct ERS
	Vehicle supplier	Scania Volvo Tesla	Responsible for adapting the vehicles to use the ERS system
Infrastructure	Road owners	Trafikverket Municipalities	Owners and operators of roads, where ERS can be placed.
	Road constructors	Svevia Skanska NCC	Those who construct new roads and adapt old ones
End-users	Users	Taxi companies Truck-haulers Private users (long term)	The users of electric roads
Environment	The local and global health of the planet	City air-quality GHG emissions	Seeing the environment as a stakeholder of its own
Society/City	Researchers	KTH, LTH CTH etc.	Provide a foundation for further research.
	Citizens	Concerned Citizens	Electrification provides the ability to conduct "silent" transportation

Table 2.1 was used to categorize and find interview subjects initially. The identified stakeholder groups were modified during the interview process. For instance, users were divided into public transport and transporters of goods since they operated differently and had differing demands.

2.3.3 Collaboration with case subjects

Data was also collected to enable a specific case study. As described under 2.2.1, a case study has been conducted in collaboration with the authority the Public Transport Administration in Region Stockholm, and Elonroad. The Public Transport Administration provided several reports and investigations, as well as answered questions during interviews.

Singular data points/pieces of information were received via email from Elonroad, the Public Transport Administration and a Bus operator, primarily between Mars and May 2021. The email conversations with the Public Transport Administration included the following representatives from the Public Transport Administration:

- Requirements Specialist Bus Depot and Terminal,
- Specialist Bus and Depot,
- Vehicle Strategist Buses, Strategic Development,
- Project Manager, Strategic Development.

The email conversations with Elonroad included the roles:

- CEO,
- Chief Innovation Officer.

The conversations with the bus operator include the roles:

- Purchaser
- Maintenance manager

Some information was provided by the bus operator Keolis via one phone call in April 2021. Additionally, Elonroad provided an Excel Model which was used to calculate the amount of ERS needed, the document is not included in this thesis due to confidentiality. The trustworthiness and validity of the information provided is discussed under 2.6 Trustworthiness.

2.4 Data analysis

The analysis is a central part of any thesis. Here, the theoretical framework meets the empirical material, together exploring, and solving problems, as well as pointing to conclusions (Alvehus, 2019). This study was mainly qualitative, but with quantitative elements in the case-section. Given the novelty of the field and the nature of the research question, a natural consequence was that most of the data gathered was of a qualitative nature. The process used to analyze qualitative data is presented below.

2.4.1 Qualitative data analysis

Simplified, it can be said that qualitative data requires qualitative analysis methods. When analyzing qualitative data, the classification of answers often is subject to interpretation. Answers can fit into several categories for instance. In order to make interpretations more trustworthy, it is beneficial that two or more people make independent analysis of the qualitative information and discuss in which categories the information can be placed. (Nyberg and Tidström, 2012) In this study, the two authors have adhered to this by discussing the information and classifications thoroughly.

When conducting the qualitative analysis, the process presented by (Brinkmann and Kvale, 2015) was used in this thesis: coding, condensation and interpretation. The initial literature review of the existing literature on the topic of commercialization of ERS and stakeholder analysis was used to create a priori categories. These categories were used to create the interview guide for the empirical study. Then, working iteratively between data collection and theory throughout the interview process, important areas that the literature review had missed but interview subjects emphasized were added to this list of themes. It became evident which themes were important and less important, making it natural to iteratively alter the a priori-based first theme formulation.

The results from the interviews where ultimately coded, using the themes as buckets, to simplify comparison. Following the coding process, the condensing phase began. During the condensing phase, the transcribed data from the interviews were read, searching for agreements and disagreements between the different stakeholders, aiming to understand different standpoints. Finally, the data was interpreted and discussed, with the aim of steering the discussion in a way that results in a contribution to the field. The next section describes the process of analyzing the quantitative data.

2.4.2 Quantitative data analysis

Quantitative data, consisting of numbers, are often analyzed using statistical methods. During this study, the quantitative analysis process was limited due to lack of existing data, as the field is new and benchmarks etc. are lacking. However, data was provided by Elonroad and the case subject the Public Transport Administration, which sufficed for analyzing an investment decision. The quantitative analysis that was conducted did not analyze a sample population using statistical methods, it highlighted a specific situation aiming to provide deeper insight into it. The program Microsoft Excel was chosen as it allows for visually intuitive financial modelling as well as sensitivity analysis.

2.5 The process of the thesis

To put the different parts of the thesis together, and highlight the sequence the process followed, an overview of the work is presented in Figure 2.1.

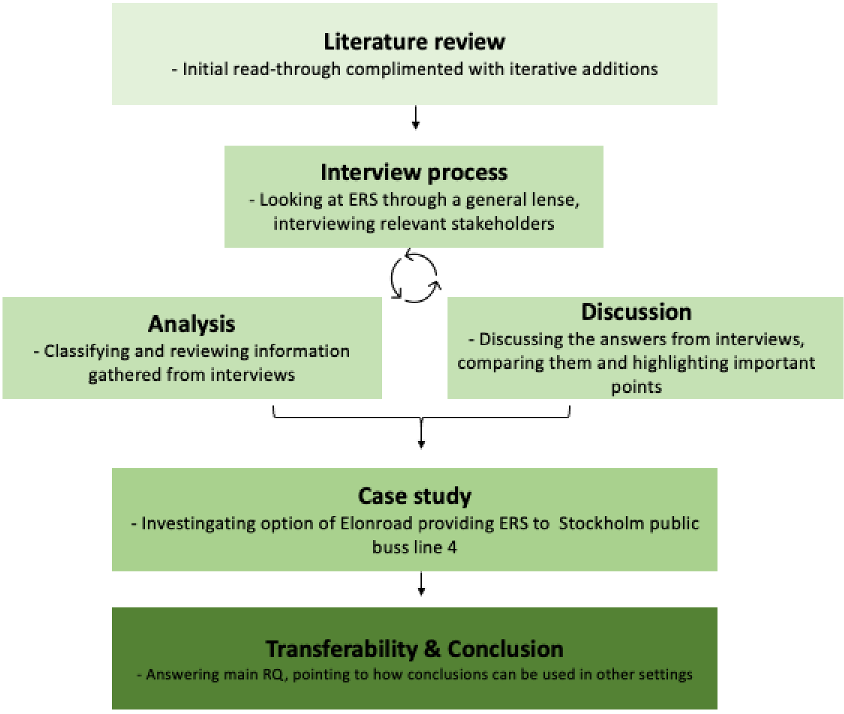

Figure 2.1. Illustration of the work process (Personal Collection)

2.6 Trustworthiness

To assess the quality of research, one must assess the trustworthiness of the work. Conventionally there have been four bases for judging the quality of research: validity, reliability, generalizability, and objectivity (Denscombe, 2014). Denscombe (2014) states that these criteria are not easily used on qualitative research since they were created with quantitative research in mind. He instead presents adjustments to each base of judgement to better fit the review of qualitative research. These are presented below with the old category in parentheses:

- Credibility (validity)
  - The reassurance that the qualitative data has been produced and checked in accord with good practice.
- Dependability (reliability)
  - To what extent could another researcher come up with comparable findings, if given the same information?
- Transferability (generalizability)
  - To what extent could the findings be transferred to other comparable instances?
- Confirmability (objectivity)
  - Qualitative data is never completely unbiased as it has been created through the researchers' interpretations of the data. Whether or not the researcher has tried to reduce their influence and/or has been transparent with his or her biases.

For credibility, the literature review has used peer-reviewed papers and articles, as well as published books. To verify the data, triangulation between the interviews and the literature review was used to increase credibility and validity of the data.

For the case study the data used was firsthand data, given from the respective parties upfront, as described under 2.3.3. the Public Transport Administration and Keolis had no apparent reason to be biased and provide untrustworthy data. They investigate several options on how to increase the performance and lower the environmental impact of the public transport, reasonably without preferring any specific solution going into the investigation process. Also, the reports provided were scrutinized by several parties, including outside consultancy, which can reduce the chance of false statements and data.

The data provided by Elonroad has the potential to be more biased, given that the company sells ERS and of course wants to push for their solutions. Also, the products are not tested as thoroughly as many other already widely used products such as electric buses, making datapoints concerning for example service life a bit more speculative. However, if Elonroad were to sell their systems to the Public Transport Administration it would be after a public procurement process where contracts are agreed upon based on said performance. This makes is more unlikely that Elonroad, or other ERS providers, would present biased data to a public body.

In this thesis, the opinions of the stakeholder groups are generalized to fit all stakeholders within each group, even though, in most cases only one stakeholder from each stakeholder group were interviewed. As presented under 2.3.2.1, it was deemed that this was enough since the stakeholders interviewed are all big players in their respective stakeholder groups.

For dependability it is important that the researchers show the procedures and decisions that have been used/made so that other researchers can evaluate the works dependability (Denscombe, 2014). The procedures and work process of this thesis are outlined and presented in chapter two, where also research approach and choice of methodology is discussed. The interviews that have been held has been transcribed and documented for the purpose of auditing. The authors believe that the information provided in the thesis should be enough for another researcher to judge the thesis on dependability.

Transferability requires the authors to supply relevant information about the research for other researchers to base a comparison on (Denscombe, 2014). In this thesis the interview subjects and their employers are, in general, anonymized but their occupational title and/or background is presented in A.3. In the case on Region Stockholm all numbers and calculations used are presented so that another researcher should be able to apply the model to other road sections of ERS.

To gain confirmability of the thesis, the authors should be transparent with their biases (Denscombe, 2014). The broad topic of ERS in urban environments was suggested to the authors by Elonroad as they were the corporate mentor of the thesis. The topic was then narrowed down to commercialization of ERS in urban environment through discussions with mentors at division of production management at LTH. So even though all available technological solutions have been considered throughout the research process, Elonroad and their solution has been close at hand and was therefore used as the suppliers of ground bound, conductive ERS in the Region Stockholm case study.

3 THEORY

This chapter addresses questions related to stakeholder analysis and commercialization; concepts required to answer the research questions. The first part of this chapter describes stakeholder theory and the second describes commercialization and commercialization theory.

3.1 Stakeholder theory

Two tools for understanding the landscape of a product or company are Stakeholder mapping and analysis. These tools stem from the broader concept of stakeholder theory.

Stakeholder theory was first introduced as an alternative to previous models which either had a more simplistic view of the responsibilities of a manager (i.e. managing only employees, suppliers, and customers), or which said that the only reason for firms to exist was to make profits and serve the shareholders (Jones, Wicks and Freeman, 2017). To properly understand stakeholder theory, one must first understand the term "stakeholder". "Stakeholders" are described by Eric Freeman (2010) as "*... groups and individuals that can affect, or are affected by, the accomplishment of organizational purpose.*". There are many different definitions of the term but this description is one of the most frequently used in stakeholder theory (Miles, 2017). This definition covers both internal and external parties of interest.

Stakeholder theory can be seen as an umbrella term for primarily three different research tracks: Instrumental, descriptive, and normative stakeholder theory (Freeman, 2015). Instrumental stakeholder theory primarily focuses on the hypothesis that companies that practice stakeholder management will be more successful than equal competitors who are not. Descriptive stakeholder theory tries to map the company's stakeholders and describe the different connections that exist between the stakeholders and how the stakeholders and company actually act. Normative stakeholder theory describes how managers should act with different stakeholders (Freeman, 2015). This thesis will mostly touch on the descriptive path since the thesis will use stakeholder mapping as a tool to understand the potential commercialization strategies of ERS.

3.1.1 Stakeholder mapping

The ideal starting point for creating a stakeholder map is a historical analysis of the environment of the firm in question. If that kind of historical documentation does not exist, one can instead use a generic stakeholder map as a reference point (Freeman, 2010). In Freemans (2010) generic stakeholder map he includes the following actors: governments, local community organizations, owners, consumer advocates, customers, competitors, media, employees, special interest groups, environmentalists, and suppliers. This paper aims to create its own stakeholder map which substitutes the Firm with ERS as the center of the map to answer RQ1.

After the creation of a stakeholder map with the purpose to identify the different stakeholders, one can use other mapping techniques to gain an understanding of a stakeholder's influence. One way of doing this is using a tool called the Power interest matrix (Johnson, Scholes and Whittington, 2008). This matrix divides the stakeholders of a firm into four different sections based on two factors, the level of interest each stakeholder has in a specific strategy and how much power they possess to impose their interests on said strategy. Depending on which group the stakeholder is placed in, a different engagement strategy is proposed. The four groups and their corresponding, general, engagement strategies are:

- High power, high interest
  - Key players.
- High power, low interest
  - Keep satisfied.
- Low power, high interest
  - Keep informed.
- Low power, low interest
  - Minimal effort

It should be noted that the exact strategy of how to handle the stakeholders in each quadrant changes depending on the existing strategies of the company and the decision at hand. (Johnson, Scholes and Whittington, 2008)

When the environment of the product/innovation has been understood from the stakeholder point of view, a next step is to decide how to introduce the product/innovation to the market. This process is further described under "Commercialization Theory".

3.2 Commercialization theory

The topic of commercialization is a key part of this report's research question. In this section, the concept of commercialization and its relevance is first introduced. Following that, suggestions on different methods to execute commercialization are presented. Then, frameworks created to increase chances to succeed with chosen ways to commercialize are presented, seeking to provide insight in what is important when commercializing different products. Last, the literature about commercializing systemic innovation is presented.

Going forward, commercialization of innovation can be defined as the activities required for introducing an innovation to the market, coined by Datta, Reed & Jessup (2013).

This theory section, and this study's subsequent analysis, extends the knowledge and understanding of commercialization of innovation. According to Datta et. al (2013), the field is under-researched and therefore not as well understood as other aspects of innovation. They believe the reasons for this is that researching commercialization of innovation requires expertise in multiple disciplines, and that research often focuses on specific aspects of the process instead of identifying common themes. This highlights the importance of generalizing the findings in this thesis, to contribute to filling the identified gap in theory.

3.2.1 Introduction to commercialization

Innovation can be seen as the lifeblood of organizations, and within a corporate setting, the outcome of innovation is manifested as commercialized products (Schendel and Hitt, 2007). Activities surrounding commercialization of innovations often start with idea generation and end in product launch (Datta, Reed and Jessup, 2013). The ability to commercialize technological innovation can be defined as a firm's capacity to bring innovation to market and reach some of the mainstream (Datta, Mukherjee and Jessup, 2014). However, succeeding in the process of commercialization is far from guaranteed, estimates suggest that only one of every 3000 new-innovation ideas is commercialized into a successful product (Datta, Reed and Jessup, 2013). In 1991, out of 16000 new products almost 90% failed to meet their business objectives (Balachandra and Friar, 1997).

Businesses rise and fall based on whether they discipline their commercialization efforts (Nevens, Summe and Uttal, 1990). Nevertheless, companies are pressured to pursue commercialization of innovation, driven by globalization (Datta, Reed and Jessup, 2013). For the dramatically increasing number of small start-up firms developing technology with significant potential commercial application, the main problem is the process of commercialization rather than invention (Gans and Stern, 2003).

3.2.2 Commercialization methods

There are many possible ways to commercialize and lenses to look through, for instance concerning via what type of organization the innovation will be launched and where in the value-chain it will be active.

The choice of technology commercialization method and strategy is increasingly relevant for technology-based new ventures, led by advances in business process outsourcing and open innovation practices (Symeonidou, Bruneel and Autio, 2017).

Looking at commercialization from an organizational standpoint, Aslani, Eftekhari & Hamidi (2015) summarized what they defined as the available commercialization methods:

- Licensing,
- Strategic Alliances,
- Joint Venture,
- Development of new companies based on university technologies (Spin-off),
- Exhibitions,
- Joint research contracts (projects),
- Offering consultative Services,
- Technology transfer and innovation networks,
- Venture capital (VC)

Different methods are useful in different industries, depending on the nature and complexity of the industry (Aslani *et al.*, 2015). Datta et al. (2013) highlights that the capabilities the innovator has should impact the choice of commercialization method. However, VC backed commercialization efforts results to a larger extent in initial public offerings (IPOs), which indicates that being backed by a VC is beneficial (Hsu, 2004, p. 2). For the specific method chosen, Markman, Siegel & Wright (2008) developed a taxonomy showing organizational requirements for the given method, created from an ecosystem view.

The commercialization method can also be described in more general actions. When choosing commercialization method, Ceccagnoli & Rothaermel (2016) state that the innovator has three strategic options:

1. Develop and commercialize the innovation itself, if necessary, through forward vertical integration,
2. Develop and commercialize the innovation jointly with a partner through strategic alliances of a joint venture,
3. License the innovation to other company/companies and let them develop and market the innovation in exchange for royalties.

The optimal strategy to pursue depends on the availability and type of complementary assets, the height of imitation barriers & the number of capable competitors (Ceccagnoli and Rothaermel, 2016).

