The Ownership Structure Dilemma and its Implications on the Transition from Small-Scale to Large-Scale Electric Road Systems

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Abstract

This master thesis is written on behalf of KTH Royal Institute of Technology and the Swedish National Road and Transport Research Institute (VTI). The study investigates how infrastructure ownership could affect the transition from small-scale to large-scale electric road systems (ERS) and how infrastructure ownership affects the foreseen future roles of the ERS stakeholders. The authors have used a qualitative research method, including a literature study within the areas of infrastructure transitions and infrastructure ownership and a case study on ERS. Conclusions are based on the chosen theoretical framework and the empirical findings from conducted interviews within the following stakeholder segments; agencies, electric utilities, road carriers, construction firms and road power technology firms.

The transport system is a large sociotechnical system, which is characterized by a high level of complexity, capital intensity and asset durability which makes it difficult to accomplish radical system transitions. Political regulations and progressive environmental targets have created a demand for new solutions within the transport system. One widely discussed, possible solution is ERS, which are considered to be beneficial from both an environmental and socio-economic perspective. The main identified barriers for a transition to ERS are related to the complex system design. Further, the matter of how the ERS infrastructure should be owned and financed remains unclear.

It will be argued that the government needs to play a key role, both as a coordinator and financier, during the initial phase of an ERS expansion. In order to obtain a high level of competence, which is considered as vital, it is important with close cooperation between different public and private stakeholders and to have a procurement process which is strongly focused on functionality. The authors suggest that in order to decrease system complexity and increase stakeholder cooperation, cross-sectorial system suppliers should be formed. During an initial deployment of ERS towards a national system, it is suggested to only have one cross-sectorial system supplier which manages the constructions and operations of ERS, in order to decrease complexity and increase knowledge. As the system and technology matures and knowledge regarding ERS has been established, it is suggested by the authors to introduce competition at the cross-sectorial system supplier level nationally.

There are many barriers for public private partnerships (PPP) during an initial expansion phase of ERS due to large investments, immature technology and the necessity for an overall control of a large-scale system. In addition, early investments in a large-scale system is considered as unattractive among private actors due to the high risks. However, it will be argued that PPP structures or private ownerships are suitable in closed systems as the level of complexity is lower. These systems should be subsidized by the government as they will drive innovation and stimulate the development. Depending on the degree of capital intensity and governmental regulations, PPP structures could become suitable also in a national system, when the system has matured. The suggested stakeholder structure with cross-sectorial system suppliers facilitates for a possible future PPP structure.

Sammanfattning

Denna masteruppsats är skriven på uppdrag av Kungliga Tekniska Högskolan och Statens väg- och transportforskningsinstitut (VTI). I studien undersöks hur ägarskap av infrastruktur skulle kunna påverka skiftet från småskaliga till storskaliga elvägssystem och hur ägarskapet av infrastrukturen påverkar de förutsedda framtida rollerna hos elvägssystemets intressenter. Författarna har använt sig av en kvalitativ forskningsmetod, vilken inkluderar en litteraturstudie inom områden för infrastrukturskiften och ägarskap av infrastruktur samt en fallstudie inom elvägssystem. Slutsatser är baserade på det valda teoretiska ramverket och de empiriska resultaten från de genomförda intervjuerna inom följande intressentsegment; myndigheter, energibolag, godstransportörer, konstruktionsfirmor och tillverkare av elvägsinfrastruktur.

Transportsystemet är ett stort socioteknisk system, vilket karakteriseras av en hög nivå av komplexitet, kapitalintensitet och lång livslängd på tillgångar, vilket gör det svårt att uppnå radikala systemskiften. Politiska regleringar och progressiva miljömål har skapat ett behov för nya lösningar inom transportsystemet. En diskuterad möjlig lösning är elvägssystem, vilket anses vara fördelaktigt både från ett miljömässigt och socioekonomiskt perspektiv. De huvudsakliga identifierade barriärerna för ett skifte till ett elvägssystem är relaterade till den komplexa systemdesignen. Vidare är frågan rörande hur infrastrukturen till ett elvägssystem ska ägas och finansieras fortfarande oklar.

Det kommer att argumenteras för att staten behöver ha en nyckelroll, både som koordinator och finansiär, under den initiala expansionsfasen av ett elvägssystem. För att uppnå en hög nivå av kompetens, vilket anses vara avgörande, så är det viktigt med ett nära samarbete mellan olika statliga och privata intressenter och att ha en upphandlingsprocess som starkt fokuserar på funktionalitet. Författarna föreslår att för att minska systemets komplexitet och öka intressenternas samarbete, så borde tvärsektoriella systemleverantörer formas. Under en initial utbredning av elvägssystem mot ett nationellt system, så föreslås det att enbart ha en tvärsektoriell systemleverantör som sköter konstruktion och verksamhet av elvägssystemet för att minska komplexiteten och öka kunskapen. Allt eftersom att systemet och teknologin mognar och kunskap om elvägssystem etableras, så föreslår författarna att konkurrens ska introduceras på tvärsektoriell systemleverantörsnivå nationellt.

Det finns många barriärer för offentlig-privat samverkan (OPS) under den initiala expansionsfasen av elvägssystem på grund av stora investeringar, omogen teknologi och behovet av övergripande kontroll i ett storskaligt system. Dessutom anses tidiga investeringar i ett storskaligt system vara oattraktivt hos de privata aktörerna på grund av de höga riskerna. Det kan dock argumenteras för att OPS-strukturer eller privat ägande är passande för slutna system då nivån av komplexitet är lägre. Dessa system borde subventioneras av staten då de kommer driva innovation och stimulera utvecklingen. Beroende på graden av kapitalintensitet och statliga regleringar, skulle OPS-strukturer också kunna vara lämpliga för ett nationellt system, när systemet har mognat. De föreslagna intressentstrukturerna med tvärsektoriella systemleverantörer underlättar för en möjlig framtida OPS-struktur.

Acknowledgement

This master thesis finalizes our master of science in Industrial Engineering and Management at KTH Royal Institute of Technology. We are grateful for the opportunity given by KTH Royal Institute of Technology and the Swedish National Road and Transport Research Institute (VTI) which enabled this thesis. We want to direct a special thanks to our supervisor at KTH Royal Institute of Technology, Stefan Tongur, for all his support and engagement during our thesis. We are very grateful for the guidance from Sofia Lundberg, our supervisor at the Swedish National Road and Transport Research Institute, who has been extremely helpful and has introduced us to many interesting people. Finally, we want to express gratitude to all the interviewees for their engagement and valuable input.

Emma Bednarcik Abdulhadi and Marina Vitez
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List of Abbreviations and Definitions

ERS	*Electric Road Systems* are defined as roads which support dynamic power transfer to vehicles while driving.
PPP	*Public Private Partnership* is a collaboration between a public actor and at least one private actor in which the private actor provides a service or a project and are responsible for part of the financing, design, construction, operations and/or maintenance of the public service.
Large-scale system	Refers to a national system which connects regions. An example of a large-scale system is if Stockholm, Malmö and/or Gothenburg were to be connected by electrified roads.
Small-scale system	Refers to a system on a local level. An example of a small-scale system is if roads within a logistics area or a city were to be electrified.
Closed system	Refers to a system with a limited number of users That is not open for society.
Open system	Refers to a system which is a part of the public infrastructure and is available for society

1 Introduction

This master thesis is written on behalf of KTH Royal Institute of Technology and the Swedish National Road and Transport Research Institute (VTI). The study aims to investigate how infrastructure ownership could affect the transition from small-scale to large-scale ERS and how it affects the foreseen future roles of the ERS stakeholders. This chapter begins with a problem background of the subject in question and further describes the purpose of the study. The chapter explains why the subject is relevant both from a scientific and industrial perspective and how the study contributes to each perspective. Lastly, the contributions and delimitations of the thesis are presented.

1.1 Problem Background

The transport system is a large sociotechnical system, which has evolved over the last 100 years. The system is highly complex as it includes numerous stakeholders, organizations, institutions and technological components which are deeply interdependent after co-developing over time (Geels, 2002). As the system is characterized by a high level of complexity, capital intensity and asset durability, it is difficult to accomplish radical system transitions (Markard, 2011).

Recent political regulations and progressive environmental targets have created a demand for new solutions within the transport system. The Swedish political ambition is to have a national vehicle fleet which is independent of fossil fuels by 2030 (Trafikverket, 2012). In order to reach the ambitious target, it will be necessary to develop and re-evaluate the current infrastructure, since efficiency development and re-planning of the transport logistics are forecasted to be insufficient (Trafikverket, 2013). Consequently, a window of opportunity for new innovations is created.