3.2.3 Commercialization frameworks

When looking to commercialize, there exist several frameworks that describe what is important to keep in mind to maximize chances of commercial success. The frameworks described are more general and abstract than the concrete methods described above.

A bedrock in the field of commercialization and startups is the book Crossing the Chasm, originally written in 1991 but revised in 2014, where Geoffrey A. Moore explores the topic of marketing high tech products for companies in the startup phase. Using the terms coined in the technology adoption lifecycle (Beal and Bohlen, 1956), the "Chasm" is the step between early adopters and early majority. Moore discusses several aspects of marketing disruptive innovation. He highlights the importance of establishing a "beachhead" market to grow from, a stronghold where customers relate and talk to each other, to cross the chasm. Another relevant phenomenon is the innovator's dilemma, presented by Christensen (1997) in the book "The innovator's dilemma". It refers to the decision that business must make between catering to their customers' current needs or adopting new technologies and innovations which will answer the customers future needs. Slater & Mohr (2006) agrees that innovators must cross the chasm, but also overcome the innovator's dilemma. The issue of the innovator's dilemma is relevant in this thesis as the subject innovation, ERS, is a new technology that businesses can choose to adopt to cater to possible future needs.

Another important concept in the space of commercialization in high tech markets is customer acceptance. Customer acceptance is key when for instance aiming to establish a beachhead market. Chiesa & Frattini (2011) constructed a framework that concludes that the commercialization of an innovation can influence customer acceptance in two main ways:

1. Affecting the extent to which the players of the innovation's adoption network provide support to the new products.
2. Affecting the attitude that early adopters develop towards the innovation after purchase and usage, thus affecting the word-of-mouth they spread to later adopters.

3.2.4 Commercialization of systemic innovation

Since this study investigates ERS, commercialization theory related to innovations with similar characteristics is of extra interest. This group of innovation can be categorized as systemic innovations.

Systemic innovation can be defined in several ways, but the one chosen is one of several definitions presented by (Midgley and Lindhult, 2017). They state that an innovation can be defined as systemic when its purpose is to change the fundamental nature of society, for instance to deliver on major transitions concerning ecological sustainability. This definition is prevalent in relevant literature about commercialization. ERS falls under the definition of systemic innovation, according to Tongur (2018).

Innovation can be defined as systemic and radical, having both radical and systemic elements such as the innovation of hydrogen cars (Partanen, Chetty and Rajala, 2014). When commercializing this type of innovation, Partanen et al. (2014) emphasize the importance of the surrounding network and strategies concerning partners. They conclude that to successfully commercialize radical/systemic innovation, strong ties with customer partnerships and at least some ties with complementary suppliers are probably required to overcome the liabilities associated with being a small and new enterprise. The importance of the network surrounding actors pursuing commercialization of systemic innovation is strengthened by Chiesa & Frattini (2011). They claim that lack of support is a critical reason for failure. Also, they state that a negative attitude of early adopters is especially dangerous for radical innovations.

Zooming in on commercialization of systemic innovation within sustainable technology, the challenge is to find suitable business cases in which the new technology can fulfill user demands, from both financial and environmental points of view (Loorbach and Wijsman, 2013). Tongur (2018) adds that to commercialize sustainable infrastructure technologies, such as ERS, studies tend to neglect the importance of socio-technical change, for example investments in alternative infrastructure.

Tongur (2018) concludes that for systemic innovations, commercialization suffers from the chicken-and-egg dilemma because of its dependence on investments and long time-horizons. He also states that when commercializing systemic innovations, focus should be both on the long-term investment horizon and offering but also on alternative products with shorter investment horizons. This highlights the importance of finding suitable business cases early in the commercialization journey.

3.2.5 Example of commercialization of systemic innovation

The emergence of EVs on the road and charging-station networks, spearheaded by Tesla, is an example of what can be considered successful commercialization of systemic innovation. This case is used to strengthen the relevance of presented theory as well as deepen it. A way to check the relevance of the theory presented is to apply it on a similar problem, to see if the frameworks are useful and applicable.

Maine & Thomas (2019) conducted an in-depth analysis of how Tesla entered and disrupted the automotive market, succeeding in an industry where hardly any start-ups survive. The authors found that Tesla did not follow a Disruptive Innovation strategy, a term defined by Bower & Christensen (1995) to describe innovations that create new value networks and markets and eventually disrupt current markets. Tesla chose to target high prestige & high margin markets with their new technology and business model. A disruptive innovation is an innovation that creates a new market and customer value network, eventually displacing established market leaders.

Instead, Tesla followed the attacker's advantage strategy (Thomas and Maine, 2019), described in the framework presented by Gans & Stern (2003). It is based on the notion that Tesla's innovation cannot preclude effective development by the incumbents, and incumbents' complementary assets cannot block the value proposition for the new technology. An innovator positioned like Tesla should enter the product market by establishing technological leadership, investing in complementary assets and entering niche markets (Gans and Stern, 2003). Tesla did just this and managed to capitalize on the advantage they got from entering the market with a novel value proposition, forcing the competitors to face the challenges of architectural innovation (Thomas and Maine, 2019). Also, they conclude that this strategy could be used by other alternative energy start-ups, which is an important insight for the emerging ERS industry.

Studies have been made to apply the insights from the Tesla case on the commercialization of fuel cell vehicles. Hardman, Shiu & Steinberger-Wilckens (2014) identify that Tesla's market entry method follows new market high-end encroachment, selling only to new customers in new markets, since there was no market for battery powered electric sport vehicles pre-Tesla. However, they also identify that Tesla's product can be seen as following a new attribute strategy, rather than a new market one. The authors state that the Tesla-case is highly relevant for companies attempting to commercialize fuel cell vehicles, showing the viability of targeting high-end markets directly. The authors also state the importance of a roll out of hydrogen-refueling networks, inspired by Tesla's investment into their battery recharging stations. Overall, the models presented in this theory section is applicable and relevant to the Tesla case, and thus likely useful for other analysis of commercialization of systemic innovation. However, ERS is a very different product from luxury electric cars, ERS end-customers are likely not targeted in the same way, meaning some frameworks will be used differently.

4 FINDINGS

This chapter presents views and opinions expressed during the interview process. The information gathered is intended to provide data to answer ***RQ1*** *as well as parts of* ***RQ2****.*

4.1 Stakeholder map

As discussed in 2.3, themes of interest were created through literature review and then iteratively throughout the interview process. These themes were then concretized into categories. The stakeholder groups are briefly introduced under 4.1. The thoughts and opinions of the stakeholder groups on each category were then summarized in Table 4.1. In the sections following the table, the stakeholder groups' opinions are further presented, divided into the same categories as the table.

Since ERS was put in the center of the stakeholder map instead of the firm, the map does not have the all the same actors as a general stakeholder map. ERS, being a big infrastructure system, affects many different parties throughout its deployment and has been found to have a quite different stakeholder map compared to your typical company. The map in Figure 4.1 presents

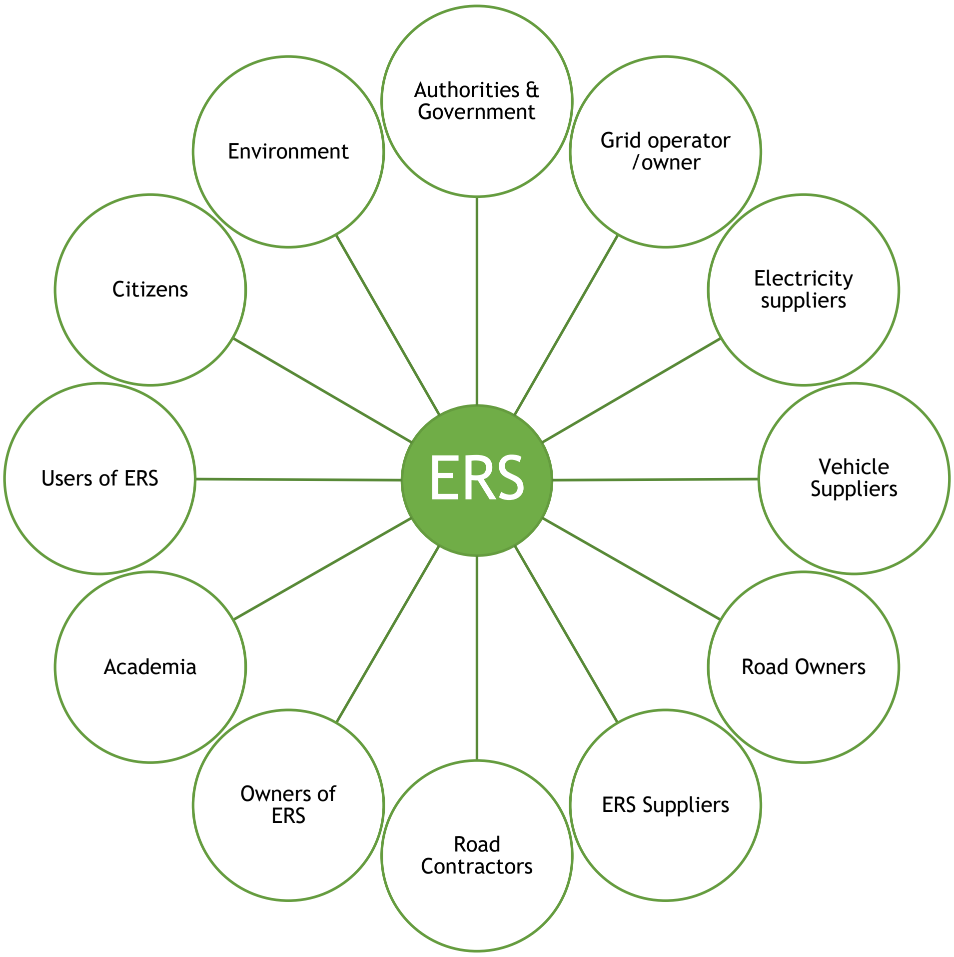

Figure 4.1. Map of identified stakeholders for ERS (Personal Collection)

general groups of stakeholders that were identified during the literature review and during the interviews. This general map was adjusted in order to fit better with the Swedish ERS stakeholder environment. The final map used is shown in Figure 4.2.

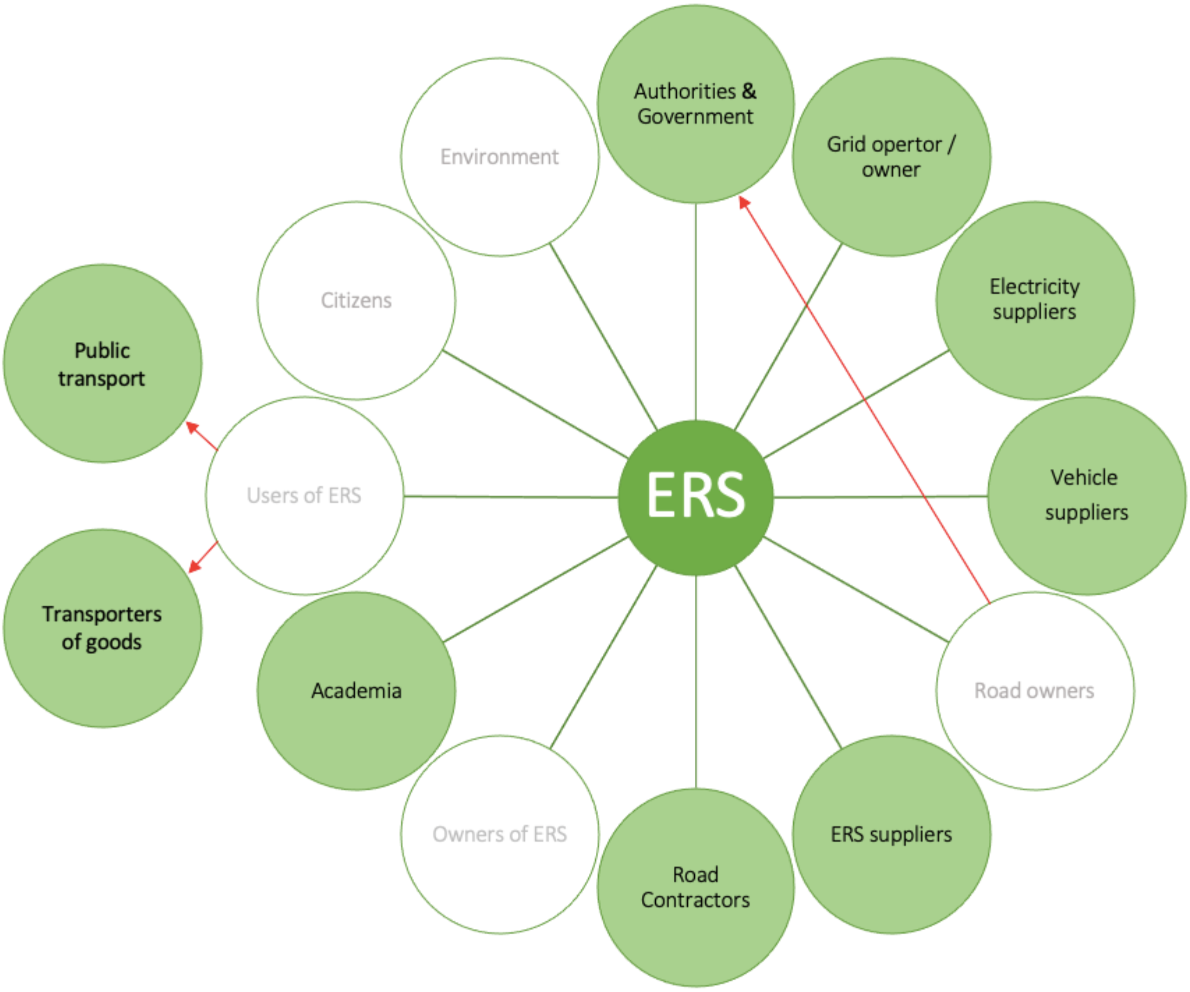

Figure 4.2. Map of identified stakeholders for ERS, adapted to the Swedish urban market. Green groups were interviewed in the interview study. Red arrows represent merger or splitting of groups. (Personal collection)

4.1.1 Stakeholder groups for interviews

This section presents and defines the stakeholder groups that were interviewed. The stakeholders were identified through literature review or through previous interviews. Theses stakeholders are not the same as the ones in Figure 4.1 as the stakeholders for the interviews are more focused on the Swedish market. In Sweden, the road owners are the cities and state, therefore the road owners are included in the Authorities & Government group. Users are divided into the most prominent users, Transporters of goods and Public transport. Taxi and garbage collector companies are not included in the interview study, this due to time constraints and difficulties in finding interested interviewees with sufficient knowledge about the topics. Also, capital owners such as infrastructure funds that potentially could be owners are not interviewed. However, this stakeholder group was discussed with a management consulting partner with experience of working with these types of companies.

4.1.2 Authorities & Government

Swedish governmental, regional, or municipal agencies.

4.1.3 Electricity suppliers

Companies whose business involves providing electricity to the customer, through a service or per kWh, without concession.

4.1.4 Grid operator/owner

Companies that have been assigned concession by the authorities to own and operate parts of the Swedish electricity grid. This group is separated from the electricity suppliers' group since companies with concession are heavily regulated and cannot sell electricity themselves.

4.1.5 ERS suppliers

Companies that supply the technology behind ERS.

4.1.6 Vehicle suppliers

Companies that supply vehicles.

4.1.7 Road contractors

Companies that build and maintain public roads in Sweden.

4.1.8 Transporters of goods

Companies whose main operation is the pickup and delivery of goods.

4.1.9 Public transport

Companies that are responsible for the local and regional public transportation, such as bus, train, and tram operators.

4.1.10 Academia

Experts on ERS from Swedish universities and research institutes

Table 4.1. Summary of interviewees' responses to interview questions categorized after common areas of discussion.

Stakeholder / Category	Authorities & Government	Electricity supplier	Grid operator/owner	ERS Supplier	Vehicle Supplier	Road constructor	Transporter of goods	Public transport	Academia
Beach head market	Public transport (buses)	Public transport (buses), transporter of goods	Municipally owned businesses e.g., buses & garbage collectors	Public transport, taxi & food delivery	Public transport (buses) & garbage collector	Public transport (buses), taxis and industries		Public transport (buses)	Public transport (buses), taxi and distributors
Owner of infrastructure	ERS suppliers, Contractors	Electricity supplier	Grid owner if government ban is lifted	ERS supplier, Electricity supplier, infrastructure fund	Government must invest	Energy company (Vattenfall, E.on)	State / local government	State, municipality & region Public transport	Public transport (buses), taxi and distributors
Biggest barrier	Large scale stakeholder cooperation	Large scale stakeholder cooperation Early stage; politic, grid owners, Later stage: Finding users	Buyer of the ERS, battery development	Getting up the number of users	Economic feasibility	Lacking legal support/ structure	Economic feasibility	Lack of overarching authority.	No players acting as operators/maintainers
Important partnerships		Vehicle manufacturer and ERS supplier, Cooperation with all stakeholders with one central investor in ERS	Investor and ERS suppliers	Electricity suppliers, vehicle manufacturers and brand owners	All actors must work together	State and operator			Municipalities
Important stakeholders	Vehicle suppliers, road operator & grid owner	Grid owner, user	Grid owner, contractor, Owner, CPO, System integrator	Municipalities, electricity suppliers, grid owners, transporters & brand owners	Municipalities & Government, user	State and end users	Receiver of goods, haulers	Citizens, operators	Truck operators, ERS operator/builder
Perceived value adds	Lower investment, battery size	Useful when stationary charging is not a viable solution. Increased uptime.	Higher uptime	Higher uptime, reduced battery size, information flow and gathering	Reduced battery size	Smaller batteries	No urban upsides (only interested in long haul)	Weight and space constraint	No need to stand still, Enable autonomous vehicles
Main order qualifier	Responsibility and accountability from ERS operator	Feasible business case and long-term commitment from customers.		Being able to save time, money and resources compared to alternative solutions	EU-wide standard and agreement	Legal development	Cheaper than stationary charging & standardized solution	Possibility to even do it	

4.2 Findings from interview study

In this section the interviewees response to the questions asked are presented, category wise.

4.2.1 Beachhead market

The concept of finding a beachhead market can, as discussed in section 3.2.3, be an important first step in commercialization of innovation, which became apparent during the interviews as several stakeholders emphasized the importance of finding that first market.

Several interviewees discussed the importance of finding a player that can purchase and profitably use ERS by itself, becoming a reference case and a point to build the road-network from. As described under 3.2.3, Tongur (2018) stated that systemic innovations suffer from the chicken-and-egg dilemma because of its dependence on investment and long time-horizons. Finding a first customer that can benefit from ERS without having to rely on other players also signing up to use the road was brought up as a solution to the chicken-and-egg dilemma.

A general view shared by all stakeholder groups is that public transport bus companies, such as SL (Stockholms Lokaltrafik), owned by Region Stockholm, would be ideal first customers. Even the public transport group agreed with this. Arguments include the fact that the buses run on fixed routes according to a schedule, making it possible to find exactly where electric roads should be placed. The extensive knowledge of where and how buses move enables calculating the potential return on investing in ERS. It also enables calculations on how much the ERS would be used by the bus company alone, which can be used to calculate a business case.

Several other factors indicating that bus companies could benefit from electric roads were presented during the interviews. For instance, electric buses carrying all the power they intend to use in a shift in an on-board battery must return to terminal stations to charge, forcing them to leave their routes and stay idle for an extended period, resulting in the bus companies needing more buses to serve the same number of customers. Also, it costs the drivers unnecessary time to have to drive to and from the terminals.

Another interesting market discussed by interviewees representing vehicle manufacturers & electric grid operators/owners were garbage collectors. The arguments for why these would benefit from electric roads and serve as a potential first market are similar to those of the bus companies. The garbage trucks move on set routes, on set schedules and need to move to and from garbage stations often during the same shift. Again, this repeated movement is ideal for electric roads. The ERS provider group also mentioned players that for instance deliver groceries per subscription, a group with similar characteristics to the garbage collectors.

Road constructors and vehicle manufacturers discussed industrial applications of the ERS. Industrial transportation often follows fixed routes, for instance within a harbor or around an industry plant. For example, goods move to and from the harbor in Gothenburg excessively.

However, many industrial applications discussed are outside the scope of urban environments, thus excluded.

A final market that was frequently mentioned during interviews, primarily by academia and road constructors, is the taxi market. Taxi companies are increasingly moving over to battery electric vehicles, for instance Taxi Stockholm uses Tesla cars excessively, due to higher lifetime ROI than from using combustion engine vehicles. This has led to great queues on charging stations around for example Stockholm and Arlanda airport, constituting a time waste and thus lost revenue for the drivers. Interviewees brought up that taxis spend a lot of time on certain routes, for instance between the city of Stockholm and Arlanda Airport, indicating that electric roads on these roads could be beneficial enough to make taxi companies attractive beachhead markets.

Note that none of the stakeholder groups mentioned personal vehicles as viable first users. The consensus was that for personal vehicles to become a viable customer the ERS first had to be deployed nationwide and another sector needs to lay the groundwork.

4.2.2 Owner of infrastructure

Investing in an ERS requires a lot of capital and the return on investment depends on how much the ERS is used. This combined with the fact that the electric charging market is a market with rapid technology development presents the owner of the ERS with great risk (Natanaelsson *et al.*, 2021). Judging from the interviews, only a handful of the stakeholders are willing to carry this type of risk and instead believe that someone else would be a good potential owner and risk taker. For example, both distributor of goods and vehicle supplier groups believe that it is the state or local government that would/should own the ERS. When asked, the general opinion of the authorities and government group is that the suppliers of the ERS technology, or the contractors that build and maintain the current road system would be better suited as owners. The governing body that was interviewed also stated that its unwillingness to invest was partially due to the current, right-wing leadership being less inclined to make big investments. They also stated that if the rule would shift to a more left-winged leadership then the chance of investing would possibly be higher.

Four stakeholder groups expressed interest in owning the infrastructure. The first one being grid owners/operators. The problem is that in Sweden, the grid owners are required to have concessions from the government to own and operate the grid. This concession is considered a government assigned monopoly and therefore comes with certain obligations. The concession holders are not allowed to be operating any business outside owning, operating, and expanding the grid where they have concession. Therefore, a company with concession such as E.ON or Ellevio, are not legally allowed to own and operate ERS. But if the regulations were to be changed so that the concession include ERS, then grid operators expressed interest in taking the role of owners. They already have a capital heavy business with long pay-back times and long depreciation periods, characteristics shared by ERS.

The second group to show interest in owning ERS infrastructure was electricity suppliers. The interviewed party looks to sell electrification as a service and believed that offering infrastructure for ERS could be a valuable service for them e.g., as part of a business model where they provide a functional solution for a fixed fee, to customers.

selling ERS could be a valuable service for them to offer, if they can find a beneficial business model where they can offer a fixed, monthly fee to the users of the road.

Third, public transport providers state that they potentially could be the owners, given that municipality, state, and region work together to provide financing.

Fourth and final group interested in owning ERS infrastructure is the technology suppliers themselves. In that case they would lease or sell usage of the road to the users and by doing so, taking on the risk themselves. An interviewed partner from a management consulting firm added that if an ERS provider gets a contract showing recurring revenue, infrastructure funds or private equity firms would probably be interested in investing capital directly into owning the ERS or into ERS providers which in turn would own the ERS.

4.2.3 Biggest barriers

Evidently, there are large barriers blocking commercialization of ERS in urban environments. Not a single stakeholder sees the infrastructure system transition as easy.

The most frequently mentioned barrier was economic feasibility. Especially distributors and vehicle suppliers emphasized that they must be able to reap positive returns if they were to put any bets on ERS. Higher utilization of ERS significantly decreases cost per charge for the infrastructure, making the case more financially feasible. However, the distributors and vehicle makers are not interested in transitioning into using ERS before economic upsides can be proven. They state that they will transition to ERS if other companies/parts of society transition first, proving the system and generating traffic to the roads, making it cheaper to join. An ERS supplier adds that getting the number of users up is a barrier, getting the large quantities of electric vehicles to want to transition into charging through the road. The ERS provider states that if electric vehicle owners requested ERS, adjustments of electric grids and roads would follow.

Development in battery technology was also suggested as a potential hindrance for ERS advances. The grid operators/owners, one of the stakeholder groups with the biggest expertise-pool regarding energy storage/solutions, emphasized that batteries are getting cheaper while their capacity is increasing. Cheaper batteries imply that making them smaller saves less money, reducing one of the potential advantages of ERS. Academia as well as government representatives also stated that the mix of metals used in batteries are likely to be changed going forward, to battle dependence of conflict-minerals and scarcity of metals. Interviewees stated that this might remove the urgency of reducing battery consumption for environmental reasons as well.

Another mentioned barrier was the legal issues regarding ERS. A road contractor working with ERS stated that legal issues are a major barrier in the short-term. The issue is that if an accident happens on a road where an ERS is placed, the burden of proof lies on the operator/owner of the ERS. This means that if an accident happens, on a stretch of road with ERS, then the ERS operator/owner must prove that the accent was not caused by the ERS. Usually, the burden of proof is on the plaintiff, but laws and regulations have not yet been set for ERS, because of the newness of the technology. They stated that this is making it more difficult to move from supervised demo-projects to commercial-scale projects, since it puts operators/owners at risk of financial liabilities associated with fines and legal costs.

The legal matter of road ownership and responsibility is also highlighted as a barrier necessary to address. For instance, municipalities own regional roads, but the Public Transport Administration owns national roads. Placing ERS over municipality borders can create difficulties because the road owner and concession holder may vary between municipalities. There are also discussions in process whether the ERS owner owns and should maintain the entire road, the upper layer and the ERS or only the ERS.

Public transport providers expressed that there is a lack of an overarching authority that can be the driving force in an infrastructure shift to ERS. They describe several authorities that have stake in the matter, but none that holds ultimate responsibility in the way they would have preferred.

A barrier mentioned that concerns electrification of transport in general, as well as ERS, is the inertia built into the systems, slowing down electrification in general and adoption of ERS. Change takes a lot of time, an example brought up was that vehicle manufacturers often have a great proportion of their workforce working on developing combustion engines, being experts in their field. If they were to transition to an electric engine focus, either that workforce must be re-educated which takes a lot of time, or new people must be hired who have relevant knowledge and education.

Interviewee subjects representing academia stated that there is a shortage of players wanting to take the role as operators/maintainers of ERS, which can serve as a barrier for commercialization of the system. However, as discussed under 4.3.2, there exists actors that are interested in taking this role.

Finally, authorities & government, and electricity suppliers emphasized that the sheer level of cooperation required between several stakeholders is a barrier. Authorities & government emphasized how infrastructure innovation of systemic character can fail if stakeholders back out. An example given was a case where an ERS demo-project was in process but had to be canceled completely due to a major vehicle manufacturer backing out. This barrier highlights the importance of partnerships, which will be discussed in the following section.

4.2.4 Important partnerships

Deploying ERS in any environment is a complex task that requires a lot of collaboration between the different actors and as described in section 3.2.3, partnerships with customers is likely required to successfully commercialize ERS. The vehicle supplier and electricity supplier groups emphasized this by saying that all actors must work together to deploy ERS.

Both academia and road constructors believe that a partnership between the ERS suppliers and state and/or local government would be important. This is because of the legal barriers mentioned above, and the fact that most roads in Sweden are either owned by the Swedish Transport Administration (Trafikverket) or the local municipalities. A public transport provider adds that close collaboration between state, region and municipality is required to bridge barriers such as finance and ownership, as well as legal barriers.

The grid owner/operator group thinks that a partnership between the ERS supplier/manufacturer and the party that invests in the ERS infrastructure would be beneficial, even though cooperation with other stakeholders also plays an important part. The electricity supplier group thought that a partnership between the vehicle manufacturers and the ERS suppliers would be important to make sure that the technical integration is done right. Finally, the ERS supplier group expressed that a partnership consisting of vehicle manufacturers, transporters and energy companies would be beneficial, interlinking the entire chain from energy- and vehicle production to users.

4.2.5 Important stakeholders

All interviewees discussed the stakeholder environment. Generally, interviewees emphasized that all stakeholders are needed to make ERS happen. Important stakeholders mentioned include, but are not limited to, the following:

- Vehicle suppliers
- Road operators
- Grid owners
- Contractors
- ERS owners
- System integrators
- Municipalities & government
- Receiver of goods in cities
- Haulers
- Truck operators
- ERS operators & builders
- Citizens
- Energy supplier

Grid owners, municipalities, government authorities & road operators were frequently mentioned as very important. Grid owners were by many said to be an important stakeholder, but it turns out that they are limited in their power to hinder ERS. The grid owners' concession forces them to comply with requests of connecting customers to the grid while taking a reasonable fee for the connection. However, there are no guidelines for how long it may take, giving grid owners a small, but potential opportunity to delay ERS. It should be noted that the grid operator/owner group did not express any intent to hinder ERS deployment.

Municipalities were by all stakeholders described as an integral part in deploying ERS since the municipality owns the roads and control licensing and constitute an important possible customer/investor/partner for ERS advances. The municipality, and state, can through various authorities control and impact what happens to what it owns and what affects citizens. Also, the citizens were emphasized as a stakeholder because they are affected by how the ERS looks and they can, via petitions, block access to build at certain places.

Vehicle suppliers are described as critical since the ERS cannot run without vehicles adjusted to the system. However, interviewees from vehicle suppliers and academia claimed that the technology required to produce/adjust vehicles to work with ERS is not a barrier and something companies will be ready to supply once customers start requesting them on a larger scale. A vehicle supplier with experience from ERS stated that they will sell vehicles no matter which charging type becomes dominant, they can easily adjust their production to match demand.

One stakeholder that was mentioned were receivers of goods in cities, for instance stores. Interviewed transporters stated that almost all stores only accept deliveries during a short window in the morning, which all delivery trucks/cars must adapt to. This means that transporters must drive into the city with trucks with idle capacity, because they do not have time to deliver full truck loads, and then return to their terminals and wait until the next day to be used again. Because of the long idle time at the terminal, they can charge their trucks overnight and can bring enough battery capacity onboard to last their route without losing uptime. Hence, making one of the main selling points, increased uptime, from ERS non applicable.

Electricity suppliers were also discussed in a few interviews. Their business is to produce and sell electricity, which according to a road constructor is similar to operating and selling electricity via an electric road. This means that electricity suppliers are important both as producers of the electricity the ERS system and vehicles run on, but potentially as the part performing the transactions around the electricity going into vehicles. The electricity supplier group agreed that they are potential owners of ERS infrastructure.

4.2.6 Perceived value adds

Several interview subjects discussed the topic of city environment and noise, bringing up the importance of an electrified vehicle fleet to get rid of particles and disturbing engine sound. Another important value of ERS that authorities & government, vehicle suppliers, ERS suppliers and Road constructors mentioned is the possibility to reduce battery size. Given an expansive ERS, vehicles can charge their batteries continuously and thus reducing the need for large batteries to extend the range. Smaller batteries also enable cheaper EVs, as the cost of the battery is a large part of the total cost of EVs today. This aspect was mentioned by a few groups but further highlighted by Authorities and Governments. However, as mentioned under 4.2.3, the costs of batteries might drop.

Academia, grid operators/owners and electricity suppliers stated that they believe that one important value added is that ERS reduces the need for stationary charging for EVs. This in turn reduces the need to stand still and thus increases the potential uptime of EVs using ERS. Academia also mentioned that an ERS is likely a prerequisite to enable an autonomous EV fleet with reasonable uptime.

Public transport providers highlighted that stationary charging can be unfeasible due to space constraints, for instance it can be hard/impossible to find space for a bus to charge within a city center. ERS can add the value of not requiring designated space where vehicles can stand still.

The ERS provider group added that ERS can work as a datalink between roads and vehicles. Data can be gathered about for example how vehicles move and how much power they need. Drivers can receive information about for example hazards on the road ahead. Also, they state that the datalink can aid in the future potential roll-out of autonomous vehicles.

4.2.7 Main order qualifier

A main order qualifier is a characteristic or prerequisite that must be met for the stakeholder to invest in or use ERS. This is the category where the groups differ the most. Authorities & Government require responsibility and accountability from the ERS operator. They believe that the ERS must be safe and accepted by the citizens.

For vehicle suppliers and delivery companies to invest in ERS, they require a standardization that means that all potential areas use the same ERS solution in all relevant cities. The vehicle suppliers go so far as to say that they want to see an EU-wide standard and an agreement between the countries of the EU to use the same ERS solution. At the same time, the vehicle manufacturers also stated that if there exists a big demand from their customers, as mentioned above, they can in a reasonably short timespan adapt their electric trucks to use the requested ERS. The delivery company also put heavy emphasis on the fact that the ERS must be financially viable for them and their subcontractors, both in short and long term. They also stated that stationary charging is a viable option for their current operations and that for them to choose ERS it must also be cheaper than deploying stationary charging. The electricity supplier group also put emphasis on economic feasibility, they want a profitable business case with a long-term commitment from customers.

Academia has identified the utilization rate of the ERS as a key part. According to them, a high utilization is required for the system to be profitable for all parties. If the ERS does not reach the necessary utilization, then stationary charging poles will be a cheaper and more efficient solution since it is more scalable, less reliant on utilization, and can be deployed in a smaller scale than ERS.

In the next section, the information gathered in this Findings section will be analyzed.