There is no leading solution for how the environmental target for the transportation sector is to be reached. One widely discussed alternative is ERS, which are considered to be a beneficial solution from both an environmental and socio-economic perspective. ERS are defined as roads which support dynamic power transfer to vehicles while in motion. A large-scale deployment of ERS would imply a system transition within the transport sector. The vision is to build large-scale ERS which connect cities and enable electricity charging for heavy-duty vehicles during transports, compensating for the insufficient battery capacity and allowing the vehicle to be driven on stored electricity in between the ERS. Naturally, a change of the current transport system would imply an impact on most of the system actors (Tongur, 2013).

The main identified barriers for a transition towards ERS are related to the complex system design as the high number of subsystems and components would have to change simultaneously. To manage a transition, the subsystems would have to be more closely linked compared to the current system (Tongur, 2013). There is currently a lot of ongoing research and several active demonstration projects of ERS around the world (Sundelin, 2016).

The traditional ownership structure and financing of infrastructure have been questioned due to the constrained governmental budget and the increased demand for new infrastructure investments. PPP, among else, has been discussed as a potential alternative to traditional financing of infrastructure within the transportation sector (Carbonara, et al., 2015). Historical cases of system transitions, such as the Swedish railroad and telecommunications development, have shown that infrastructure ownership has had a significant influence on the development (Hasselgren, 2011); (Blomström & Kokko, 2002).

The matter of how the ERS infrastructure should be owned and financed remains unclear and there is an intention to investigate a more diverse spectrum of ownership structures in general for transport infrastructure (RUAB, 2015). Due to the perceived difficulties with a transport system transition and due to the strong influence of infrastructure ownership in previous system transitions, it is vital to study the ownership structure's possible effects on the transition from small-scale to large-scale ERS. Consequently, it is also important to investigate how the ownership structure affects the foreseen future roles of the stakeholders within ERS and evaluate if there is any willingness to invest in the ERS infrastructure among the stakeholders.

This master thesis is made within the academic area of infrastructure system transitions and includes a case study of ERS, on which existing theory and historical cases will be applied. Actors within different ERS stakeholder segments will be interviewed in order to get a broad picture of the stakeholders' foreseen future roles within ERS and their thoughts on the ownership structure's effects on a future infrastructure transition from small-scale to large-scale ERS. Furthermore, the case study will include a closer investigation on one of the ongoing demonstration projects, eRoad Arlanda, in order to provide an understanding of the current state of ERS and provide an example of a small-scale project.

1.2 Purpose

The purpose is to investigate how infrastructure ownership could affect the transition from small-scale to large-scale ERS. The purpose is also to investigate how infrastructure ownership affects the foreseen future roles of the stakeholders within ERS and evaluate if there is any willingness to invest in the ERS infrastructure among the stakeholders. The deeply rooted, traditional structure of infrastructure ownership and financing will be compared to an alternative solution of PPP. The study will include interviews with both private and public actors in order to obtain different perspectives and a nuanced perception of what the ownership structure's implications are in the Swedish setting. The empirics will be analyzed in the academic context of infrastructure system transitions and will contribute to the academic area with new empirical material.

1.3 Research Questions

- How does infrastructure ownership affect the foreseen future roles of the stakeholders within ERS?
- How could infrastructure ownership affect the development from small-scale to large-scale ERS?

1.4 Contributions

This thesis will complement theory within the field of infrastructure system transitions and the ownership structure's effects on these transitions, by contributing with new empirical material within the area of ERS. There is a clear gap in literature regarding ERS ownership and financing, which also constitutes a barrier for a possible national deployment. The gap is rather expected as ERS have not yet reached a large-scale deployment in any part of the world. By studying both existing theories and historical cases, together with the empirical findings from the conducted case study, there is a possibility to bridge the gap in literature to some extent.

The study will contribute to an increased understanding of the possible effects of infrastructure ownership on the transition from small-scale to large-scale ERS. The study also provides an increased understanding of how the infrastructure ownership affects the foreseen future roles of the stakeholders and if there is any willingness to invest in the infrastructure among the stakeholders. By also mapping the stakeholders' incentives and perceived risks with participating in ERS, it is possible to better understand the rationale for their foreseen future roles. Lastly, the authors will give an ownership recommendation based on the case study, historical cases and existing theories within infrastructure system transitions.

This study is of high relevance from a sustainability perspective since it contributes with findings and conclusions which are necessary for an implementation of ERS. As stated earlier, ERS could contribute to the independency of fossil fuels within the vehicle fleet and the study is therefore strongly connected to sustainable development.

1.5 Delimitations

This study will concern only the ownership of the physical road and electricity infrastructure and not investigate the IT infrastructure or any required additional technical components for heavy-duty vehicles. Furthermore, it is not within the scope of this thesis to investigate the technology of ERS on a detailed level nor to conduct a detailed investigation of the technology of services or solutions connected to ERS. Thus, the related literature of the mentioned fields will not be reviewed.

The traditional ownership structure of infrastructure and private actor financing, through PPP, will mainly be investigated when studying infrastructure ownership and financing. There is a wide set of literature that could be investigated within the area of infrastructure ownership and financing. There are a number of methods and possibilities to increase allocated capital to infrastructure, such as increased allocation from the government, pension fund financing, public debt financing and municipal financing, among else. An investigation of the mentioned methods is not in the scope of this thesis.

Interviews with stakeholders will be conducted within the following segments; agencies, electric utilities, road carriers, construction firms and road power technology firms. These actors are either strongly connected to the industrial system perspective as they are administrative authorities or strongly connected to the physical road and electricity infrastructure. Additional stakeholder segments will not be investigated.

1.6 Thesis Outline

Chapter 2 – Methodology: The research approach and the chosen method for collecting and analyzing data is presented and discussed. The chapter describes how the chosen method is sufficient for answering the research questions and also discusses the reliability and validity of the study.

Chapter 3 – Theoretical Framework: The chapter presents the theoretical framework of this thesis and aims to provide a broad picture of today's knowledge within the areas of infrastructure system transitions and infrastructure ownership.

Chapter 4 – Empirics: The chapter is divided into the subchapters: *Case study background* and *Empirical findings*. The case study background aims to explain the phenomenon of ERS and how the discussion regarding a possible implementation has emerged. Barriers for a large-scale ERS deployment is also discussed. As ERS are a rather new phenomenon, the case study background is mainly based on information and documents which are non-scientifical. Further, the empirical findings are presented and summarized for each stakeholder segment.

Chapter 5 – Discussion: The empirical findings are analyzed in relation to the theoretical framework and the most important and central subjects for discussion are presented. The discussion is divided into the subchapters: *stakeholders' future roles and their willingness to invest in ERS*, *the necessity for cross-sectorial system suppliers*, *the implications of cross-sectorial system suppliers as infrastructure owners*, *the ownership structure's effect on the ERS transition* and *future work*.

Chapter 6 – Conclusions: A summary of the main conclusions of the study and the author's recommendations are presented.

2 Methodology

In the following chapter the chosen method for conducting the study and to answer the research questions is presented. In the beginning of the chapter, the research approach and why it is suitable for the purpose of the thesis is described. Thereafter, the research process is described in detail and discussed. Finally, the reliability and validity of the method are discussed.

2.1 Research Approach

The research area of this thesis is infrastructure system transitions and the ownership structure´s effect on these transitions. The methodology that has been chosen for investigating the subject is divided into a literature study and a case study within ERS. The literature study was conducted to generate a theoretical framework in order to increase the understanding of the empirical context. Within the case study, an empirical case study background and an interview study have been conducted, as an approach to investigate the chosen area. The purpose of the case study was to gather empirical material from different stakeholder segments within ERS and to analyze and discuss the findings together with existing theories and historical cases of infrastructure transitions. The case study will contribute to the academic field of ownership structure´s effect on infrastructure system transitions with new empirical findings within ERS.

The studied phenomenon is considered to be highly complex as it concerns transitions within the transport system, which is strictly regulated on a governmental level and includes numerous subsystems, components and stakeholders (Geels, 2002). As the quantitative approach is criticized for reducing the complexity of the investigated phenomenon in question, it would not be a sufficient approach for this research (Collis & Hussey, 2014). When conducting a case study it is possible to gather rich, empirical material which captures and explains the complexity of a phenomenon which is necessary for this study (Blomkvist & Hallin, 2015). It also enables an in-depth knowledge and can generate original results since the phenomenon is studied in its natural context (Collis & Hussey, 2014). In addition, a case study was chosen as a method due to the authors' beneficial accessibility to the local ongoing demonstration project, eRoad Arlanda, which consists of numerous relevant stakeholders. The authors also had accessibility to stakeholders outside of eRoad Arlanda, mainly due to the extensive contact network of the supervisor at the Swedish National Road and Transport Research Institute.