5 STAKEHOLDER ANALYSIS

---

*This chapter analyzes information presented in 4. Findings, which covers topics from both **RQ1** and **RQ2**. First, the stakeholders' incentives are analyzed, which, complemented by the stakeholder map, covers the topics around **RQ1**. Second, perspectives on ownership, followed by analysis on how business cases on ERS can be conducted, are presented which partly covers **RQ2**.*

5.1 What drives the stakeholders?

This section discusses what drives stakeholders, which is part of **RQ1**. The interpretations of the stakeholders' drivers come from a mix between interview statements and analysis made by the authors. Each groups drivers stem, in most cases, from a single individual with a broad perspective of their stakeholder group. As discussed under 2.3.2.12.3.2.1 Interview sampling strategy and 2.6 Trustworthiness, this was deemed a feasible approach and that the drivers of the individual stakeholder's should reflect the drivers of the entire group.

5.1.1 ERS providers

The ERS providers are partly driven by the desire to reduce emission from driving as well as from making batteries, with grand vision about the future of electric transportation. The entrepreneurs behind ERS believe in their systems, while other players on the transport scene might believe in hydrogen fuel cells, for instance. Having focused on the upsides with one solution, as well as having a stake in it, can create a bias that colors for example sales arguments.

The ERS providers are also financially driven. In Sweden, the ERS players are small and primarily funded by research grants. To keep growing the businesses and develop the ERS, an important driver is to secure orders and thus cashflow. Having commercially untested products as well as needing orders to generate cashflow might lead to ERS providers to a position where they exaggerate the upsides of ERS to convince customers and investors.

5.1.2 Vehicle suppliers

The vehicle suppliers are companies, seemingly driven by the mission to guarantee satisfactory returns for the shareholders. Because of this, the stakeholder group is less likely to push for certain solutions but rather follow what the markets want. This becomes evident for instance when the group expresses that they will not develop ERS-compatible vehicles until the markets start to demand it.

The financial focus also becomes evident in the argumentation around inertia presented in 4.2.3, the stakeholder group claims that a barrier blocking electrification is inertia built into the systems. One could argue that the inertia is present because the vehicle providers react to demand shifts, aiming to preserve revenue streams, instead of proactively steering the market towards, for instance, more sustainable solutions. This can be seen as an example of the Innovator's dilemma, discussed under 3.2, where vehicle makers decide between catering to the needs of their customers versus adopting new technologies and innovations which will answer the customers future needs. The interview responses from the stakeholder group indicate that the group aspires to both cater to current needs but also future customers.

5.1.3 Electricity suppliers

The electricity supplier stakeholder group showed interest in being an active part in the emergence of ERS. Like the vehicle supplier group, electricity suppliers strive for economic feasibility. The stakeholder group can expand its business by selling more electricity and/or offering new services to the market. Using ERS as a new sales channel and/or service could allow them to sell more and to premium prices, as well as develop their business.

However, interviews indicated that the electricity supplier group is also focused on working proactively, ahead of the market, creating solutions to future problems. This differs from the vehicle suppliers, who seem more reactive as discussed in the previous section. This could be derived from the fact that electricity suppliers can only differentiate themselves through price, energy source and brand. There is little room for adjusting the price as electricity can be regarded as a commodity. Instead, electricity suppliers focus on energy sources and brand. Also, the energy market is closely scrutinized by the media. These factors combined makes it important for electricity suppliers to be proactive and constantly seek new and better solutions to differentiate themselves from competitors. The electricity vehicle manufacturers face similar scrutiny, but they can differentiate themselves and stay competitive in more ways.

5.1.4 Grid owners

Grid owners are constrained by the concession-requirements. They are awarded local monopoly, but their profits are capped, they cannot conduct other businesses, and they must make sure that the grid works for the aspiring users. Instead, grid owners' main incentive is to keep the grid operational to keep their concession. To achieve this the grid owners do thorough planning, and they seek to gain information about the required development as soon as possible since the process of expanding the grid takes a long time. Therefore, the grid owners are interested in the evolution of ERS, as a wide deployment of the technology would impact the usage of the grid.

5.1.5 Road constructors

Road constructors are financially driven enterprises; therefore, they are naturally interested in everything that may change their business, which ERS has the potential to do. This stakeholder group often holds contract-based responsibility for maintenance of roads. Deployment of ERS would impact how roads are maintained, something road constructors must learn and adapt to. Also, road constructors will most likely be part of installing ERS. This offers opportunities for the stakeholder group to expand their business, naturally making them inclined to advocate ERS.

5.1.6 Authorities & Government

This stakeholder group is not commercially driven to the same degree as for example vehicle providers. Many of the decision makers are elected by the people or politically assigned. Therefore, there exists an internal drive to be re-elected. An example brought up in interviews was that the current more right-wing leadership of Stockholm did not wish for the government to make big investments but rather rely on players in the market, since their voters prefer lower taxes and less governmental involvement in the market. Even if an ERS investment would make sense and benefit society in the long run, politicians in general must avoid going against voter sentiment. However, the green stamp associated with electrification and ERS presents an opportunity for politicians to show that they are serious about climate change, something that voters increasingly prioritize.

5.1.7 Public transport

The public transport stakeholder group is considered an end user and consist in Sweden of government-owned administrations. This group is affected by political elections via budget and directions from regional councilors. However, the organizations are driven by officials that are more permanently assigned. There seems to be a greater drive to succeed with the mission to create an optimal public transport system rather than to focus on elections.

During interviews, a drive to be competitive versus other modes of transport such as walking, biking, and driving were apparent. This pursuit involves making sure travel time is as low as possible compared to the other options. It also involves managing the brand, where showing that becoming greener is focal.

5.1.8 Transporters of goods

The transporters are public companies, driven by keeping up their profits by keeping cost of drivers and vehicles low. ERS systems offer an opportunity to increase uptime on electric vehicles but driving shifts would require drivers that work uncomfortable hours. Currently, stores receiving goods and transporters are deeply synchronized and the logistic flows are arranged to fit the current system. Transporters have no intrinsic drive to change the system. However, the transporters ambition to keep customers could lead to them adopting more green technologies, even at higher prices than the current systems.

5.1.9 Academia

This group is not driven by either elections or quarterly reports, rather by a curiosity about what the future of transport and mobility will look like. The researcher on ERS projects wants to see their technology work in a market setting, hoping for commercial buoyancy and high utilization. The more environmentally focused researchers have expressed hope that ERS will aid in transitioning to a fully electric vehicle fleet.

5.2 Stakeholder interdependence

For ERS to become profitable, the companies from different stakeholder groups must work together as ERS requires players from all groups to do their part. There can be no ERS without the grid operator, there is no use for vehicles with ERS-support without ERS, there is no ERS without the roads etc. Thus, they are all interdependent in this endeavour. From the stakeholder analysis it was found that many stakeholders share the drive of searching for profitable business development opportunities.

This endeavour to find profit indicates that proving that the establishment of ERS can be financially feasible could encourage all interdependent companies to commit to ERS deployment. To explore the financial feasibility, it is important to find potential first customers as well as potential owners of the ERS.

The less financially driven groups, academia as well as authorities and government, are in a good position to research and find these situations where financial viability can be shown. Analyzing **RQ1** revealed the need to dive deeply into a prominent use case, involving proof of financial feasibility. This as a part of creating a fuller understanding of how ERS can be commercialized in urban environments, which is the main research question addressed in this thesis.

In the following two sections, the important questions of this first customer and potential owner will be discussed.

5.3 Stakeholders' perspectives on ownership

After gaining understanding about what drives the different stakeholders, the next step is to address the two most pressing questions related to commercialization of ERS and the **RQ2** of this thesis. These are the questions of ownership and first customer. This section discusses ownership from different stakeholders' perspectives, the next section discusses issues related to first customer.

Different stakeholders point to different potential owners of the infrastructure, as described under 4.3 Owner of infrastructure. Vehicle manufacturers and distributors pointed to state/regionally owned structures, and state representatives leaned towards ERS suppliers or contractors owning the road. The contractors did not see ownership of ERS as within the scope of their business. Consensus around the holistic picture and different players' roles in relation to potential ERS development have not been reached, which is natural given the novelty and complexity of the technology.

Vehicle manufacturers and major distributors are players that are analyzing logistics and transport trends on an international scale. They emphasized the need for international standards to allow for vehicles to move between different regions and countries as well as to maintain a functioning second-hand market for the EVs. Both groups expressed that the government should be the owner/investor in ERS. This indicates that their perception of the most reasonable owner is colored by the group's priorities, given that the government as potential owner is likely to focus on international standards and collaboration with other countries.

During interviews with people active in academia, the view that the potential end users bus operators, taxi companies and garbage collectors are likely owners was presented. This might be because of researchers' outside-in perspective and a deep understanding of how different actors behave and what drives them.

According to both the contractor and the energy provider groups, energy providers are reasonable owners. This difference in opinion between the groups probably stems from the more holistic outside-in perspective held by academics while the energy providers and contractors work more hands-on and have a more practical, less visionary perspective about potential owners.

These differences in opinion highlight that the stakeholders' different perspectives and agendas influence their thoughts and ideas about appropriate owners of the ERS. This indicates that to find potential owners, it can be beneficial to move from the top-down approach followed during the interviews, when ownership was discussed in general terms, to a more bottom-up one. This could be done by first focusing on finding and analyzing high-potential use cases and start thinking about who should own it in the specific situations where a use case has a positive outlook. The next section, 5.4, will further discuss use cases/business cases and how they can be conducted for infrastructure innovation of systemic character.

If electricity suppliers were to buy the ERS from an ERS supplier then that would solve the problem for the ERS suppliers of not finding a buyer or first owner of the ERS. However, the issue of finding first potential users that want to commit to using the road without a widespread deployment of ERS persists and would instead be moved to the electricity suppliers. Electricity suppliers do in general have better financial capabilities than the ERS suppliers today, so they would probably be able to deploy the ERS themselves to a greater extent. Hence having electricity suppliers as owners would improve the prerequisites for deploying ERS in urban environments but not solve all the issues associated with ERS.

5.4 Designing the business case

Digging deeper into a case to further study the commercialization of ERS, specifically **RQ2**, can add depth.

The ERS supplier, public transport, and energy supplier, who are driven by or limited by financial factors, need to be able to present a financially feasible and trustworthy business case before committing, or raising capital to invest in the road. Once more, the chicken-and-egg dilemma introduced under 3*.2.3 Commercialization of systemic innovation* presents itself. The problem with business cases that includes systemic innovations such as ERS is that it may rise, or fall depending on the reached utilization. Utilization can be hard to estimate since it is defendant on several different players. This makes it hard to capture the true value of a shared ERS system whilst still being able to present a reliable business case. Two options how to tackle this issue have been identified and are presented in the following two paragraphs.

First, the quantitative part of a business case can be based on one user only, and the positive effects from additional users can be exemplified with hypothetical new users and/or qualitative discussion to highlight the potential upsides. This option puts high requirements on the customer that the business case relies on, and it deviates from the shared-infrastructure intention of ERS. This option results in not capturing the full potential value of ERS in the business plan. However, it removes financial uncertainties and the risk of lower utilization than expected that is associated with collaboration between several different users.

The second option identified, which solves problems of not capturing the full value of ERS, is to form partnerships between several organizations, together committing to using ERS. If several users partner together and the guaranteed utilization rate goes up, it becomes easier to find compelling business cases for ERS with short enough pay-back time to justify the investments. The importance of the network surrounding actors pursuing commercialization of systemic innovation is discussed under *3.2.3 Commercialization of systemic innovation*. The theory states that the support as well as the attitude of the early adopters are critical success factors, which becomes evident in this discussion. The challenge with this option is to form the partnerships and networks.

Potential partnerships, interesting for further research, could be between players that are good potential users individually, and that overlap in their intentions. For instance, a committed collaboration between urban bus operators, taxi companies and garbage collectors, could help solve the chicken-and-egg dilemma. However, the initiation of the partnerships and responsibility over the process can be difficult. A public transport provider stated during the interviews that there is a lack of an overarching authority that can initiate these types of larger collaboration projects as well as making sure the laws and permission-processes are adjusted to enable ERS in urban environments.

This thesis includes a case study. The case, which will be described under section 6. Case Study Line 4 is studied in collaboration with the Region Stockholm Transport Authority. As described, the most prominent beach head market according to the interviewees are bus operators. To test this, the public transport authority in Stockholm, the Public Transport Administration, was chosen as case subject. During discussions with the Public Transport Administration, it was concluded that bus Line 4 was the line that would benefit the most from ERS. The case study is conducted using the approach described in option one. This is because Region Stockholm is assumed to be able to financially back this project, and able to reach the required utilization by itself. Time limitation also played a factor as a large-scale cooperation model would take a significantly longer time to create.

6 CASE STUDY LINE 4

This chapter details a case study and the results. The case is about analyzing public transport Line 4 in Stockholm, comparing the current biogas/biodiesel solution with stationary charging and ERS-based solutions, respectively. The chapter contains an introduction to Line 4 and why it was chosen, a stakeholder analysis, a financial breakdown, environmental impact as well as a qualitative analysis.

6.1 Stockholm city electrification background

Stockholm is keen on finding new ways to combat climate change. Especially electrification has been put high on the agenda, for instance, a new commission, the commission of electrification, has been established (Region Stockholm 2021). Certain parts of Stockholm have higher levels of particles in the air than what EU regulations allow, which can lead to fines and several politicians are keen on addressing this issue. Also, the contracts established between Region Stockholm's public transport authority and providers of biogas & biodiesel are starting a 3-phase expiring process in 2022. These factors, among others, make the current situation, a transitional phase, in Stockholm interesting.

An important part of electrifying Stockholm is to electrify bus line 4, which runs through several crowded parts of the inner city and is popular with travelers. Currently, the buses on the line run on biodiesel and biogas, but interest has been shown to switch to deploying electric buses powered by stationary charging or ERS. The following section will further describe line 4.

6.2 Line 4

Line 4 is a bus line in central Stockholm, reaching from the bus stop "Radiohuset" to the bus stop "Gullmarsplan" with a distance of around 12 km one way (Region Stockholm, 2021). It is one of the bus lines with the highest daily load in the entire county, with departures every 4 to 15 minutes on weekdays and every 6 to 15 minutes on weekends and holidays (SL, 2020). It is a popular line, and it carries more passengers yearly than the entire SJ network. The line is illustrated in Figure 6.1.

The high load and high frequency of departures imply that a large number of buses are required to operate the line. If you want to deploy EVs on a route like this using stationary charging, more buses are needed to replace the buses that are charging, incurring a greater investment cost. There is also a lack of space in the city, there is simply not enough room to deploy stationary chargers in the center of the city. Also, there is a lack of depot space around the city center meaning that buses will have to drive long distances to get to their depots for slow charging. The option, charging EVs with stationary fast chargers in the city, is deemed infeasible by the Public Transport Administration and will thus not be as deeply analyzed as other options.

One benefit of EVs is that they produce less noise compared to conventional combustion vehicles, although this only applies to lower speeds. A study in Gothenburg showed that above 50 kph, the noise from electric buses and combustion buses are the same (Forsmark, 2019c). Hence, if the goal is to reduce noise, electric buses should be deployed on stretches with low average speed. The speeds of Line 4 buses are low, and the average speed does not exceed 20 kph on most stretches, meaning that deploying EVs on that stretch would reduce noise (Holgersson, Wadell and Posada, 2019).

Another upside of line 4 regarding ERS deployment, is that it consists mostly of straights (as seen in Figure 6.1), which enables efficient ERS deployment since the rails themselves are straight.

Electrification of line 4 has been of political interest according to Region Stockholm, further incentivizing Region Stockholm to investigate the different options. This is because of the popularity and visibility of the line.

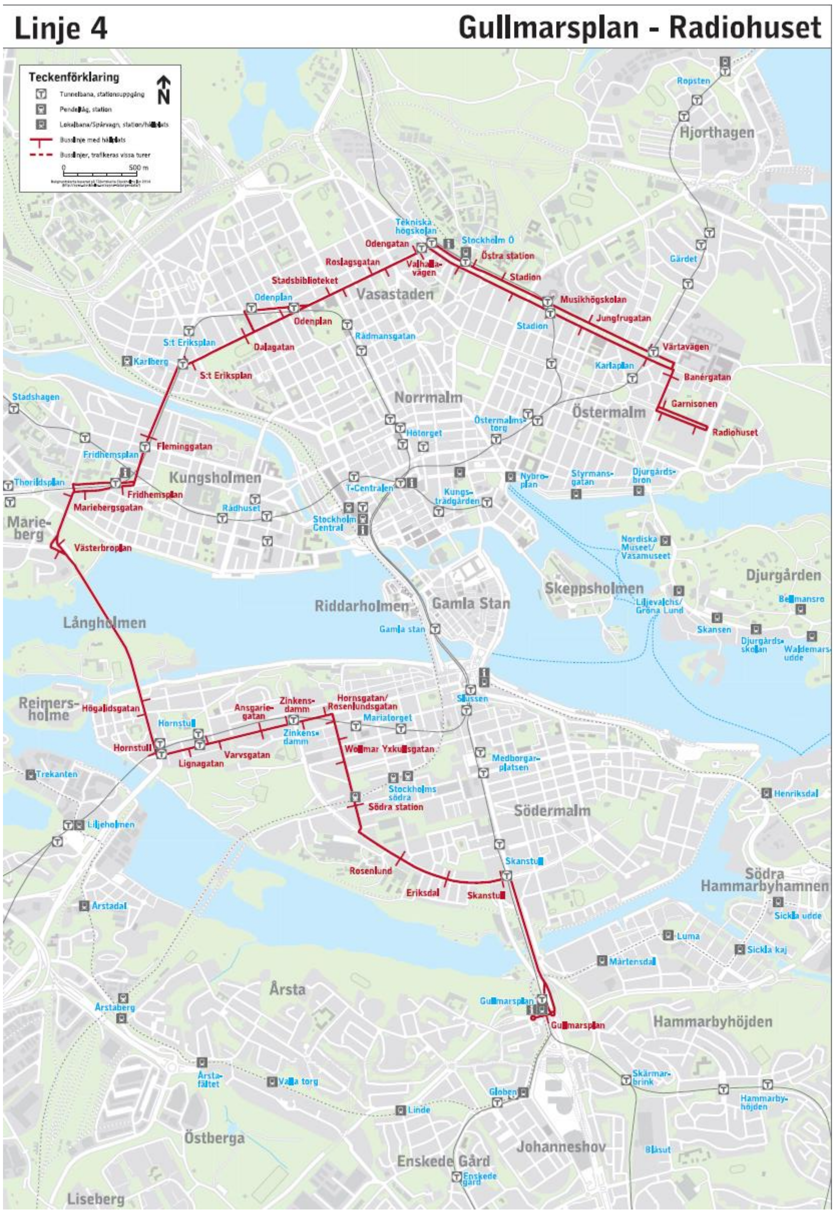

Figure 6.1. Map over bus line 4 in Stockholm with bus stops (the Public Transport Administration Region Stockholm 2021)

6.3 Stakeholder analysis line 4

When a big decision is to be made in a company, that affects many different players, one can use stakeholder analysis as a tool to see how the company should deal with the different stakeholders. This can be done by using a power interest matrix where each stakeholder's power over, and interest in the decision is estimated. This matrix then serves as a guideline when deciding how to manage each stakeholder and their interests.

6.3.1 List of stakeholders

In the case of line 4, a list of stakeholders was made specifically for this stretch of road. This list was based of the generic ERS stakeholder map in Figure 4.1 and consists of the following stakeholders:

- Elonroad (ERS provider)
- Citizens of inner Stockholm
- Keolis (Bus operator)
- Stockholm municipality (Road owner)
- Electricity supplier
- Ellevio (Grid owners)
- Vehicle Supplier

Since the decision to deploy ERS on line 4 is a matter for the Public Transport Administrations they are not included in the matrix.

6.3.2 Power interest matrix

The positioning of each stakeholder in the power interest matrix presented in Figure 6.2 is based on data gathered during the literature review, the interview study, and the authors analysis of said data. Many stakeholders have been found to have a high interest in the deployment of ERS at line 4 as the deployment of such an infrastructure could have a great effect on many.

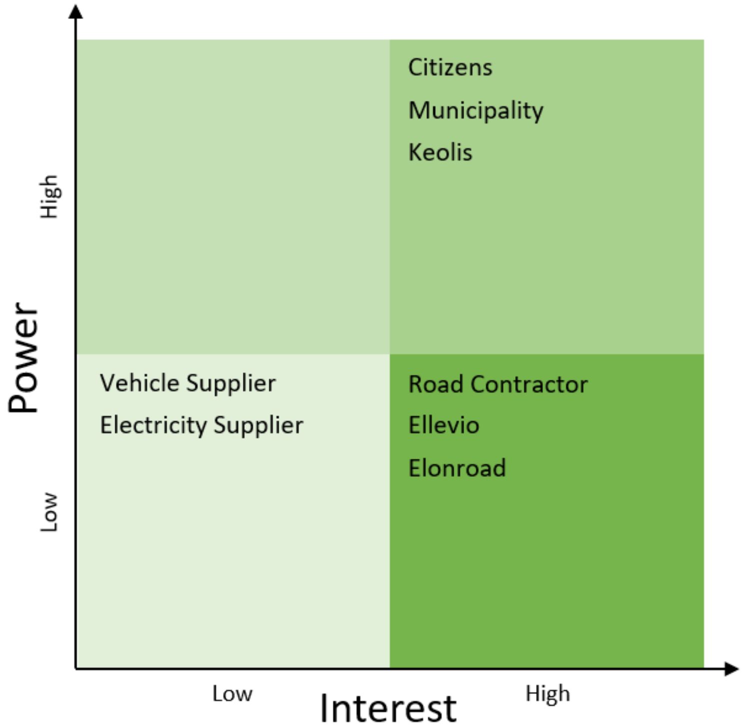

Figure 6.2. Power interest matrix for deployment of ERS on line 4. Order of appearance does not reflect ranking within each square. Adapted from Johnson et. al. (2019)

Vehicle suppliers and electricity suppliers are assumed to have low interest in the deployment of ERS on line 4 because it would represent only a small portion of their business. Vehicle suppliers can offer vehicles that can connect to the ERS, if the customers demand it. In the case of line 4, the investment in buses would be around 264 MSEK, which is small when compared to the large vehicle manufacturers total revenue. For instance, Volvo Trucks and Scania had revenues of around 200 BSEK (Volvo, 2021) and 125 BSEK (Scania, 2021) respectively in 2020. Hence, their financial interest in this specific project is deemed to be low. Their power over the project is also deemed to be low since there exist more than one vehicle provider on the market and it can be assumed that if one actor will not offer ERS-ready trucks, others will.
The same reasoning was used for the Electricity suppliers, the electricity these buses consume is assumed to be small in comparison to the total amount of electricity that the electricity suppliers provide. Therefore, their interest was concluded to be low. Although, electricity suppliers have shown interest in ERS in general and a successful project could move their interest from low to high. Also there exist many electricity suppliers on the market so the individual power of each electricity supplier is deemed to be low.

The citizens are expected to be highly interested in the deployment in ERS since they are living and/or traveling on or near the ERS. Therefore, things like safety and noisy construction projects concern them. For example, many people are concerned with the dangers of running high voltage rails in roads where their pets and children could reach. The citizens are also assumed to care about environmental factors, such as air quality where they work or live, ERS has the potential to reduce local emissions, and therefore the citizens could be interested in the ERS project from that perspective. They were also found to have the ability to appeal the decision of deploying ERS close to their homes, giving them power to potentially delay, if not stop, the deployment by multiple years. In the end it is also the citizens that vote for and elect the public officials that govern the municipality and region, so if they are not happy with the actions of the officials the officials might lose their jobs, forcing them to pay attention to the interests of the citizens. Following this reasoning, the municipality should have high interest in the project since its outcome may affect the next election if the project would be conducted in their area. The municipality also owns the road where the ERS is planned to be deployed so their permission to build is a necessity for the project. Therefore, the power and interest of the municipality is also considered to be high.

Keolis is the bus operator on line 4. This means that the Public Transport Administration have hired Keolis to own and operate the buses on line 4. Keolis also operate other bus lines in Stockholm. Being the operator, they are highly interested in the technology used on the roads and in the buses they operate. the Public Transport Administration expressed that they have some say about how their bus lines are operated and what buses should be used, but Keolis are still to be considered a powerful player as they operate under long-term contracts and a change in bus operator could be considered a difficult and long process.

The road contractor in question is in this case the party that builds and maintains the roads where the ERS could be deployed. Their interest is deemed to be high since the way that they maintain their roads may very well change where the ERS is situated. The power of the road contractors is deemed to be low. Elonroad has expressed that they can cover installation, service, and maintenance of the ERS so that the road contractor does not have to, theoretically reducing the reliance on the road contractor. As with electricity suppliers and vehicle suppliers there exist more than one road contractor that offers services, further reducing their power over the project.

Ellevio, being the concession holder in inner city Stockholm, has a great interest in the possibility of an ERS being deployed in their area. It is their responsibility to connect the ERS to their grid and to make sure that their grid can handle the extra electric effect required by the ERS. As mentioned in findings, the grid owners have limited power to hinder projects that require connection to their grid because of the terms of the concession, therefore they are assumed to have low power in the matrix.

Elonroad is being considered as the ERS supplier in this case as it is their data that have been used in the models presented under 6.4 and is assumed to be very interested in the outcome of the project. The ERS suppliers for the project will be decided through a public procurement process as the Public Transport Administration is a public unit. And even though there are fewer ERS suppliers than electricity suppliers, Elonroad is also assumed to have a somewhat reduced power over the project since the Public Transport Administration must invite all interested ERS suppliers to the public procurement process. If Elonroad would win a future procurement process then they would most certainly move to high power, high interest and become a key player.

6.3.3 Stakeholder management

Through stakeholder mapping, using the power interest matrix, engagement strategies for each quadrant were created. Based on this, Region Stockholm should work closely with the key players Citizens, Municipality, and Keolis. Since Region Stockholm is a public agency the relationship with Citizens and Municipality can be deemed critical.

Road contractors, Ellevio, and Elonroad should be kept informed about the progress of the project and how the rollout would look. This is to make sure that Ellevio can prepare the electric grid for the increased load ahead of time. For Elonroad it is important that they are aware of how the public procurement process is going so that they can prepare their offer. Even if they do not win, a pilot project like this one, if financially viable, can be used to show that ERS is viable in urban environments. The road contractor wants to keep an eye on how their roads may change and keeping them informed can help with planning eventual refurbishing of the roads.
As for electricity suppliers and vehicle suppliers they might be interested if the project gains much financial attention and if ERS is rolled out on a national scale. But until then, the minimal effort of keeping in good standards with their sales team should be enough.

6.4 Financial analysis

Important parts of making decisions regarding the choice of infrastructure are the financial aspects. To analyze and compare the financial impact associated with the different choices, an Excel-model was made. The model considered initial and future investments, maintenance costs and driving cost per kilometer.

In this analysis, it is assumed that the Public Transport Administration is the one investing in the buses to simplify the comparison of the options. Today the Public Transport Administration leases their buses from operators such as Keolis, but the economic effect is the same over time.

6.4.1 Input values

This section lists the input values used to conduct the financial calculations. As stated under 2.3.3, the values were mostly provided by the Public Transport Administration and Elonroad. The following data sources were used in the model, listed here instead of after each individual input value presented:

- Utredningsstudie: Övergång till eldriven busstrafik i Stockholms län (Forsmark and Böhlin, 2019)
- PM Affärsmodeller och trafikavtal (Forsmark, 2019a)
- PM Elbuss i Stockholms innerstad och på Lidingö (Forsmark, 2019b)
- PM Miljöeffekter (Forsmark, 2019c)
- Kapacitetsstarka fordon på linje 4 (Andersson *et al.*, 2019)
- Nulägesbeskrivning Linje 4 (Holgersson, Wadell and Posada, 2019)
- Elonroad excel model (2021)
- Mail conversation with employees at Elonroad (2021)
- Mail conversation with employees at the Public Transport Administration, Region Stockholm (2021)
- Phone calls and text messages with Keolis employees (2021)

The roles of the participants of the mail conversations mentioned in the list above are presented under 2.3.3 Collaboration with case subjects.

First, general input values applicable outside of Line 4 are listed, followed by line 4 specific input. The general input values are separated from line 4 specific to make it easier to use the general values when analyzing other lines than line 4.

6.4.1.1 *General Input Values*

The general input values are placed in the following categories:

- Combustion buses and fuel prices
- Electric buses and electricity prices
- Infrastructure prices
- Maintenance costs
- Service life
- Additional input

These categories are broken down and shown in this section, in order. The purchase prices for combustion buses and fuel prices are shown in Table 6.1, kbm in the consumption column stands for kilo biomass.

Table 6.1 Economics of combustion engine buses

Combustion buses & fuel price	Purchase cost (MSEK)	Consumption (kbm/km)	Fuel price, incl tax (SEK/kbm)
Biogas 12m	2,3	0,7	9,8
Biogas 18m	3,1	0,8	9,8
Biodiesel 12m	2,3	0,48	10,5
Biodiesel 18m	3,1	0,52	10,5

The purchase price for electric buses of three different types, as well as their electricity consumption and electricity price are shown in **Error! Reference source not found.**. depot-charged electric buses are defined as buses that charge solely in terminal stations during the night or between shifts. These require larger batteries as they must carry all the energy they aspire to use during a shift. Top-up charged electric buses are defined as buses intended to be fast charged during their shifts, thus not requiring as large batteries. Charge in motion buses are defined as those that use ERS to charge, thus needing batteries only to travel between terminals and the start of the ERS.

Table 6.2. Economics of electric buses

Electric buses & electricity price	Purchase cost, including battery (MSEK)	Battery price, lifetime 7 years (MSEK)	Consumption, (kWh/km)	Electricity price incl. tax (SEK/kWh)
Depot-charged el. Bus 12m	3,5	1,4	1	0,9
Depot charged el. Bus 18m	5,2	1,7	1,5	0,9
Top-up charged el. Bus 18m	4,3	0,8	1,5	0,9
El. Bus ERS 18m	4	0,5	1,9	0,9

In Sweden, a regional public transport authority can currently apply for an Electric bus premium from the Swedish energy authority to cover some of the cost of purchasing electric buses for public transport use. You can apply for 20 % of the procurement cost or 100% of the price difference between the closest comparable diesel vehicle, up to 25 MSEK / year (SFS 2016:836). This has not been included in the calculations as it is a political decision that could be changed during the project but is noted as a potential, upside of electric buses.

The prices for purchasing various infrastructure needed for the electrification-options are shown in Table 6.3. The additional terminal spots are pricey partly due to the limited space around terminal locations. The electricity power stations cost between 1-3MSEK. The Elonroad ERS price includes installation. The connection to grid-row shows cost per electricity power station. The low effect chargers are recommended by Elonroad to be used for slow charging in terminals, for instance overnight, costing 20.000-40.000 SEK each.

Table 6.3. Price of infrastructure for electrification

Charging infrastructure prices	Investment size (MSEK)
Terminal charger (per bus)	0,25
Top-up charger (per pole)	3
Additional terminal spots (per extra electric bus)	10
Adjustment of terminal spots (per electric bus)	0,03
Overhead charging (per km)	9
Elonroad ERS (per km)	5
Electricity power station	2
Connection to grid (MSEK/kW)	0,0007
Low effect charger (~6 kW)	0,03

Maintenance costs are presented in Table 6.4. Generally, the electric buses require 20% less maintenance than combustion buses (Forsmark and Böhlin, 2019). For the main city lines in Stockholm, the maintenance costs are approximately 5,1 SEK per kilometer for biogas/diesel buses. This includes everything from tools needed to tax for the mechanics. The electric buses, costing 20% less, cost around 4,08 SEK per kilometer to maintain. Note that these costs only apply to the main inner-city lines 1-4 and 6, since maintenance costs vary with speed and driving pattern. The maintenance costs also increase with total bus weight, indicating that reducing battery size and therefore total weight, enabled by ERS, would reduce the maintenance cost. However, the weight's impact on maintenance cost is not investigated nor taken into consideration in this thesis.

Table 6.4. Maintenance costs

Maintenance costs	Cost per year & unit (MSEK)
Terminal charger (per charger)	0,02
Top-up charger (per charger)	0,15
Overhead charging (per km)	0,1
Elonroad charging (per km)	0,075
Combustion bus (per bus)	0,0000051
Electric bus (per bus)	0,00000408

The service life of various items is presented in Table 6.5. After 15 years of use, the Elonroad ERS should be refurbished. It can be fully restored for 25% of the original purchase price, 1,25 MSEK per kilometer.

Table 6.5. Service life

Service life	(Years)
Electric bus 18m (charge in motion)	20
Electric bus 18m (terminal charging)	10
Electric bus 18m (top-up charging)	10
Combustion bus 18m	13
Elonroad ERS	15
Battery 18m charge in motion	7
Battery 18m terminal	7
Battery 18m top-up	7

Finally, additional input is shown in Table 6.6. In Region Stockholm an approximately 50/50 split between biogas and biodiesel buses are used. The combustion engine buses, as well as the electric buses that charge stationary, are heated using biodiesel. The heating in buses charging in motion are powered electrically and is reflected in the higher energy consumption.