The research approach of this study is considered to be abductive. As ERS are rather unexplored, which implies a gap in literature, there were limited literature to investigate within the area in the beginning of the study. The authors were forced to initially gather some empirical material in order to better understand the phenomenon. However, there are some areas connected to the study which have earlier been explored and documented, such as infrastructure system transitions and the ownership structure's effects on historical transitions. It was also possible to initially study some existing literature within ERS. The available literature and previously conducted studies allowed the authors to frequently compare the empirical findings with existing literature, which is why the research approach is considered to be abductive. However, since there is a clear gap in literature in some of the

areas, such as ERS, the research approach is considered to be strongly influenced by an inductive approach.

This study has both a descriptive and exploratory purpose. It is descriptive since infrastructure system transitions and infrastructure ownership have previously been thoroughly investigated. However, the thesis is also exploratory since ERS are a relatively new and unexplored phenomenon, as it has not yet been deployed at a large-scale in any part of the world. Hence, there is a lack of earlier investigations and cases to review within the area (Blomkvist & Hallin, 2015).

2.2 Research Process

The study was conducted during a period of 20 weeks during the spring of 2016. The subject of the thesis was originated from the Swedish National Road and Transport Research Institute and KTH Royal Institute of Technology. The authors were initially given a wide problem formulation, which was further refined during the preliminary investigations and with the guidance of the supervisors. In figure 1 the different phases of the research process are illustrated.

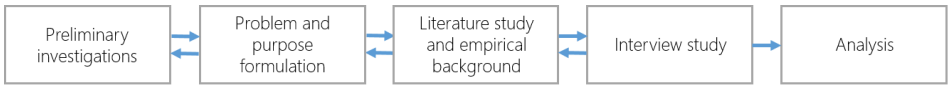

Figure 1: Research process

The research process was iterative rather than linear, since new, gathered empirical material resulted in the emergence of new areas that needed to be reviewed. During the period of which the interviews were conducted, literature connected to the empirical material was read and reviewed simultaneously. An iterative research process was considered as suitable since there initially was a lack of a clear hypothesis due to the rather new and unexplored phenomenon. Consequently, new findings appeared frequently, which affected the direction of the study and also the final discussion and conclusions (Blomkvist & Hallin, 2015).

Some preliminary investigations were conducted in the beginning of the research process in order for the authors to start navigating and understanding the context in which the study would be performed (Collis & Hussey, 2014). Seminars and meetings regarding different aspects of ERS were attended and several discussions with the supervisors at the Swedish National Road and Transport Research Institute and KTH Royal Institute of Technology contributed to a greater understanding of ERS in general and the challenges for reaching a large-scale deployment.

A literature study and an empirical case study background was conducted simultaneously in order to gain knowledge of the studied phenomenon, as well as investigate what had already been studied within area. In the beginning of the process, a wide spectrum of material within the area of ERS, system transitions, technology shifts and ownership structures was reviewed in order to find an appropriate focus of the thesis. The initial material review was necessary when refining and specifying the problem formulation. Finally, a gap in the existing material could be found and the purpose of the thesis and research questions could be formulated.

The chosen material was also necessary to review in order to conduct interviews with relevant and carefully prepared questions and also to be able to analyze the material. However, due to the abductive research approach, not all literature areas were reviewed before conducting the interviews since new interesting and relevant areas of literature were discovered during the interviews and explored afterwards. Furthermore, the used literature has been critically reviewed as the made assumptions and used methods have been acknowledged (Blomkvist & Hallin, 2015); (Collis & Hussey, 2014).

The reviewed literature and empirical material are presented in two different sections, *Theoretical framework* and *Case study background*. The theoretical framework strictly presents existing academic theories within the areas of infrastructure transition and infrastructure ownership, while the case study background presents both academic and empirical material related to the case study in order for the reader to better understand the phenomenon of ERS. The separation of the two sections is also reasonable from a scientific perspective as there is limited scientific literature within the area of ERS.

Finally, the empirical findings were analyzed together with the reviewed literature which resulted in a discussion of the most important findings and conclusions.

2.2.1 Literature Study

The literature study was initiated early in the research process to create a theoretical framework in order to increase the understanding of the empirical context. Literature within the areas of infrastructure transitions and infrastructure ownership have been reviewed. Within the area of infrastructure transitions, a sociotechnical perspective on transitions was reviewed and literature regarding barriers for transformation in the infrastructure and transport sector were studied. The area of infrastructure ownership was studied through the subareas of infrastructure systems as natural monopolies and the implications of PPP. Two historical cases, the Swedish railroad and telecommunications development, were also studied in order to gain knowledge regarding how ownership structure affected these system transitions.

The reviewed literature is based on strictly scientific articles, reports and books. The scientific articles that have been reviewed have been published in journals such as *Journal of Infrastructure systems*, *Technovation* and *Research Policy*. The literature study is based on material that have been extensively reviewed in a scientific manner before publishing and is therefore considered as highly credible. The scientific material is presented in the *Theoretical framework* section in this thesis. The material has been found through various channels.

Many of the scientific articles have been found through Google Scholar or KTH Primo, which is a search tool for scientific articles, reports and books provided by the library at KTH Royal Institute of Technology. Some scientific articles have been given to the authors either from the supervisors or have been recommended by the interviewees.

2.2.2 Case Study

ERS were chosen as case study since ERS have been discussed as a possible solution to the environmental challenges of high emission levels within the heavy-duty transport sector. A transition to ERS would require large investments and due to governmental budgetary constraints there is a necessity to investigate new financing solutions. Investigations on alternative financing solutions open up for the discussion of having an ownership structure where both private and public actors are involved. ERS are therefore suitable as a case study within the research area of ownership structure´s effect on infrastructure system transitions.

2.2.2.1 Empirical Case Study Background

Presenting an empirical case study background was necessary in order for the reader to understand the phenomenon of ERS and the background to why this study is of relevance. In the case study background section, information pointing to a sense of urgency for a technology shift within the transportation sector, due to political restrictions and environmental goals, are presented. The concept of ERS is thereafter explained thoroughly and it is explained why ERS are perceived as a possible solution to the environmental issues. Finally, the Swedish ongoing demonstration project eRoad Arlanda is presented.

The information presented in the case study background section is mainly gathered from non-scientifically reviewed sources, since there is a limited number of scientific articles within the area of ERS. Though, some scientific articles have been used in the section as well. The reviewed reports written by authorities have been written by well-established and trusted authorities such as the Commission of Infrastructure (Infrastrukturkommissionen), International Energy Agency (Energimyndigheten), the Swedish National Road and Transport Research Institute and the Swedish Transport Administration (Trafikverket). Also, a few number of webpages have been used, such as *www.naturvardsverket.se* and *www.trafikverket.se*, where the source of the webpages have been critically analyzed before the material were used. Several of the reports published by agencies have been recommended by the interviewees during the interview study or have been given to the authors by the supervisor at the Swedish National Road and Transport Research Institute.

2.2.2.2 Interview Study

An interview study was conducted in order to be able to answer the research questions of this thesis. Due to the fact that ERS are a relatively unexplored phenomenon and consequently the lack of enough relevant quantitative information to gather, an interview study was considered as a suitable method. Interviews are an appropriate approach since it is difficult to form hypotheses regarding the new subject. Therefore, conducting surveys was not considered since the questions have to be determined and formulated in advance. In addition, there is no possibility for spontaneous follow-up questions when conducting surveys, which was necessary in the study of this phenomenon in order to obtain all relevant information from the stakeholders (Collis & Hussey, 2014).

To answer the first research question, which regards how the infrastructure ownership affects the foreseen future roles of the stakeholders within ERS, it was important to understand the overall incentives for the stakeholders to participate in ERS and the stakeholders´ overall perceived risks and barriers with ERS. Additionally, in order to understand how the ownership structure affects the stakeholders' foreseen future roles, it was also important to investigate the stakeholders' willingness to invest in the infrastructure. Furthermore, it made it easier for the stakeholders, which sometimes had limited knowledge about ERS, to answer questions regarding their future role when they first were asked to talk about their overall incentives, risks and barriers and willingness to invest. Hence, the interview questions were formulated to answer to the following categories; overall incentives, overall perceived risks and barriers, willingness to invest and future role. The empirical findings connected to the first research question are presented in these categories.

In order to answer the second research question regarding how the ownership structure affects the development from small-scale to large-scale ERS, it was important to interview the stakeholders about this matter, as they possess knowledge about the different systems that would be part of ERS, such as the transport and energy system. In the empirical finding section, the answers connected to this research question have been presented in a fifth category (in addition to the previous four connected to the first research question) called ownership structure´s effect on ERS development. The five categories, which the interview questions have been based on and are used to present the empirical finings, are displayed in figure 2.