Table 6.6. Additional input

Additional input	
Heating biogas/electric (stationary charge)	0,1 l biodiesel per km
Charge in motion heating:	included in running price
Current biogas/diesel split:	50/50

6.4.1.2 Line 4 specific input values

When analyzing line 4, line-specific input values were used. They are placed in the following categories:

- Buses required to run the line
- Terminal space & chargers
- ERS needed to power the line
- Current buses
- Line yearly usage

The number of buses required to run the line, and how many are currently running on it, are shown in Table 6.7. Note that top-up charged buses are not included. This option was not considered because the Public Transport Administration deemed the option infeasible due to high traffic volumes and space constraints.

Table 6.7. Buses required.

Buses needed	Buses needed	Buses currently on the line
Required number of buses, combustion	33	33
Required number of buses, ERS	33	0
Required number of buses, terminal charging	46	0

The number of additional terminal spaces, chargers and power stations are shown in Table 6.8.

Table 6.8. Terminal space, chargers, and electric power stations.

Terminal space & chargers	Units
Additional terminal spaces needed	13
Required terminal chargers	40
Electric power stations	6

The amount of ERS needed in kilometers is shown in Table 6.9. The Overhead ERS calculation assumes that approximately 40% of the distance needs to be electrified. The amount of ERS the Elonroad solution requires is calculated by Elonroad using their internal tools and methods. The solution is based on charging using ERS while driving, complimented with four one-minute stops along the route, at popular buss-stations, charging using the ERS, as well as charging with low effect (~6kW/bus) at terminals during night. The ERS is calculated to charge with an effect of 100kW.

Table 6.9. Kilometers of ERS needed

ERS needed	(km)
Total line distance, both ways:	24
Total Elonroad ERS needed (Elonroad calculation)	5,7
Total Elonroad ERS needed, incl. Safety margin (Elonroad calculation)	7,3
Total Overhead ERS needed:	9,6

The current state of buses used is important to know since it determines when investments are required if the current combustion-based solution is kept, shown in Table 6.10. Buses are continuously bought and sold, and their service life can vary. Also, buses are moved between regions around to keep the average fleet age in line with regulations. The average purchase year plus the average service life of buses is used to indicate when new investments are due. Most of the inner-city buses were bought in 2014, some were bought 2011.

Table 6.10. Age of combustion buses in use

Buses in use:	33 ea.
Average purchase time bus:	2013
Average service life bus:	13 years

Finally, the distance driven per year on line 4, summing up the activity of all buses, is 1,5 million kilometers. The lines yearly usage is an important input as it drives yearly cost difference between biogas/diesel and electricity used to power the buses.

6.4.2 Excel model design

To perform the calculations, Microsoft Excel was used. The model was designed to be easy to follow and adjustable, to analyze other lines than line 4. The model uses the general input values with the line 4 specific calculate the relevant output. The model used input data to find initial- and future investments as well as the yearly costs of maintenance for the options.

All calculations are traceable in the model, going from input to output, except for the required kilometers of ERS using the Elonroad solution. This is because the method that Elonroad uses to determine the amount of ERS needed is confidential.

To compare the investments, accumulated costs and investments were plotted and net present values were calculated. Net present value was calculated by discounting investments and costs to the base year. In the plot showing costs and investments, the net present values were not

included, the plot was conducted to show when and how much different alternatives would affect the cashflow.
The Excel model uses the investment times presented in the timeline in Figure 6.3, the timeline starts at year 1, representing year 2023.

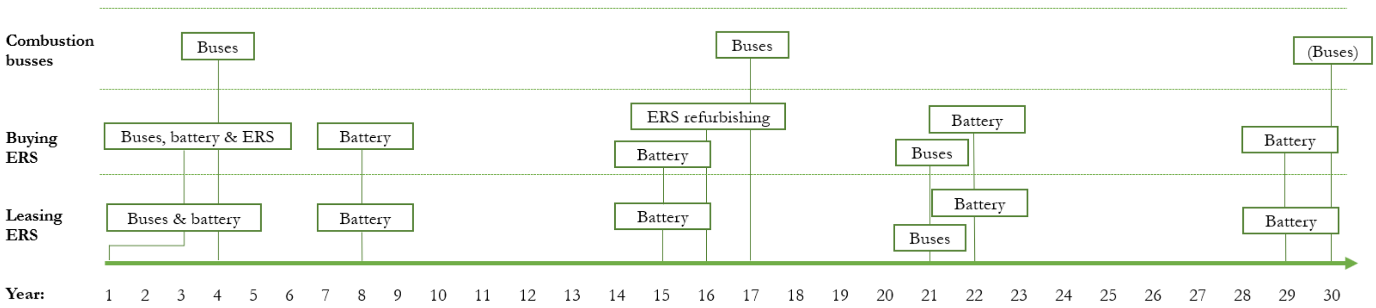

Figure 6.3. Investment timeline for different options for line 4. Payments in parentheses are not included in the calculations of net present cost. Begins in 2023 (Personal Collection)

6.4.3 Investment sizes and maintenance costs

This section presents the output from the model. The investment sizes as well as yearly maintenance are be presented.

Table 6.11 shows investment size and maintenance for the combustion buses. Note that the investment is not necessary until year 2026.

Table 6.11. Investment & maintenance combustion buses

Combustion engines	
Investment Size	MSEK
Purchasing 18m biodiesel/gas buses	102,3
Initial Investment	102,3
Yearly Maintenance (MSEK)	MSEK)
Maintenance bus	7,65
Total yearly maintenance:	7,65

Table 6.12 shows investment size and maintenance cost for the Elonroad charging option, including the buses, the road, and the electric power stations.

Table 6.12. Investment & maintenance Elonroad charging

Elonroad charging	
Investment Size	MSEK
Purchasing 18m el. buses with charge in motion tech	132
Purchasing of ERS	36,5
Purchasing of electric power stations	16
Connecting to Grid	0,28
Low effect charger (6 kW)	0,99
Initial Investment	185,8
Yearly Maintenance (MSEK)	MSEK
Maintenance bus	6,12
Maintenance ERS	0,55
Total yearly maintenance:	6,67

Table 6.13 shows investment size and yearly maintenance of the overhead charging option. As the table shows, both the investment size and maintenance cost are higher than for the Elonroad ERS option. Also, the overhead charging option requires more space and impacts the cityscape. These factors combined render the overhead option inferior and it will not be analyzed further.

Table 6.13. Investment & maintenance overhead charging

Overhead charging	
Investment Size	MSEK
Purchasing 18m el. buses with charge in motion tech	132
Purchasing of Overhead Structure	86,4
Purchasing of electric power stations	16
Connecting to grid	0,28
Initial Investment	234,68
Yearly Maintenance (MSEK)	MSEK
Maintenance bus	6,12
Maintenance ERS	0,96
Total yearly maintenance:	7,08

Table 6.14 shows investment size and yearly maintenance of the terminal charging option. Like the overhead option, the investment size and yearly costs are higher than the ERS option. In addition, it takes extra time to drive between the line and the terminal to charge, which increases the amount of driving hours and thus labor cost, adding cost to the terminal charging option. The terminal charging option will not be analyzed further.

Table 6.14. Investment & maintenance terminal charging

Terminal charging	
Investment Size	MSEK
Purchasing 18m el. buses	239,2
Purchasing of terminal chargers	10
Additional terminal spots	130
Initial Investment	379,2
Yearly Maintenance	MSEK
Maintenance bus	6,12
Terminal charger maintenance	0,8
Total yearly maintenance:	6,92

6.4.4 Leasing model

One alternative to owning the road is leasing it from another player. ERS suppliers, Electricity suppliers and Authorities and Government groups presented this as a possible and interesting solution to the chicken and egg problem. Therefore, the possible costs for leasing an ERS was calculated to compare with owning the ERS. The difference between owning and leasing the ERS in costs is that instead of investing in and paying for the maintenance of the ERS, the Public Transport Administration pays a fixed fee every year to the owner of the ERS.

There is currently no market for leasing ERS so there was no leasing fee to benchmark against. Therefore, an estimation of the leasing fee was calculated using annuity. The calculations are described in A.1.4 Leasing cost calculations. The potential collaboration between Elonroad and the Public Transport Administration could be seen as a strategic alliance, discussed under 3.2.2 Commercialization methods. It can also be regarded a joint research contract.

Two different leasing models were considered, one with a contractual length of 15 years and one with 30 years, based on the lifetime of Elonroad's ERS. The investment costs for the ERS provider were then spread out evenly over these years. The assumed investment costs that were used are:

- Investment in ERS.
- Refurbishing of ERS.
- Investment in electric powers station.
- Cost of connecting the ERS to the power grid.
- Purchase of low effect charger

After around 15 years of operation the ERS needs to be refurbished, Elonroad estimates the cost of doing this is about 25 % of the initial cost of the ERS. After the ERS has been refurbished its service life is extended by another 15 years. Since the 15 years models contract ends before the refurbishing, that cost is not included for that model, but instead it is assumed that Region

Stockholm extends their contract at the 15-year mark for an additional 15 years with the same leasing fee. The resulting calculations, using a 10 % leasing markup, can be found in Table 6.15.

Table 6.15. Estimation of ERS leasing fee for two different contract lengths.

ERS Leasing fee		
Present Value of Owning ERS (MSEK)	59,16	66,32
Leasing Period (years)	15	30
Annuity factor	0,096	0,065
Leasing fee Annuity (MSEK)	5,699	4,314
Leasing fee Annuity due (MSEK)	5,428	4,108
Final leasing fee		
Leasing markup (%)	10 %	10 %
Leasing fee (MSEK)	5,97	4,52

The next section will compare the Elonroad ERS option with the current system. The calculations conducted indicate that the other options are inferior, thus excluded.

6.4.5 Elonroad ERS versus combustion buses

This section shows the accumulated costs and investments as well as the net present value for the options of:

- Keeping the current solution using combustion engines
- Purchasing Elonroad ERS
- Leasing ERS with 15-year contracts
- Leasing ERS with 30-year contract

Generally, the ERS options require bigger investments, but electricity is cheaper than biogas and biodiesel, meaning the ERS option becomes more attractive the more it is used. Figure 6.4 shows the accumulated costs & investments.

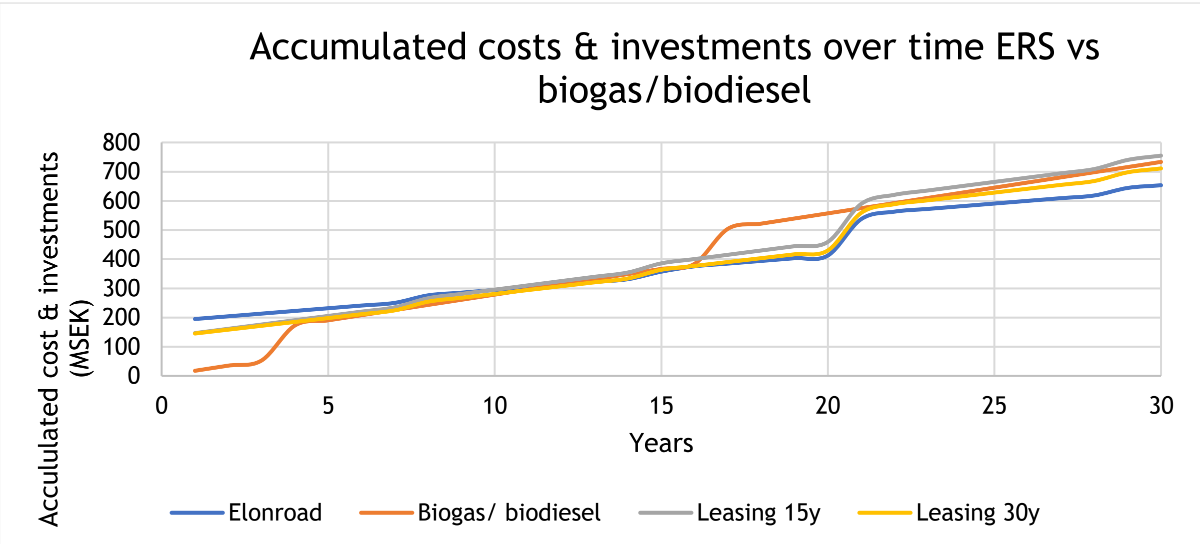

Figure 6.4. Costs & investments ERS vs biogas/biodiesel with a 5% discount rate (Personal Collection)

As Figure 6.4 shows, after ~11 years the option of purchasing ERS accumulates equally large costs and investments as keeping the combustion buses. For the 30-year leasing contract, the graph passes the biogas/diesel graph after 10 years. The 15-year lease contract intersects with the biogas/diesel option back and forth during the 30-year horizon.

The net present values, with three different discount factors are shown in Table 6.16

Table 6.16. Net present cost ERS versus combustion for 1%, 5%, and 10% discount factor

Net present value			
	MSEK (1% discount factor)	MSEK (5% discount factor)	MSEK (10% discount factor)
Biogas/biodiesel	645,9	419,7	281,9
Buying ERS	584,6	412,9	317,0
Leasing ERS (15y)	634,5	443,2	335,0
Leasing ERS (30y)	592,2	419,6	323,2

6.5 Environmental impact

Electricity powered transportation comes with different environmental impact than combustion powered transportation. In this case, the aspects considered are the direct emissions, noise, and alternative uses for the fuel.

Using biogas and biodiesel emits particles that reduce the quality of air. As stated under 6.1, certain parts of Stockholm have higher levels of particles in the air than what EU regulations allow. One reason for this is that when Stockholm was built, architects and city planners wanted to limit cold air from the Baltic Sea from blowing in. This resulted in some streets having bad air passthrough, keeping particles there for longer. In these areas, it is especially important to not emit more particles. Changing to ERS operated EVs could help Stockholm improve the air quality to below the EU limit and therefore avoid potential fines and/or sanctions. This would in turn make ERS, and other emission reducing technologies more financially attractive.

The buses on Line 4 seldom drive at speeds exceeding 20 kph which means that the electric buses would produce less noise than conventional combustion buses. However, many other vehicles travel along the same roads as the line 4 buses. The reduced noise resulting from switching to electric buses would probably not be noticeable amongst all other sources of noise during peak hours unless other vehicles also change to electric engines.

One effect of switching to EVs is that they require larger batteries than combustion vehicles. The batteries used today contain rare earth minerals, are hard to recycle and is the main negative environmental effect from EVs. As seen in the timeline in Figure 6.3, the batteries need to be changed every seven years, potentially causing a large negative environmental effect. But as it has been discussed above, multiple stakeholders believe that this negative effect will be reduced in the future. Research is focused on finding less rare elements to use in the batteries, and on making the recycling of batteries easier and more efficient. One upside of using ERS charging EVs instead of depot charging EVs is that they require smaller batteries, hence reducing the environmental effect from the batteries.

6.6 Case discussion

This section discusses the financial analysis, compares the options, discusses the stakeholders, and finally recommends a way forward.

The financial feasibility varies with discount rate, price on biodiesel/biogas, various investments required, leasing markup and price on electricity. In the calculations the price on biogas/biodiesel as well as electricity is assumed to be constant. This will unlikely be how the prices will behave, but it was deemed outside of the scope of this thesis to speculate in prices. Instead, the Excel model allows for easy adjustments of prices if needed. The leasing markup is a percentage markup on the annuity of the investment in ERS that the ERS provider is expected to take in return for taking on the risk of owning the road. The 10 % leasing markup used in the model was chosen as a reasonable markup, but this value was not deemed critical in the analysis as any value above 0 % resulted in owning ERS having a lower net present cost than leasing ERS. This is a result of the design since the leasing fee is based on net present value calculations with a leasing markup. Setting this markup to 0 % would result in the leasing and owning alternatives having the same NPV.

The net present costs given three different discount factors are shown, in Table 6.16, to illustrate how it varies. Notably, the order of net present costs changes when the discount factor is changed. Higher discount factor promotes biogas/biodiesel. Higher discount factor means higher value of money today relative to the future value, which promotes investing later rather than sooner. Overall, a 5% discount factor is deemed the most reasonable and the net present costs it renders will focal when comparing the options.

Given a 5% discount rate, keeping the combustion engine solution has higher net present cost than the alternatives Buying ERS and Leasing ERS (30y). However, the net present cost for the Leasing ERS (15y) option is higher than keeping the combustion solution. The 15y lease has higher net present value because the investment is spread out over fewer years.

It can be concluded that the options of leasing ERS (30y) and buying ERS have similar net present cost and financial consequences over time. The accumulated size of costs and investments becomes lower than for the combustion engine option after 10 years (lease 30y) and 11 years (buy). Investing in the infrastructure demands more capital up front but has slightly lower net present cost. Both options are viable, and choice between them can be determined by the financial status and strategies of the organizations involved.