Figure 2: Categories used to present empirical findings

The current transport system can be conceptualized by figure 3. In Sweden, the system designers are the government and the Swedish Transport Administration. The Swedish Transport Administration is responsible for the procurement of various products and services connected to the transport system. The providers of these products and services are referred to as sub-system suppliers, which are active in certain segments. This conceptualization is inspired by Tongur (2013). The chosen actors for the interview study will be characterized both by their stakeholder segment and by their conceptual level within the transport system in accordance with figure 3.

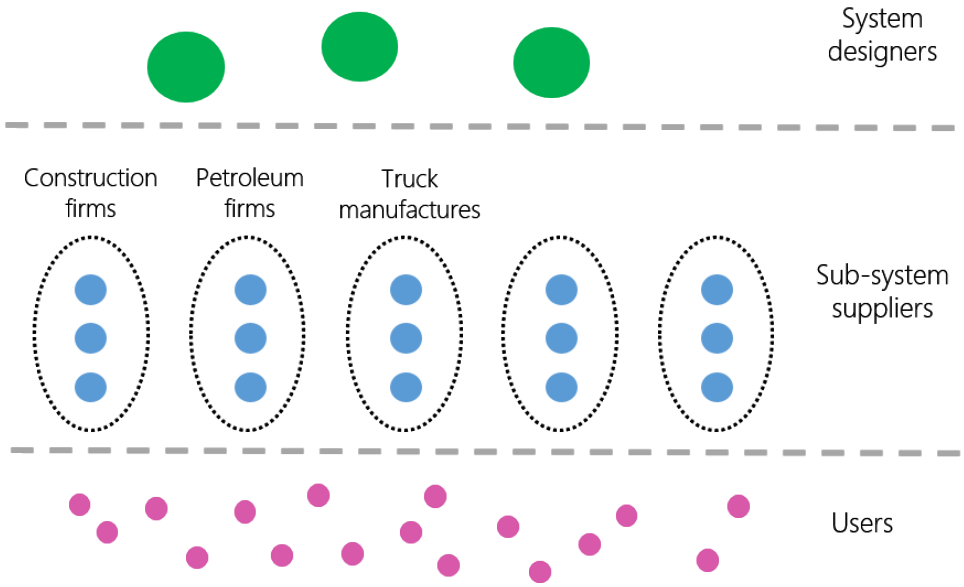

Figure 3: Conceptual model of the current transport system

Interviews have been conducted within the stakeholder segments; agencies, electric utilities, road carriers, construction firms and road power technology firms. Furthermore, the segments construction firms, electric utilities, road power technology firms are characterized as sub-system suppliers. Agencies are characterized as system designers and road carriers are characterized as users. The reason for conducting interviews within the mentioned stakeholder segments is that the stakeholders are currently involved in the large systems that would become a part of ERS if they were to be deployed. As the stakeholders possess deep knowledge about these systems, it is of high significance to obtain their input regarding ERS. Lastly, both private and public actors are highly active in the mentioned systems and the stakeholders can thus contribute with their experiences of these interactions. Due to the mentioned reasons, it was of high relevance to interview stakeholders within the segments about their future role in ERS and how they believe that the development of ERS will be affected by the ownership structure.

Interviews have been conducted with stakeholders both within the project eRoad Arlanda and stakeholders who were not yet involved in ERS at the time of the study. The number of included actors in the interview study within each segment and the number of conducted interviews are presented in table 1. A detailed list of the conducted interviews is displayed in Appendix A.

Table 1: The number of actors and interviews within each stakeholder segment

	Agencies	Electric Utilities	Road carriers	Construction firms	Road power technology firms
Total number of interviews	6	3	3	2	2
Number of actors	3	3	3	2	2

The small-scale setting was both interesting and important to investigate since it could provide a deeper understanding of the ownership structure's implications in a local, small-scale setting. It could also provide an understanding of the possibilities of extending the ownership structure concept and apply it at large-scale. Therefore, it was important for the purpose of the study to conduct interviews with project members of eRoad Arlanda. Some additional questions were added in the interviews with the owners of RUAB, which is the formed corporation that takes care of eRoad Arlanda's businesses, regarding their incentives for investing in an ERS project and their perceived risks. Furthermore, the involved stakeholders of eRoad Arlanda have actual experience from ERS, which is valuable in such a new and unexplored phenomenon. These stakeholders obviously see benefits with participating in an ERS project. Their experiences are of great interest and could be a necessity in order to understand the implications of ownership structure when developing ERS into larger systems as well. One of the owners of RUAB, Kilenkrysset, was not interviewed as they don't have an active role in the project eRoadArlanda.

Complementary interviews with stakeholders within the different segments were however necessary in order to be able to study the trends within the chosen segments, since eRoad Arlanda has a very limited number of stakeholders within each of the selected segments for the study. Another reason for conducting interviews outside eRoad Arlanda was to remain indifferent and unattached to the different ERS technologies and only study ERS as a system concept. Since the stakeholders may represent and promote different technologies it was important to get diverse inputs from the chosen stakeholder segments. In addition, the companies' characteristics, in terms of financial resources among else, more or less differ between the stakeholders within each segment. Adding stakeholders within each segment ensures a wider perspective on the phenomenon and enables a result which is representative for various cases and environments.

Data Collection from Interviews

The empirical findings were gathered by performing semi-structured interviews with the stakeholders in order to gather as much valuable information as possible from the interviewees since it opens up for elaborated answers. Semi-structured interviews with open-ended questions are used as it is difficult to formulate a hypothesis due to the complex and rather unexplored phenomenon (Collis & Hussey, 2014). Also, by semi-structured interviews and open-ended questions, the authors were able to obtain a flexibility in the interviews, which was positive as the interviewees sometimes had deeper knowledge regarding the subject than the interviewers and they were allowed to speak freely about the subject

(Easterby-Smith, et al., 2012). When allowed, the interviews were audio-recorded to focus all attention on reflecting and responding to answers from interviewees and creating a beneficial interview climate.

In total, 16 semi-structured interviews were conducted. A detailed overview of the conducted interviews can be viewed in Appendix A. To the greatest extent possible, the interviews were conducted through personal meetings in a calm setting. At some occasions, when there was no possibility to meet in person due to geographical distances, the interviews were conducted over the phone. During the phone interviews, there was a limited possibility to make audio-recordings and notes were taken instead. During the phone interviews, both authors were present and listened to the interviewee's answers where one of the authors was solely focusing on asking the questions while the other one was taking notes. In total, 5 of the 16 semi-structured interviews were conducted over the phone. Commonly, both authors participated during the interviews which implied that both authors had a chance to interpret the answers which gave the authors an opportunity to discuss and compare interpretations when necessary, which enabled the authors to detect occasional misinterpretations. However, occasionally one of the authors could not participate during the interviews which changed the dynamics of the interviews.

In the beginning of every interview the purpose of our research was explained and the interviewee clarified their role within the company, agency or organization. Thereafter, one of the authors conducted the interview by asking questions while the other one was listening and occasionally asked spontaneous follow-up questions. By letting one interviewer take the lead and ask the questions that person could focus on that all the prepared questions were covered during the set out time. Meanwhile, the other person could focus on analyzing the answers given and ask complimentary questions which provided us with more elaborated answers. Also, it created a convenient dialogue environment.

Data analysis

The interviews were transcribed throughout the interview study by listening to the audio-recordings. When all interviews within a stakeholder segment had been conducted and transcribed, the empirical material was analyzed and the empirical findings were formulated. Both the trends of commonly expressed opinions and also different opinions raised by the interviewees are presented in the chapter of *Empirical findings*. In order to provide the reader with a clear overview, the trends within all stakeholder segments are presented in a matrix in the beginning of the empirical findings chapter. These trends are further elaborated in the subsections about the stakeholders. Within each subsection, matrixes with the different raised opinions by each actor are presented.

When the empirical findings were written for all stakeholder segments, the authors contacted the interviewees in order to ensure that the interviewees felt comfortable to be addressed in the conducted manner. The interviewees were also given the opportunity to read the material to get an understanding of how the material was presented, they also had the possibility to make corrections and to approve the material.

After compiling the empirical findings, they were analyzed in relation to the theoretical framework and an in-depth discussion regarding the ultimate findings could be written. Thus, the findings from the interviews in combination with the literature study and the case study background compose the base for the discussion and conclusion of the thesis. Preliminary results were presented continuously for the supervisor both at the Swedish National Road and Transport Research Institute and KTH Royal Institute of Technology in order to verify the direction of the thesis and to gain essential input on future work.

2.2.2.3 Writing the Report

The report has continuously been written throughout the study. The sections have been written, updated, deleted and added due to the emergence of new findings, resulting in the necessity to read and review new literature and theory during the study. The research questions have also been updated throughout the study. Initially the research questions were wide, but after gaining knowledge about the research area they could be re-formulated into more specific questions. Moreover, different ways of presenting the material have been tested in order to find a suitable way to present in order to facilitate for the reader.