Looking past the financial analysis, switching from combustion engines comes with non-financial upsides. Using ERS instead of combustion engines offers an opportunity to remove emission of particles that reduces the air-quality. Also, electric engines are less noisy. Buses drive slowly on line 4 and in slower speeds the noise from the engine is dominant in relation to the noise from the tires, which increases the relative upside of switching to a more silent engine. Compared to other electrification alternatives, the Elonroad ERS option is cheaper and does not affect the cityscape as much as for instance the overhead charging option.

From the stakeholder mapping, key players identified are the citizens, Stockholm municipality and the bus operator Keolis. These have a lot of say in the strategical decision that Region Stockholm takes as citizens elect the Region Stockholm officials, Keolis having long-term contracts with Region Stockholm and Stockholm municipality owning the roads in Stockholm. While these groups were the most important, many groups were found to have a great interest in this project and could move to positions of more power throughout the deployment process. Hence there are many groups for Region Stockholm to keep in the loop throughout the project, which can be expected because of the size and systemic character of the infrastructure project.

To conclude, this case study indicates that electrifying line 4 using ERS is a prominent way of going forward with reducing emission and should be validated and investigated further. The case also indicated that it is theoretically possible to solve the chicken-and-egg dilemma by finding a business case that is viable even without considering the intended shared nature of the infrastructure. This will be elaborated further under 7. Commercialization analysis.

6.6.1 Risks

This section addresses some risks associated with the case. This case-analysis tackles a complex infrastructure investment involving several stakeholders, millions of SEK and stretches over a large timespan. These factors together add uncertainty. For instance, over a 30-year period a lot can happen when it comes to prices, requirements and development of alternative technology.

Trustworthy information, from the primary sources, were used. This information however only reflects the current situation. If for instance electricity prices surged while biogas/diesel prices dropped, it would skew the equation and perhaps render the electric road solution more expensive. However, as stated earlier, the aim of this analysis is not to speculate in future prices.

Another risk, associated with the novelty of electric roads, is that they do not work as intended over time. Electric roads have not been tested over decades. However, responsibility of keeping the ERS working as intended can be placed on the ERS supplier when negotiating the contracts. Also, as stated in 1.4 Delimitations, deeper analysis of the technology is not part of the scope of the thesis.

A sensitive input is the choice of discount factor, it greatly affects the results. Choosing discount factor is subjective and reflects perceived confidence in economic growth, the own organization et cetera. This is a general uncertainty associated with discounting cash flows. The chosen main discount rate of 5% was deemed reasonable given the low yielding, high security-nature of the cash flow generated from the proposed 30-year contracts.
Other sensitive parameters are the prices of the buses. The largest investments are the buses, meaning that if the purchase price of average lifetime is deviates from the model it could heavily

skew the results. The chosen values are the ones provided by the Public Transport Administration and Keolis and are deemed trustworthy.

6.6.2 Delimitations

Three main delimitations have been made. First, legal aspects have not been analyzed. These are deemed out of scope. However, these are important aspects that future researchers and decision makers are urged to investigate.

Second, the environmental impact-analysis is kept on a qualitative level. In order to deepen the analysis, for instance reduction in CO2-equivalents and dB could be calculated and translated into monetary terms.

Third, future revenue from other users were not analyzed quantitatively. It is an important aspect and a potential upside that makes the investment in ERS more attractive. However, this case study aimed to investigate if the first user could benefit from using ERS as the sole user, to show how the chicken-and-egg dilemma potentially could be solved. The scenario analyzed can be seen as the "worst-case scenario" where no other vehicles choose to use and pay for the road. Therefore, future scenarios with several users were not analyzed further.

7 COMMERCIALIZATION ANALYSIS

This chapter analyzes information gathered throughout the thesis. It focuses on formulating insights related to commercialization, aiming to analyze the main research question: How can ERS suppliers commercialize their products in an urban environment?

Commercialization theory, see 3.2.4, states that when trying to commercialize systemic innovation, specifically within sustainable technology, the challenge is to find a suitable business case. The case needs to fulfill user demands, from both the environmental and economic points of view. Another key aspect for this type of commercialization is strong ties with customers and partners.

Throughout the interview process and when analyzing RQ1, it became clear that most of the financially driven stakeholders wanted to see financial viability before they commit to ERS. Thus, showing financial viability could help form and strengthen the ties with customers and partners. the Public Transport Administration, being part of the interview process, expressed an interest to become more involved in this thesis. The information and insights they could provide enabled the creation of this first business case that multiple stakeholders had asked for. The process involving interviews, stakeholder analysis, and the interest from the Public Transport Administration in Region Stockholm culminated in the line 4 case study.

The case illustrates that ERS can be sold or leased out in a way that is financially beneficial for all involved parties. The case shows that it is possible to find situations where ERS is financially viable, compared to other options, without requiring several players committing to using the road or even national/international standards. This indicates that one way to commercialize ERS in urban environments is to first limit the difficulties associated with forming a business case involving several different customers by focusing on only one customer.

Finding a suitable first customer with compelling financial and non-financial upsides such as noise- and pollution reduction and availability constraints is only the first step towards seeing ERS on the ground, running commercially. If tax money is going to be used the ERS deployment plan must pass through controllers and decision makers, as well as go through the process of public procurement where government agencies must consider offers from all interested players, which can be a lengthy process. Also, several interview subjects discussed the complexity of the collaboration required to deploy ERS. The strength of the collaboration network is a crucial aspect, theory as well as interview subjects press on its importance. Thus, great effort should be placed on unifying important stakeholders around the vision of ERS as well as around the first commercial use case. Furthermore, interviewees expressed that more interest would be sparked in ERS if there exists a financially reasonable investment plan, as many stakeholders presented financial viability as their main order qualifier. Since this plan can be shown, it could further incentivize stakeholders to join in these collaboration networks/projects.

After finding the first customer and delivering on that contract, the desired network effects of ERS can be realized through finding synergies between the first user and other potential ones, increasing utilization and extending the ERS coverage. Likely, extending the ERS from an existing starting point is easier than establishing it because the concept is already proven, and it gets exponentially easier to find suitable users as the amount of road that is covered by ERS increases. This is the second step of the commercialization journey, and it is not covered in this thesis, but it is an interesting topic as the ERS industry progresses from demo-stage onwards. This includes finding business models which allows for monetizing external/new users of the ERS.

8 CONCLUSIONS

This chapter presents the conclusions reached throughout this study. First, a short summary of the thesis is presented, followed by answers to the research questions. After, the thesis's contribution to practice and theory, further reflections on the thesis and finally suggestions for further research are presented.

8.1 Summary

The purpose of this thesis was to study how Electric Road Systems (ERS) suppliers can commercialize their product in an urban environment, focusing on the Swedish market. This was done by finding the relevant stakeholders and what drives them, as well as by investigating whom to initially target, and how an offer could be constructed.

The project identified several important stakeholders as well as their opinions about several aspects of commercializing ERS in urban environments. The different stakeholders' drives were also analyzed, discussing how their interests and the emergence of ERS interact.

The most prominent first customer base was identified to be bus companies, referring to operators/owners of bus lines following fixed routes and schedules. In collaboration with the public bus authorities in Stockholm, the Public Transport Administration, a case study was conducted. In the case, the decision of how to power Line 4 in Stockholm was analyzed. The decision was between keeping the current biogas/diesel buses, moving to electric buses charged in terminals or along the route or to invest in ERS. The case study indicated that ERS and biogas/diesel have similar financial consequences over a 30-year period. However, the buses running on ERS are less noisy and do not emit particles. Also, expanding the ERS to cover other lines could lead to much more advantageous financials.

8.2 Answering the research questions

This section answers the research questions, using insights discovered and presented throughout the thesis. As stated in 1.2.1, the research question of this thesis was: How can ERS suppliers commercialize their products in an urban environment? The research question was divided into the two sub-questions:

RQ1: Who are the stakeholders, and what drives them, in the deployment of urban ERS?
RQ2: How should an ERS supplier construct their ERS offer, regarding whom to target and how?

8.2.1 RQ1

Who are the stakeholders, and what drives them, in the deployment of urban ERS?

The identified stakeholders in the development of urban ERS and their main driver(s) are (in no order of importance):

1. **ERS suppliers**: Driven by financial profits and improving the environment through electrification.
2. **Vehicle suppliers**: Driven by financial profits and shareholder satisfaction.
3. **Electricity suppliers**: Driven by financial profits.
4. **Grid Operator/Owners**: Driven by maintaining and developing the electrical grid while making profits.
5. **Road constructors**: Driven by financial profits.
6. **Authorities & Government**: Driven by public opinion, re-election, and environment.
7. **Public transport**: Driven by providing an optimal transport system to their consumers that can compete with other options.
8. **Transporters of goods**: Driven by financial profits.
9. **Academia**: Driven by an increased understanding in how ERS technology could work in a market setting and understanding how ERS could aid in the transition to a fully electric vehicle fleet
10. **Road Owners**: Driven by public opinion, re-election, and environment.
11. **Owners of ERS**: Being able to make financial profit from the ownership.
12. **Citizens**: Driven by affordable, safe, and environmentally friendly modes of transportation, as well as not harming the cityscape.

8.2.2 RQ2

How should an ERS supplier construct their ERS offer, regarding who to target and how?

An ERS supplier should, in the initial phase of ERS deployment, target the public transport sector and/or electricity suppliers as potential customers.

The public transport sector has shown a potential to be able to finance the deployment of ERS and electric buses since it can be cheaper and more environmentally friendly than other options for public transport. The public transport sector also has a government mandate to reduce environmental effects of their operations which is positive for ERS because of its environmentally friendly solution.

The electricity suppliers are looking for new ways to sell their electricity. Since ERS basically is a new interface for customers to receive electricity, it is plausible that electricity suppliers would be interested in buy ERS to have a new way to sell electricity and/or to sell ERS-charging as a service. However, selling ERS to electricity suppliers would only solve the ERS providers problems of selling their road. It would not solve the issue of finding users that want to commit to using ERS before the system becomes widely deployed.

An ERS supplier should seek to form a collaboration project with a regional public transport authority with the purpose of gradually deploying ERS on their bus lines. The key to success lies in the ability for the ERS provider to, through a thorough business case, show that ERS is financially profitable/feasible when compared to other options. The case should show that an ERS investment will be profitable even when solely operated by the public transport authority's vehicles and on a pilot stretch. Then the success of ERS is not reliant on any other users but instead every potential new user adds more value to an already functioning system, therefore only making the investment in ERS more profitable.

8.2.3 Main research question

The main research question is answered through the process of answering RQ1 and RQ2. The commercialization of urban ERS has shown to be an intricate problem that requires cooperation between many different stakeholders. The answer to RQ1 shows who these stakeholders are and what drives them. Strong ties with partners and customers are crucial, especially for small and new companies commercializing systemic innovation. The insights from answering RQ1 hopefully helps the ERS supplier to better position themselves in the market. It formed the answer through RQ2 that the ERS supplier should cooperate with the identified stakeholder to provide a business case to show financial viability and grow their business from there.

Furthermore, the importance of being able to show financial viability became evident. It formed the answer through RQ2 that the ERS supplier should cooperate with the identified stakeholder to provide a business case to show financial viability and grow their business from there.

8.3 Contribution

This thesis contributed in two ways, it contributed to the research field of commercialization of systemic innovation as well as to the more practical knowledge about commercialization of ERS in urban environments.

First, looking at the contribution to the field of commercialization of systemic innovation, the case can be used as an example on how finding a suitable enough user could solve the chicken-and-egg dilemma associated with commercialization of infrastructure innovation of systemic character. This insight adheres with previous researchers' findings, suggesting that screening for the most prominent use cases is a solid way to approach commercialization. This is a more actionable approach than to for instance trying to materialize grand visions or the full potential of systemic innovations directly. Whilst it is important to keep the vision and future potential in mind, the information gathered in this thesis indicates that finding concrete compelling reasons for decision makers to be first/early investors in innovations should be focal when starting the commercialization journey.

Second, zooming in on ERS, the thesis is unique in its focus on urban environments. Other studies have been done on ERS in general, often focusing on long-haul transport. This thesis has provided a stakeholder analysis for the urban environment, offering a holistic view. Also, the thesis has illustrated how calculations and modelling can be conducted to make investment decisions related to investing in ERS.

8.4 Further reflections

A general reflection is that commercialization as a topic is very wide and involves several different aspects. During interviews, reading and modeling everything from economics to politics to law have been brought up. To reach more depth, the study could have been focused on for instance the financial, legal, or environmental aspects of commercializing ERS in urban environments. However, the novelty of the technology and thus lack of previous information and research made it difficult to formulate even more narrow research questions. The research questions are determined as niched enough, as the thesis managed to reach enough depth to contribute both theoretically as well as practically.

Another reflection, related to the methodology, is that the latter part of this thesis relied on a certain level of luck. During the interview process, followed by analysis and discussion before the case study, the most prominent first user was found. The user, the Public Transport Administration, expressed quite some interest in this project and chose to provide data and access to knowledgeable people. When starting the thesis, there was no guarantee that they would be interested in collaboration. Without their help and interest, the case would either have been conducted on some “second best” first user or with only public information without someone to speak to from the case-subjects side. This issue is hard to tackle given the iterative nature of this study, the most prominent first user was unknown when the project started.

8.5 Suggestions for further research

There is plenty left to explore in this area that became evident during the research process. Four main areas for further research were identified.

First, an area that plenty of researchers work with but that still shined with its absence was the lack of consensus and best practice on how to translate environmental impact into monetary terms. For example, when financially comparing ERS and combustion engines, the reduced particle emission were merely considered a “qualitative benefit” with the ERS option. If the particle reduction were translated into money, capturing the actual benefit for the city, the option would have seemed even better. If researchers and legislators established a standard price for different emission types in different settings that were universally adopted, investments in green technology would become easier to motivate.

Second, as discussed throughout the thesis, there is a lack of proper legal frameworks supporting ERS emergence. There is a lot that needs to be defined, for instance who is responsible for accidents on roads where ERS is placed, who owns which layers of roads etc. Researchers and decision makers working with legal questions would advance the field and possibilities if they managed to define the legal playing field of ERS.

Third, more research on the network effects associated with adding more ERS into an existing network would be beneficial. When discussing establishing ERS in new areas, deeper knowledge, and rules of thumb regarding network effects would allow decision makers to understand the potential benefit of ERS more concretely.

Last, research about appropriate collaboration models and initiatives allowing for groups of end users to invest in and adopt ERS together is needed. The benefits ERS offers is driven by utilization, and to guarantee high utilization collaboration efforts are important. Deep-dives into how collaborations could be structured would provide guidance for future attempts to find prominent use-cases for ERS.

9 REFERENCES

Almestrand Linné, P., Sundström, L. and Hjalmarson, M. (2020) *Standardisation for electric road systems: A review of ITS standards for the development of electric roads*. VTI rapport 1041A. Gothenburg: VTI. Available at: http://vti.diva-portal.org/smash/get/diva2:1430101/FULLTEXT02.pdf (Accessed: 7 April 2021).

Alstom (2017) ‘Alstom presenterar APS för väg: en innovativ lösning för elvägar’, 17 November. Available at: https://www.alstom.com/se/press-releases-news/2017/11/alstom-presenterar-aps-for-vag-en-innovativ-losning-for-elvagar- (Accessed: 7 April 2021).

Alvehus, J. (2019) *Skriva uppsats med kvalitativ metod: en handbok*. 2nd edn. Stockholm: Liber AB.

Andersson, M. *et al.* (2019) *Kapacitetsstarka fordon på linje 4*. ÅF on order from Region Stockholm.

Aslani, A. *et al.* (2015) ‘Commercialization Methods of a New Product/service in ICT Industry: Case of a Science & Technology Park’, *Organizacija*, 48(2), pp. 131–138. doi: 10.1515/orga-2015-0007.

Balachandra, R. and Friar, J. H. (1997) ‘Factors for success in R D projects and new product innovation: a contextual framework’, *IEEE Transactions on Engineering Management*, 44(3), pp. 276–287. doi: 10.1109/17.618169.

Bansal, P. (Tima), Smith, W. K. and Vaara, E. (2018) ‘New Ways of Seeing through Qualitative Research’, *Academy of Management Journal*, 61(4), pp. 1189–1195. doi: 10.5465/amj.2018.4004.

Bateman, D. *et al.* (2018) *Electric Road Systems: A solution for the future?* La Défense: World Road Association (PIARC). Available at: https://www.trafikverket.se/contentassets/2d8f4da1602a497b82ab6368e93baa6a/piarc_elvag.pdf (Accessed: 7 April 2021).

Beal, G. M. and Bohlen, J. M. (1956) ‘The Diffusion Process’, in. (Increasing Understanding of Public Problems and Policies), pp. 111–121. doi: 10.22004/ag.econ.17351.

von Bonin, M. *et al.* (2020) *Electricity supply to electric road systems: Impacts on the energy system and environment*. Reserach Collaboration. CollERS. Available at: http://www.diva-portal.org/smash/get/diva2:1467139/FULLTEXT01.pdf (Accessed: 7 April 2021).