2.3 Sensitivities

When conducting a case study, it is important to work systematically, both when selecting a case, selecting data gathering method and during the analysis, to be able to discuss the general phenomenon. It is also of high relevance to explain and reflect over every choice and how the research have been conducted (Blomkvist & Hallin, 2015). A structured method chapter is therefore presented to increase the systematic level of the execution of the study.

One troubling aspect of conducting a case study is that the execution is strongly affected by the researcher. The result and conclusions drawn from the case study are more or less influenced by the researcher's opinions as it is difficult to make statistical generalizations and a numerical analysis of the empirical material. Thus, it is only possible to make an analytical analysis of the material (Yin, 2009). Also, by using interviews as a method, there is a risk of a lack of reliability due to interviewer bias and the interviewer's interpretation of the answers. The researcher can affect the answers given from the interviewees by acting in a certain manner. The way a question is asked or how the interviewer behaves have shown to have an extensive effect on the interviewee, which could affect the result of the study (Holt, et al., 2015). The researchers have tried to remain neutral in their opinions and have tried to treat all interviewees equally during the interviews in order to reduce the risks for interviewer bias. However, there is no possibility to completely eliminate interviewer bias, which should be considered in relation to the result and conclusions drawn from the study (Holt, et al., 2015). When analyzing the material from the interviews, it has to be determined if the interviewee is giving their personal opinion or giving a policy statement. The interviewee may also adjust their answers to what they think is a correct or wanted answer, which affects the reliability of the study. To reduce the risk, the depth of the interviews should be increased (Collis & Hussey, 2014). This was done by asking the interviewee to explain in more detail and to give examples. Since a literature study is conducted in addition to the case study, the credibility of the thesis increase, as the empirical findings can be compared and analyzed in comparison to existing literature.

There are some additional risks regarding using an interview study as a method for data collection, as it is difficult to replicate the interviews which is one way to ensure reliability. At least two interviews were conducted with stakeholders within each segment, and with stakeholders in several segments in order to generate both valid and reliable findings from the interviews. The findings are thus highly affected by the interviewed stakeholders and the reliability of the findings from each segment had been increased if a larger number of interviews within each segment had been conducted. However, this was not possible due to the limited timeframe of the thesis. Furthermore, as the chosen stakeholder segments for the interview study are considered to have an in depth knowledge about the systems that will be affected by an ERS transition, such as the transport and energy system, the choice of stakeholders is considered to increase the validity of the study. The chosen stakeholder segments will both be affected by and have an effect on a future transition to ERS, which is why their opinions and views are important in order to answer the research questions.

A sensitivity of the interview study is also that the level of knowledge within ERS and ownership structures have affected the answers of the interviewed stakeholders. During the study, the authors have experienced large variations in knowledge among the actors. Moreover, some of the interviewees advocate ERS, which also influenced their answers. Some stakeholders had very limited knowledge about ERS, which made it necessary for the authors to explain the concept for the interviewee further, which also could affect the given answers. Furthermore, some of the stakeholders have been involved in PPP projects earlier and they have hence real experience of such an ownership structure, while some of the actors had no or limited experience, which affected also the answers.

As mentioned, after the empirical findings had been written, the authors contacted the interviewees in order to ensure that the interviewees felt comfortable to be addressed in the conducted manner. Hence, the interviewees were also offered the opportunity to remain anonymous in the written report as well as the company in question. The interviewees were also given the opportunity to read the material to get an understanding of how the material was presented, they also had the possibility to make corrections and to approve the material. This was an opportunity to ensure the validity and reliability of the empirical material. In addition, the generalizability of the study is considered to be high within the ERS sector since several actors within different relevant segments have been interviewed. Since the study is strongly connected to the ERS infrastructure and technology, the generalizability is considered to be limited when applying the results on other infrastructure transitions with differing characteristics.

3 Theoretical Framework

This chapter presents the theoretical framework for this thesis and aims to provide a broad picture of today's knowledge within the areas of infrastructure transformation and infrastructure ownership. The section about infrastructure transformation provides a sociotechnical perspective on transformation, as well as highlighting the barriers for transformation within the infrastructure sector and transport system. The section about infrastructure ownership enlightens the characteristics of the infrastructure sector which are important in order to understand the implications of infrastructure ownership. The section also includes current knowledge regarding PPP and presents two historical cases.

3.1 Infrastructure Transitions

It is argued that infrastructure transition should be studied by integrating research on sociotechnical transitions and infrastructure. Transitions within the infrastructure sector is discussed from a sociotechnical perspective since infrastructure transitions do not solely require technological change but also changes on an institutional and organizational level (Loorbach, et al., 2010).

3.1.1 A Sociotechnical Perspective on Transformation

Hughes' (1987) Large Technological System (LTS) framework is eminent within the area of sociotechnical systems and describes the links between physical components, institutions and organizations as strong and deeply interconnected, due to the historical, long term development of the system. Geels (2002) explains how technological transitions occur by an evolutionary multi-level perspective, which has been developed from both evolutionary economics and technology studies. Geels (2002) defines a technological transition as "…major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled". The multi-level perspective comprises of three levels; sociotechnical landscape, sociotechnical regime and niche, shown in figure 4.

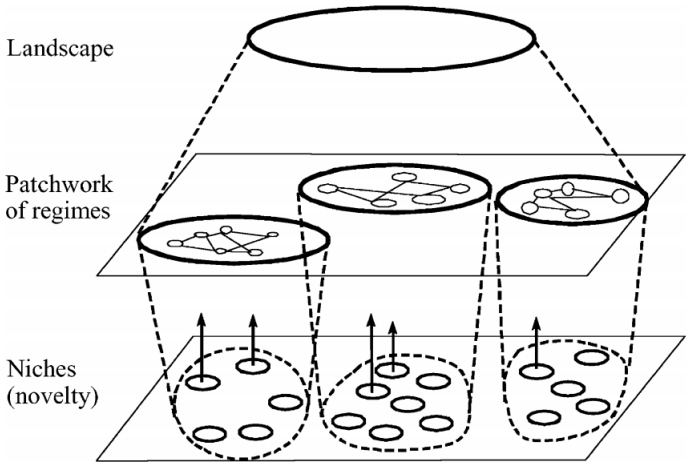

Figure 4: The multi-level perspective (Geels, 2002)

The sociotechnical landscape is macro-leveled and consists of robust, slow changing parameters which set rules for the sociotechnical regime. Moreover, it includes cultural factors, demographical trends and political variations. The sociotechnical regime comprises of a cohesive set of rules for how things are and how things are done which provides stability. The market selection is managed on the sociotechnical regime level. Incremental innovations occur in the sociotechnical regime in accordance with technological trajectories. Radical innovations occur on niche-level as the level is protected from natural market forces, which allows new technology to develop in an incubator-like environment. Radical innovations struggle to break through the regime wall and as a result often stay at the niche-level. In order for a technology transition to occur it requires an aligned development over the three levels, and thus is a complex process. Radical innovations created on the niche-level could break the wall into the next level if there is a window of opportunity, which is created by tensions, or unevenness, in the sociotechnical regime (Geels, 2002).

Hughes (1992) also describes unevenness as the driving force of development, where bulges of far developed technology, so called "salients", in the technological forefront create incentives for other technologies to move forward, while "reverse salients" are underdeveloped technologies in the technological forefront which hinder the development. Thus, it is unevenness in the technological forefront that drives the technological development forward.

There is a clear difference between radical innovation and incremental innovation, state Tongur and Engwall (2014). Incremental innovations are in line with the established trajectories within the current paradigm, while radical innovations are not. Radical innovations have the ability to destroy competence as previous knowledge could become outdated. Historically, several paradigm shifts have taken place as a result of a radical innovation which have implied a change of the fundamental conditions on the market. Consequently, a shift of paradigm is fatal for many market actors if they are not capable of making the necessary internal adjustments. The difficulty of adjusting to the new paradigm is not only a technical matter, but an internal business model dilemma since previous core competences could have become outdated and the new technology might require a different set of competences (Tongur & Engwall, 2014).

3.1.2 Barriers for Transformation in the Infrastructure Sector

Markard (2011) has studied the implications for transformation within the infrastructure sector and presents a framework from which an analysis is made. There are seven key dimensions which affect the transformation ability which are capital intensity, asset durability, regulation intensity, environmental impact, public organizations, competition intensity and systemness. Markard (2011) concludes that due to the high degree of systemness, capital intensity and asset durability in the infrastructure sector, it is difficult to accomplish transformation. Strong public involvement and regulations are also factors that characterize the infrastructure sector. Low competition is also a sector specific characteristics, since infrastructures are likely to become natural monopolies due to high capital intensity. Together, the characteristics implicate that transformation of infrastructure mainly occurs incrementally and in accordance with existing development paths, rather than radically (Markard, 2011).

Markard (2011) further explains how these factors constitute barriers for transformation within the sector. Both technical and non-technical components are strongly interdependent in infrastructure systems as the components have co-developed over time. Hence, there is a high degree of systemness as the system design is complex. There is a requirement for technological fit and institutional and organizational compatibility, in order to enable transformation. Further, the high level of capital intensity and asset durability tends to create a resistance among the actors who have invested in the infrastructure already. It also facilitates for natural monopolies as there is a great financial barrier to enter the market (Markard, 2011). Asset durability also implies a risk for the investor due to the possibility of changes in the political and regulatory framework during the asset lifetime (Dominguez, et al., 2009).

Markard (2011) also argues that the main incentives for transformation is a large necessity for re-investments in the existing infrastructure and a negative environmental impact. The environmental aspect is highly discussed and affects the demands on the infrastructure sector. It is therefore of relevance to discuss the barriers for this transformation.

3.1.2.1 Barriers for Transformation in the Transport Sector

The transport system is a large socio-technological system which have evolved over the last 100 years. The system is complex as it includes loads of subsystems, components and stakeholders such as cars, gas stations, roads, manufacturing plants, service shops, infrastructure providers and building contractors. Furthermore, the socio-technological system is deeply rooted on the socio-technological landscape level as is strictly regulated on a governmental level (Geels, 2002). The many subsystems of the transport system are characterized by being autonomously operated by different stakeholders such as road authorities and truck manufacturers and gas companies among else. Naturally, a change of the current transport system would imply an impact on most of the system actors. The actors within the current transport system are all interdependent, as vehicles are dependent on both the infrastructure and fuel supply, and vice versa, which increases complexity of a potential paradigm shift (Tongur, 2013).

At the same time, the pressure on the transport sector to change increases as transport energy use has doubled during the last 30 years. Further, if no dedicated policies are applied, road travel is expected to double by 2050, mainly due to the emerging economies of the world (Dulac, 2012).

3.2 Infrastructure Ownership

National wealth is highly dependent on the infrastructure system such as transport, electricity supply, water supply and telecommunications as almost all other industries are dependent on these systems (Markard, 2011). Transport infrastructure has over the years been owned, financed and operated alternately by the government and private actors. The decision of ownership structure depends on if the government relies on market forces to manage the transport infrastructure or not. If not, the government intervenes and thus finances, owns and manages the infrastructure assets. The government and public agencies

often engage in the infrastructure sector due to its effect on national wealth and the high degree of capital intensity (Hasselgren, 2013).

3.2.1 Transport Infrastructure as Natural Monopolies

Traditionally, transport infrastructure assets have been discussed as natural monopolies as they are difficult to manage on market-basis (Hasselgren, 2013). Mosca (2008) presents an historical overview on studies made on natural monopolies, economies of scale and competition. Until the end of the 1970s, natural monopolies were considered to occur if economies of scale could be obtained over the entire market demand. Another description is that natural monopolies occur in markets where only one actor finds it profitable to act on the market. Mosca (2008) defines the characteristics of scale economies as the requirement of high fixed costs and low or zero variable costs. Thus, scale economies constitute a barrier of entry for market actors. Due to the fact that natural monopolies are seen as a market failure, it is necessary for the government to interfere in the market by e.g. nationalizations and regulations etc. Mosca (2008) describes transport infrastructure as a typically compatible sector for natural monopolies as the infrastructure requires high capital investments and a large infrastructure is necessary before it can be properly utilized.

Mill (1849) also argued for the entry barriers within the transport infrastructure sector due to its natural monopoly characteristics. It was meant that the requirement for the large initial investments only allowed a limited number of actors to enter the industry. It is further argued by Mill (1849) that the most profitable locations for transport infrastructure construction would be exploited first, only leaving the less profitable locations, which revenues do not cover the large fixed costs, for other potential investors.

Another researcher, Jules Dupuit, is described by Mosca (2008) as "a very strong supporter of the free markets". However, since Dupuit was convinced that the transport infrastructure system had strong characteristics of being natural monopoly compatible, Dupuit was supportive of governmental interference since Dupuit thought that a private monopolist might take advantage of the situation in a negative manner.

The mathematical economist Léon Walras is also highlighted by Mosca (2008) and has explained that competition is impossible in the transport infrastructure industry since only the government has the authority to give permission to exploit the land necessary to build the infrastructure.

3.2.2 Public Private Partnership

Governments all over the world have started to seek new alternative financing solutions for infrastructure since the need for development is increasing, both due to obsolete infrastructure and due to the continuous expansion of it, but also due to constrained governmental budgets reserved for investments in infrastructure, according to Carbonara, et al., (2015). The authors argue that a collaboration between private and public actors, PPP, can therefore be a potential alternative to traditional financing of infrastructure in the transportation sector.

Another author, Yescombe (2007), gives a broad insight into PPP in the book "*Public-Private Partnerships: Principles of Policy and Finance*". In the book, the author presents several aspects that describes what a PPP consist of. One aspect is the long-term contract between the public and the private actor and during the period of the contract is the private actor entitled to collect payments from the public actor or from the users of the infrastructure. Another aspect is that the private actor is responsible for part of the financing and either design, construction or operations and maintenance of the public infrastructure or responsibility for all of them. Finally, the author describes the last aspect, after the period of the contract the ownership of the public infrastructure is restored into publicly owned if the infrastructure was privately owned during the time of the contract.

Osei-Kyei and Chan (2015) have investigated vital success factors for PPP projects in their article. The identified factors are appropriate risk allocation and sharing between public and private actors, one private consortium with several companies in collaboration instead of only one private actor, the necessity of political support, having public and community support facilitates for the evolution of the PPP project and finally the necessity of transparent PPP procurement and implementation processes.

In the article by Carbonara, et al., (2015), the authors describe the possible benefits for the government by using a PPP structure in infrastructure investments. The benefits are connected to higher efficiency, higher quality, reduced cost and more reliable public infrastructure and in addition the potential benefits of the growth of the industry and the increased employment opportunities in the region.

Carbonara, et al., (2015) further discuss risk management in PPP and present guidelines for involved actors in a motorway case in their article. Before engaging in a PPP all actors have to consider and manage possible risks that can occur since several stakeholders will be involved thus higher complexity and the actors may have invested different amounts in the partnership. Additionally, the concession periods are characterized to be long, often several years or decades which brings further risk to the PPP. The mentioned risks include all the actors in the PPP but have to be divided between them, the risks have to be shared, transferred and retained since the actor who is most suitable to manage the risk should be the owner of it (Carbonara, et al., 2015).

Further, Yescombe (2007) describes arguments used by governments to promote a PPP structure and discuss different perspectives of these arguments. One of the topics in the debate is that it is questionable if a PPP structure actually enables for additional public infrastructure investments, according to the author, with regards to macro-economic theories where the argument that if public investments increase the private investments decrease resulting in the same amount of infrastructure investments overall. However, there have been few studies made on the topic which makes the support for the argument uncertain. There are also differing opinions regarding the possible higher financial cost in PPP projects due to the more expensive borrowing possibilities of capital for the private actor than the public, since lending capital to the public sector is connected to a lower risk for the lender. In addition, there are also several opinions regarding risk transfer and if the risks that are transferred to the private actors will be better managed by the private actor and for a lower cost. The argument for using PPP due to the benefits of economies of scale, since a total

solution can be constructed at once with financial means from a private actor instead of smaller parts at a time is also debatable. The author claim that the total solution could result in a high demand on construction firms which increases the price level and that small local construction firms and new entrants will be excluded from the competition of the larger projects. In addition, the argument that a PPP structure encourage the private actors to construct the infrastructure in a different way, if they also have responsibility for operations and maintenance of the infrastructure for some time after the implementation, is discussed. They will then minimize cost for their total period of responsibility instead of only for the construction phase of the infrastructure. Though, a public actor could also engage in a total solution including the delivery of design, construction, operations and maintenance with the same outcome according to Yescombe (2007). The author also discusses arguments regarding if PPP projects, enables for additional competencies of the private actors to be used which are not taken advantage of in traditional procurements. The author also argue that a PPP structure increase the complexity of the procurement of a project more than for a traditional procurement, resulting in longer procurement period and higher procurement costs (Yescombe, 2007).