Brinkmann, S. and Kvale, S. (2015) *InterViews: Learning the Craft of Qualitative Research Interviewing*. 3rd edn. Thousand Oaks, CA: SAGE Publications. Available at: https://vbn.aau.dk/en/publications/interviews-learning-the-craft-of-qualitative-research-interviewin (Accessed: 8 April 2021).

Ceccagnoli, M. and Rothaermel, F. T. (2016) ‘Appropriability Strategies to Capture Value from Innovation’, in *Technological Innovation: Generating Economic Results*. Emerald Group Publishing Limited (Advances in the Study of Entrepreneurship, Innovation and Economic Growth), pp. 3–31. doi: 10.1108/S1048-473620160000026001.

Chiesa, V. and Frattini, F. (2011) 'Commercializing Technological Innovation: Learning from Failures in High-Tech Markets', *Journal of Product Innovation Management*, 28(4), pp. 437–454. doi: 10.1111/j.1540-5885.2011.00818.x.

Christensen, C. M. (1997) *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Brighton, MA: Harvard Business School Press.

Datta, A., Mukherjee, D. and Jessup, L. (2014) 'Understanding commercialization of technological innovation: Taking stock and moving forward', *R&D Management*, 45(3), pp. 215–249. doi: 10.1111/radm.12068.

Datta, A., Reed, R. and Jessup, L. (2013) 'Commercialization of innovations: an overarching framework and research agenda', *American Journal of Business*, 28(2), pp. 147–191. doi: 10.1108/AJB-08-2012-0048.

Denscombe, M. (2014) *The good research guide: for small-scale social research projects*. 5. ed. Maidenhead: Open University Press.

Devers, K. and Frankel, R. (2000) 'Study Design in Qualitative Research - 2: Sampling and Data Collection Strategies', *Education for health (Abingdon, England)*, 13(2), pp. 263–271. doi: 10.1080/13576280050074543.

Ekengren, A.-M. and Hinnfors, J. (2006) *Uppsatshandbok: hur du lyckas med din uppsats*. 1st edn. Lund: Studentlitteratur.

Electreon (no date) 'Charging the way forward'. Available at: https://www.electreon.com/ (Accessed: 7 April 2021).

Elonroad (no date) 'Electric Road System'. Available at: https://elonroad.com/ (Accessed: 7 April 2021).

Elways (no date) 'The future is here'. Available at: https://elways.se/ (Accessed: 7 April 2021).

Forsmark, A. (2019a) *PM Affärsmodeller och trafikavtal*. PM SL 2014-2911. Stockholm: Trafikförvaltningen, Region Stockholm.

Forsmark, A. (2019b) *PM Elbuss i Stockholms innerstad och på Lidingö*. PM SL 2014-2911. Stockholm: Trafikförvaltningen, Region Stockholm.

Forsmark, A. (2019c) *PM Miljöeffekter*. PM SL 2014-2911. Stockholm: Trafikförvaltningen, Region Stockholm.

Forsmark, A. and Böhlin, J. (2019) *Utredningsstudie: Övergång till eldriven busstrafik i Stockholms län*. SL 2014-2911. Stockholm: Trafikförvaltningen, Region Stockholm.

Freeman, R. E. (2010) *Strategic Management: A Stakeholder Approach*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9781139192675.

Freeman, R. E. (2015) 'Stakeholder Theory', *Wiley Encyclopedia of Management*. American Cancer Society (Business Ethics). doi: 10.1002/9781118785317.weom020179.

Gans, J. S. and Stern, S. (2003) 'The product market and the market for "ideas": commercialization strategies for technology entrepreneurs', *Research Policy*, 32(2), pp. 333–350. doi: 10.1016/S0048-7333(02)00103-8.

Gregory, R. and Muntermann, J. (2011) 'Theorizing in Design Science Research: Inductive versus Deductive Apporaches', in. *ICIS 2011 Proceedings*. Available at: https://aisel.aisnet.org/icis2011/proceedings/engagedscholarship/2 (Accessed: 25 April 2021).

Holgersson, A., Wadell, D. and Posada, M. (2019) *Nulägesbeskrivning Linje 4*. SWECO.

Hsu, D. H. (2004) 'Venture Capitalists and Cooperative Start-Up Commercialization Strategy', *Management Science*, 52(2), pp. 204–219. doi: 10.1287/mnsc.1050.0480.

Jacobsson, K. and Skansholm, A. (2020) *Handbok i uppsatsskrivande: för utbildningsvetenskap*. 1st edn. Lund: Studentlitteratur.

Johnson, G., Scholes, K. and Whittington, R. (2008) *Exploring corporate strategy*. 8th. ed. Harlow: Financial Times Prentice Hall.

Jones, T. M., Wicks, A. C. and Freeman, R. E. (2017) 'Stakeholder Theory: The State of the Art', in *The Blackwell Guide to Business Ethics*. John Wiley & Sons, Ltd, pp. 17–37. doi: 10.1002/9781405164771.ch1.

Loorbach, D. and Wijsman, K. (2013) 'Business transition management: Exploring a new role for business in sustainability transitions', *Journal of Cleaner Production*, 45, pp. 20–28. doi: 10.1016/j.jclepro.2012.11.002.

Midgley, G. and Lindhult, E. (2017) *What is Systemic Innovation?* Hull: University of Hull. Business School. Available at: https://hull-repository.worktribe.com/output/448837 (Accessed: 7 April 2021).

Miles, S. (2017) 'Stakeholder Theory Classification, Definitions and Essential Contestability', in *Stakeholder Management*. Bingley: Emerald Publishing Limited (Business and Society 360), pp. 21–47. doi: 10.1108/S2514-175920170000002.

Moore, G. A. (2014) *Crossing the chasm : marketing and selling disruptive products to mainstream customers*. 3. ed. New York: HarperBusiness, an imprint of HarperCollinsPublishers. Available at: http://ludwig.lub.lu.se/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=cat07147a&AN=lub.5002876&site=eds-live&scope=site (Accessed: 8 April 2021).

Natanaelsson, K. *et al.* (2021) *Analysera förutsättningar och planera för utbyggnad av elvägar*. Regeringsuppdrag. Borlänge: Trafikverket. Available at: http://www.diva-portal.org/smash/get/diva2:1524344/FULLTEXT01.pdf (Accessed: 8 April 2021).

Nevens, T. M., Summe, G. L. and Uttal, B. (1990) 'Commercializing Technology: What the Best Companies Do', *Harvard Business Review*, 1 May. Available at: https://hbr.org/1990/05/commercializing-technology-what-the-best-companies-do (Accessed: 7 April 2021).

Nyberg, R. and Tidström, A. (2012) *Skriv vetenskapliga uppsatser, examensarbeten och avhandlingar*. Lund: Studentlitteratur.

Partanen, J., Chetty, S. K. and Rajala, A. (2014) 'Innovation Types and Network Relationships', *Entrepreneurship Theory and Practice*, 38(5), pp. 1027–1055. doi: 10.1111/j.1540-6520.2011.00474.x.

RISE (no date) *Elvägar*. Available at: https://www.ri.se/sv/vad-vi-gor/expertiser/elvagar (Accessed: 7 April 2021).

Scania (2021) *Annual review 2020*. Available at: https://www.scania.com/content/dam/group/investor-relations/annual-review/download-full-report/scania-annual-and-sustainability-report-2020.pdf (Accessed: 11 May 2021).

Schendel, D. and Hitt, M. A. (2007) 'Introduction to Volume 1', *Strategic Entrepreneurship Journal*, 1(1–2), pp. 1–6. doi: https://doi.org/10.1002/sej.16.

SFS 2016:836. Förordning om elbusspremie. http://rkrattsbaser.gov.se/sfst?fritext=+2016%3A836&upph=false

Siemens (no date) *eHighway - Electrification of road freight transport*. Available at: https://www.mobility.siemens.com/global/en/portfolio/road/ehighway.html (Accessed: 7 April 2021).

SL (2020) *Tidtabell Linje 4*. Available at: https://mitt.sl.se/ficktid/vinter/V4.pdf (Accessed: 8 April 2021).

Slater, S. F. and Mohr, J. J. (2006) 'Successful Development and Commercialization of Technological Innovation: Insights Based on Strategy Type', *Journal of Product Innovation Management*, 23(1), pp. 26–33. doi: 10.1111/j.1540-5885.2005.00178.x.

Starrin, B. and Svensson, P.-G. (1994) *Kvalitativ metod och vetenskapsteori*. Lund: Studentlitteratur.

Symeonidou, N., Bruneel, J. and Autio, E. (2017) 'Commercialization strategy and internationalization outcomes in technology-based new ventures', *Journal of Business Venturing*, 32(3), pp. 302–317. doi: 10.1016/j.jbusvent.2017.02.004.

Thomas, V. J. and Maine, E. (2019) 'Market entry strategies for electric vehicle start-ups in the automotive industry – Lessons from Tesla Motors', *Journal of Cleaner Production*, 235, pp. 653–663. doi: 10.1016/j.jclepro.2019.06.284.

Tongur, S. (2018) *Preparing for takeoff : Analyzing the development of electric road systems from a business model perspective*. Diss. KTH Royal Institute of Technology. Available at: http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-225377 (Accessed: 7 April 2021).

Tongur, S. and Sundelin, H. (2016) 'The electric road system transition from a system to a system-of-systems', *2016 Asian Conference on Energy, Power and Transportation Electrification (ACEPT)*, pp. 1–8. doi: 10.1109/ACEPT.2016.7811529.

Volvo (2021) *Annual and Sustainability Report 2020*. Available at: https://www.volvogroup.com/en/news-and-media/events/2021/feb/annual-and-sustainability-report-2020.html (Accessed: 11 May 2021).

Wang, Q., Berlin, D. and Meijer, S. (2019) ‘Uncovering stakeholder influences in electric road systems using two assessment methods: The case of eRoadArlanda’, *Research in Transportation Business & Management*, 33, p. 100422. doi: https://doi.org/10.1016/j.rtbm.2019.100422.

Yin, R. K. (2003) *Case study research: design and methods*. 3rd ed. Thousand Oaks, CA: Sage Publications (Applied social research methods series, v. 5).

A. APPENDIX

A.1 CALCULATIONS

This section presents the calculations used in the excel model in the line 4 case study.

A.1.1 Average speed calculations

The average speed is an important element when calculating how much ERS is needed. If the average speed is higher, the time spend on a given segment of ERS is lower, thus a higher percentage of the road must be covered.

Using data showing the line 4 travel time, for each direction, during different parts of a day, allows for deriving the average speed. First, the time standing still on bus stops were removed because the suggested solution utilizes four stops of one minute each on selected bus stops and the additional road needed is based on the average buss velocity when actually driving.

First, the driving times for different parts of the day were calculated to see what the higher average pace was. The highest average pace occurred during "traffic downtime" and was found to be 20,9 km/h, without including stops. Since the ERS needs to be able to power the buses all day, this particular case was used to find the amount of ERS needed.

A.1.2 Kilometer Elonroad ERS calculations

To find the how much ERS line 4 needed Elonroad used their confidential model. Not all in-and outputs are disclosed here, but the ones of main interest for line 4 are.

- The energy consumption the ERS buses used were 1,9 kWh/km
- The route (from Gullmarsplan to Radiohuset and then back, or vice versa) was driven 10 times per bus
- The total route distance is 27 km
- The average velocity, disregarding stops, is 20,9 km/h (see A.1.1)
- The charge at bus stops four times per route
- The stop time to charge at bus stops is one minute each
- The effect transmitted at the bus stops is 100 kW
- The effect of the board charger is 100 kW
- The buses slow charge at depots for 10 hours per 24 hours

Using these parameters, the model rendered that 5,6 km, or 21% or the total route length, was needed to power the buses. Upon this, a safety margin of 1,6 km issued by Elonroad was added, totaling 7,2 km of ERS.

A.1.3 Net present cost calculations

To compare options with costs spread out over time, the costs should be discounted to make them comparable. In this thesis, the costs and investments were discounted to T=0, the period right before the first investment is made and costs starts to incur.

The following formula was used to discount each individual cost/investment:

$$NPC = C \times \frac{1}{(1+r)^n}$$

NPC is the net present cost, C is the size of a cost/investment, r is the discounting rate and n is the difference in year between T=0 and when the cost/investment occurs.

In the Excel model, one column was dedicated to finding the discount factor, $\frac{1}{(1+r)^n}$, for each individual year for different chosen discounting rates. Several columns were used to calculate and show costs and investments, non-discounted, for the individual years and types of buses and cost drivers. Multiplication of the cost-and investment columns associated with respective bus option with the discount factors for the respective years, then summarizing these, rendered the total net present cost for the options.

All discounting factors had the same cell, holding the discounting-rate, as input making it quick and easy to do sensitivity analysis.

A.1.4 Leasing cost calculations

As stated under 6.4.4, there is currently no market for leasing ERS there was no leasing fee to benchmark against. Therefore, an estimation of the leasing fee was calculated using annuity, shown here.

The annuity of an investment is the present value of the investment, spread over its economic lifetime, such as the present value of the annuity is equal to the present value of the investment. The value of the annuity is calculated by using the following formula:

$$a = PV \times \frac{r}{1-(1+r)^{-n}}$$

Here a is the annuity, PV is the present value of the investment, n is the economic lifetime of the investment and r is the discounting rate. This gives the ordinary annuity which is due payment in the end of the period. In the case of ERS the assumption was made that the leasing fee would be paid at the beginning of each period, this annuity is called annuity-due and is calculated by dividing the ordinary annuity with $(1+r)$.

The leasing cost is finally computed using the annuity multiplied with a markup.

A.2 INTERVIEW GUIDE

Intervjuguide för semistrukturerade intervjuer med olika intressenter kring ERS.
Baseline

- Vill du berätta om dig själv och din roll?
- Hur har du arbetat med elvägssystem tidigare?

Stakeholder analys (RQ1)

- Vilka stakeholders ser du som relevanta för kommersialisering av elväg i urbana miljöer?
  - Några mer/mindre viktiga?
- Hur ser incitamenten ut hos de viktigaste stakeholders ut gällande kommersialisering av elväg?
- Vilka stakeholders ser elvägar som något positivt och drar fram utvecklingen?
  - Vilka stakeholders kommer dra mest nytta av elvägar?
  - Vilka kommer dra den största finansiella vinsten?
  - Vilka kommer vinna mest på de miljömässiga förbättringarna?
- Vilka stakeholders utgör de största barriärerna för kommersialisering i städer?
- Kommer någon stakeholder bli mer/mindre relevant framöver?

Kommersialisering (RQ2)

- Hur tror du att kommersialisering av elvägssystem i städer skulle se ut?
  - Vilka tror du är de viktigaste aspekterna vid kommersialisering av elvägar i städer?
  - Hur ser du på möjliga upplägg av erbjudandet/affärsmodell för elvägsleverantörerna?
- Vilken roll skulle ni på [Företag/institution] vilja ha i urbana elvägar?
  - Ägare?
  - Operatör?
- Vilka aktörer tror du skulle investera i själva infrastrukturen?
- Vilka aktörer tror du skulle vilja utnyttja elvägen utan att själva investera?
- Vilka tror du kan bli "beachhead market", alltså den första stabila kundbasen som elvägssystem kan växa utifrån?
- Vilka typer av partnerskap tror du är viktiga för en leverantör av elvägar?
- Vad tror du är viktigast för kunden av elvägssystem?
- En utmaning som teorin lyfter upp är "hönan och ägget" problemet där många vill använda denna typ av infrastrukturlösning när den redan finns, men inte vara den första som investerar. Hur ser du på denna problematik?
- Har du något mer att tillägga?

A.3 LIST OF INTERVIEW SUBJECTS

Here follows an anonymized list of all interviewees during the interview process.

Table A.3.1. Anonymized list of all interviewees

Role	**Stakeholder**	**Stakeholder Group**
Director Public Affairs	Global vehicle supplier	Vehicle suppliers
Director	Research Institute of Sweden	Academia
Associate Professor, Electrical Engineering	Swedish Technical University	Academia
Project Manager	Swedish City	Authorities & Government
Infrastructure Strategist	Swedish City	Authorities & Government
Director Business Process & Sustainability	Global Freight Company	Transporter of goods
Business Developer	International Energy Company	Grid operator/owner
Business Developer	Nordic Contractor	Road contractor
Partner	Global consulting firm	External counsel
Requirements Specialist	The Public Transport Administration, Region Stockholm	Public transport
Vehicle Strategist	The Public Transport Administration, Region Stockholm	Public transport
Bus and Depo Specialist	The Public Transport Administration, Region Stockholm	Public transport
Business Developer	Swedish Energy Supplier	Electricity supplier
CEO	Elonroad	ERS supplier