There is also a widely political discussion regarding PPP structures for infrastructure investments presented in the book by Yescombe (2007). The main elements of the discussion are regarding the profits the private actor gains from investments that the public actor actually could have done themselves. Another element is if the private actor promotes their own collection of profit instead of functionality and safety of the public infrastructure. The final element of the political discussion is regarding the risk of the poor working conditions for the employees in PPP projects due to the prioritization of efficiency gains for the private actor (Yescombe, 2007).

There are also other types of public-private investments solutions. One example is described in the article by Hellowell and Pollock (2009) which is the NPD-model (Non-profit Distribution model) where profits to the private actors are limited. The surplus is returned to the government at the end of the contract instead of as for other models, where the surplus is given back to the private actors through dividends.

3.2.3 Historical Cases

In the following section two historical cases are presented. The first historical case is the Swedish railroad development and the focus is mainly on the great nationalization in the 1930s to 1940s and its implications. The case provides an example of the ownership's effect on the development. The second historical case regards the telecommunications industry and focuses on the technology shift during the implementation of GSM (Global System for Mobile Communications). The implications of the technology shift and the ownership structure during the development is enlightened.

3.2.3.1 The Swedish Railroad Development

Kullander (1994) has written about the historical railroad development in Sweden. The very first railroads in Sweden were short and privately owned and operated. In 1854 the government decided to build a main, large-scale railroad network, which stretched from north to south and east to west. While private corporations were left to constructed and operated

railroads outside the main railway network. Later on, when it was time to integrate the systems, in order to enable optimal utilization, difficulties occurred as the public and private railroads had been built with different track gauges and thus standards.

Hasselgren (2011) has analyzed the rationale behind the nationalization of the rail and road infrastructure in Sweden in the 1930s to 1940s. The development is studied based on an evolutionary model, as Hasselgren means that the transport infrastructure system can be seen as an evolutionary process, which is affected by technology, economics and politics. Public documents of the time have been investigated and have been used in the analysis.

Hasselgren (2011) describes that the government has been involved in the road and rail infrastructure since the 19th century. During the period of 1930s-1940s a drastic centralization was made, which resulted in a take-over by the government of the transport system assets. Before the radical shift to nationalization, the government had taken over some private assets in an ongoing centralization trend, due to the increased competition from the road sector. Before the nationalization, many railroads and roads were constructed and operated by private corporations. The historical development of the railroad system and the road system are described quite differently by Hasselgren (2011) as the government had been involved in the railroad development to a quite large extent compared to the road system development. Railroads were at the time market-based businesses but strongly dependent on governmental financing. The initial cost for construction was high, which called for financial support from the government and that the government absorbed a large share of the risk. This was absolutely necessary in order to enable the introduction of railroads which were a new technology at the time. The government's policy had included giving grants, concessions and loans to private railroad firms since the 1850s. As a result, approximately 70% of the railroad systems had been built and were operated independently by private actors before the great nationalization (Hasselgren, 2011).

During the 1920s-1930s the transport flows increased substantially and went from local flows to regional and national flows. Hasselgren (2011) describes that the two dominating arguments for a nationalization at the time were decreasing profits for railroad corporations and the difficulties for the many, local, private corporations to manage the increased transport flows. It was argued that the many small corporations were lacking an overall view of the system, which was considered to be required due to the national transport flows. Furthermore, Hasselgren (2011) describes that it was at the time perceived that the fragmented market and management structure made it difficult to introduce new technology due to the lack of overview. In addition, the structure was considered to be inefficient from a production and technology perspective. By nationalizing the system, coordination and planning were predicted to become easier and it was said that economies of scale would be possible to obtain. One other important argument was that a nationalization would result in an equalization of road taxes, which were high on the political agenda. Many of the corporations agreed on that the old structure had become outdated and that a nationalization would imply lower costs and a modernization of society with a national focus rather than a local focus (Hasselgren, 2011).

Blomkvist (2001) has studied the road development in Sweden and means that the nationalization of the road system had clear support from a large group of private actors, who were otherwise expected to promote a market-based solution and competition, rather than a governmental monopoly. The lobbyists were certain that the technological development would benefit from the centralization and thus benefit the system at large.

Counter arguments were also raised at the time, such as the necessity for competition in order to improve the efficiency and technology development. It was also argued that the large new organization would be too large in order to manage low costs and obtain efficiency. In the end, the arguments for a nationalization were considered stronger than the counterarguments (Hasselgren, 2011). According to another report by Hasselgren (2013), there was a strong opposition towards the nationalization from regional and local actors, which claimed that a nationalization would interfere with the local flexibility and influence.

Hasselgren (2011) also states that arguments based on socio-economics and discussions regarding natural monopolies were not put forward during the discussion, although the arguments are usually leading the economic discussions regarding transport infrastructure.

Hasselgren (2013) claims that the public ownership within the transport sector has not been questioned to any larger extent, which the author means could be perceived as a successful policy adjustment by the government. However, questions have been raised regarding alternatives for additional financing. Hasselgren (2013) means that the government has considered and nurtured the effects from technology, economics and politics and has created a well-functioning system, as the consensus suggest. Discussions regarding ownership and privatization have not been raised distinctly, according to Hasselgren (2013). At the same time, the author states that certain governmental agencies have been divested to private actors and a deregulation of rail transports has been made, among else, which suggests that there is an openness for an alternative ownership structure (Hasselgren, 2013). In Sweden the company "SJ" had a monopoly on operating the trains for a very long time (Alexandersson, et al., 2012).

In his report, Bogart (2009) has studied the cost inefficiency of the railroad sector between 1880s-1912 across a number of countries and investigates how the rise of state ownership has influenced railroad inefficiency over time. The period of 1870s-1913 was characterized by the rise of governmental ownership within the railroad sector globally. Before this period, the majority of the railroad infrastructure was privately owned. Bogart (2009) states that private ownership was believed to be more efficient compared to public ownership, as private ownership encourages competition and stimulates innovation.

Bogart's (2009) results show a great variance in the trends of inefficiency across countries. However, in general the study shows that nationalizations (a governmental take-over of existing assets) resulted in increased inefficiency, while governmental, new railroad constructions resulted in decreased inefficiency. Furthermore, a counterfactual analysis, also included in the report, proposes that the increase of state ownership lowered the inefficiency in most countries and in the most important economies that were included in the study. However, the effects within each country varied depending on how the state's ownership increased; by nationalization or new constructions. Moreover, Bogart (2009) emphasizes the

importance of a cost-efficient railroad system as inefficiency can imply substantial costs due to the size of the system and its' spillover effects on other industries.

Saltsjöbanan

During the 1890s there was a discussion and an intention to build a residential seaside resort close to Stockholm. Knut Agaton Wallenberg took the opportunity and bought the land that later became Saltsjöbaden. There was a necessity to create sufficient communications between Stockholm and Saltsjöbaden in order to make the area more attractive for residents and visitors. Therefore, Knut Agaton Wallenberg financed the construction of the railway Saltsjöbanan, which connected the center of Stockholm and Saltsjöbaden. The improved communications increased the land value in the area of Saltsjöbaden which was profitable for Knut Agaton Wallenberg. However, the railway was profitable from the start as it was utilized for goods traffic by companies which were located in Nacka and owned by Wallenberg. Saltsjöbanan was finalized in 1983. At the time it was quite common that railway companies bought land in the suburbs and constructed railways connections between the new area and the center of Stockholm in order to profit from the increasing land values (Svallhammar, 2008).

3.2.3.2 The Swedish Telecommunications Development

In the Swedish telecommunications industry, extensive standardization and liberalization processes have occurred. The processes have had high impact on implementation of new technology and the possible emergence of new entrants in the industry.

Standardization

Dunnewijk and Hultén (2007) present that the standardization process within the telecommunications industry in Scandinavia started in the late 1960s. The National Telecommunications Authorities in Scandinavia started the NMT-group (Nordic Mobile Telephone Group) which purpose was to create an analogue standard which enabled roaming between all Nordic countries by a system with low-cost infrastructure with no exclusive supplier rights but an open competitive system. The NMT-standard was developed during ten years and the high flexibility of the system, enabling roaming between and within the Nordic countries, was favorable compared to other standards (Dunnewijk & Hultén, 2007).

Henceforth, Dunnewijk and Hultén (2007) describe that within the telecommunications industry there were still several different standards worldwide for analogue mobile telephone systems in the early 1980s. According to Pelkmans (2001), a disadvantage with the analogue mobile telephone systems was the absence of interoperability of the systems and the impossibility of cross-border roaming. In 1982, the Conference of European Posts and Telecommunications (CEPT) gathered a group they called GSM (Global System for Mobile Communications, former Groupe Speciale Mobile) to develop a digital system standard for the mobile telephone with both public and private governance (Hultén & Mölleryd, 2003). GSM is a digital mobile system which is non-proprietary and interoperable with other systems (Pelkmans, 2001).

The Commission of the European Communities described that the incentives for having one digital mobile telephone standard was expected to benefit the European economic

development. The beneficial flexibility for the users could benefit the business life since availability would increase internationally due to the interoperable system and also due to the beneficial effects a single market would imply on the telecommunications industry in Europe. Concluding, the Commission of the European Communities advocated the importance of competition in the telecommunications sector (Hultén & Mölleryd, 2003). According to Pelkmans (2001) one incentive for constructing an international standard was the need of economies of scale since the market in individual West European countries was insufficient. The reason for the successful standardization and implementation of GSM are due to the collaboration of private and public actors, according to the author. The involvement at European Commitment level had high impact on the progress of the development of the GSM standard (Pelkmans, 2001).

According to Fuentelsaz et al. (2008) it was a high risk decision of CEPT to determine on a standard thereof ignoring the effect of market mechanisms in the selection process. On the other hand, Gandal et al. (2003) discuss the importance and the effects of how the standard of GSM was chosen, either through global regulation or through open market. Among others were price rates, technology development and deployment of the GSM technology in Europe and the United States affected by the decision. The global regulation approach was used to choose a standard in Europe and the open market approach was chosen in the United States, the decision made in Europe can be considered successful compared to the decision in the United States (Gandal, et al., 2003).

In the report by Blomström and Kokko (2002) the industrial evolution within several industries are presented. Regarding the Swedish market, the authors describe an important collaboration between Ericsson and the Swedish Telecommunications Administration (Televerket). The Swedish Telecommunications Administration was the owner of everything in the telecommunications sector and had full responsibility to operate the system in Sweden in the 1950s (Blomström & Kokko, 2002).

The company SRA (Svenska Radio Aktiebolaget) was formed by Ericsson, ASEA and AGA which initial purpose was to construct radio transmitters. The Swedish Telecommunications Administration and SRA started collaborating within mobile phone systems in the 1950s and the collaboration was successful when the NMT system, pitched by the SRA and the Swedish Telecommunications Administration in 1969, was approved to be developed. Since the development of the system lasted for a decade, the need for financing for this period was crucial. The NMT system could be seen as a “public good” in some way and Ericsson was not interested to invest in the system, though the Swedish Telecommunications Administration was interested to invest. The authors present several reasons for Ericsson´s success in the digital mobile system and terminal sector. One of the reasons was the collaboration with the Swedish Telecommunications Administration. The Swedish Telecommunications Administration provided with financing for long periods of time during the R&D for the NMT system and also during the time for the development of the GSM technology. The Swedish Telecommunications Administration was involved early in the development processes and invested in the systems when the risks were perceived to be high and when the revenues and benefits were unclear. The collaboration between the private and the public actors therefore enabled the development and construction of the mobile phone systems (Blomström & Kokko, 2002).

Concluding in the article by Blomström and Kokko (2002), the authors display important findings common for different sectors. Common for several findings are the importance of the involvement of public actors in technology shifts. Both regarding long-term financing solutions from public actors enabling extensive R&D, institutional reforms affecting growth and development and how public or semipublic actors facilitate distribution of knowledge and research. However, the author express some risks connected to such a collaboration, it often results in high cost and is not beneficial to stimulate a competitive business environment. The authors describe that the direct involvement of the state distorts competition in the market and that R&D projects over a long period of time in general suffers from low success rates (Blomström & Kokko, 2002).

Liberalization

According to Dunnewijk and Hultén (2007), the liberalization of the telecommunications industry in Europe did facilitate for new actors to enter the market and did also inhibit extreme pricing within the sector. Further, the authors describe that there was a shift of the network operators' role when new technology was implemented in the telecommunications industry. The operators went from network managers to content organizers during the shift towards newer generation telecommunications technology. The liberalization of both fixed and mobile telecommunications in the 1980s and the partial privatization of the former public operators in the sector in 1980s and 1990s resulted in an increase of mobile network operators, according to the authors. Due to the increase of number of actors in the market and the following competition amongst them, resulted in decreasing prices and increasing usage (Dunnewijk & Hultén, 2007).

During the liberalization of the telecommunications industry in Sweden, the Swedish Telecommunications Administration was converted into Telia in 1993. Even though Telia had advantages in form of knowledge and market shares etc. compared to new entrants, no market restrictions were set up against the company. The motivation for not limiting Telia was that the telecommunications industry was facing several major technology shifts which enabled for new entrants to establish in the market and to compete with Telia in areas they had not yet gained any advantageous knowledge. The liberalization of the telecommunications industry in Sweden enabled for international actors to enter the Swedish market and due to the new actors' high willingness to invest, it resulted in great technological breakthroughs (Andreasson & Sjöberg, 2012).

Hultkrantz (2002) describes the liberalization process of the telecommunications industry in Sweden in three main steps. The liberalization process occurred gradually and before 1980 the telecommunications industry was governmentally regulated. The first step in the liberalization process was when the Swedish Telecommunications Administration was transformed into the publicly owned company Telia. In the second step, the government aimed to obtain some competition in the market but there was still a willingness to keep the monopoly Telia had. Telia determined the interconnection fees for the other operators and the high fees limited the entry of new operators thereof was also competition limited. In the third step, Telia decreased the interconnection fees due to the willingness of the government to increase competition in the industry. Lower interconnection fees enabled for new operators

to enter the market which increased competition in the telecommunications industry (Hultkrantz, 2002).

Beauty Contest

When the third generation (3G) of mobile telephone system arrived after the NMT and GSM systems, the European Parliament decided in 1998 that all member countries in EU should enable for the deployment of the new technology. In Sweden, the Swedish National Post and Telecom Authority (Post- och telestyrelsen) established in 1993 with the purpose to monitor telecommunications, IT, mail and radio industries, was responsible for assigning 3G licenses to the operators. The settlement between the operators was not conducted through an auction where the highest bidder received a license but through a so-called beauty contest. In the first test the applicants were evaluated on financial capacity, technical and commercial feasibility (based on a given proposal from the applicants) and the applicants' access to knowledge and experience in the area. If the applicants passed the first test they were through to the next stage in the license process. In the second and final stage the applicants were evaluated on their offering regarding size of network coverage based on population, geographical surface area and level of scattering in the country. In addition, how fast the applicants could offer the given coverage was also evaluated. When the beauty contest was over, four operators were given 3G-licenses. Notable was that Telia was not given a license since the Swedish National Post and Telecom Authority considered their proposal to be technically unfeasible but were later on given the opportunity to share license with Tele2 (Wessel, 2007).

4 Empirics

The chapter includes a case study background and the empirical findings from the conducted interviews. The case study background focuses on ERS and aims to explain the issues which led to the emergence of the discussion regarding ERS. ERS are explained in general and the demonstration project eRoad Arlanda is presented. The empirical findings section is organized by each stakeholder segment where the trends but also individual opinions of each actor are presented.

4.1 Case Study Background

This section provides a thorough background for the case study of ERS. It aims to provide an understanding of why the subject is currently discussed and what ERS are.

4.1.1 Sense of Urgency for a Technology Transition in the Transport Sector

The transport sector accounts for approximately 23 % of the world's CO2 emissions (IEA, 2015) and the heavy-duty vehicle segment accounts for one third of the emissions from the road transport sector (Tongur & Engwall, 2014). During the last 30 year, transport energy use has doubled and if no dedicated policies are applied, road travel is expected to double by 2050, mainly due to the emerging economies of the world (Dulac, 2012). The main identified reason for the high emission levels is the extensive use of fossil fuels, as 95 % of the utilized fuels within the sector are derived from crude oil (Mathiesen & Lund, 2008).

Efficiency development and alternative technologies for conventional smaller vehicles have been rather progressive as environmentally friendly energy storage systems, such as batteries, are considered as an established solution. However, most energy storages have lower energy density, in comparison to fossil fuels, which consequently implies that the driving range is strongly affected by the weight of the vehicle it supplies. In order to supply a heavy-duty vehicle with an environmentally friendly storage system, the large capacity of the system would imply a substantial increase in cost and weight and a reduction of transport volume. Consequently, environmentally friendly energy storage systems are not considered to be a suitable solution for the heavy-duty vehicle industry, since it is unable to meet the core demand of heavy transports (Tongur, 2013). Hence, emissions generated by the heavy-duty vehicle segment is considered to be the most problematic within the transportation sector due to the dependency of fossil fuels and the lack of sufficient alternatives (IEA, 2012).

The fossil fuel dependency of the heavy-duty vehicle segment is crucial for the total impact of the transport sector as the heavy-duty vehicle segment is predicted to be responsible for 40 % of the increase in oil demand globally in 2035, while the entire transport sector is predicted to account for 50 % of the oil consumption in 2035. In addition, the combustion engine suffers from substantial losses as the approximate efficiency of the engine is 30-50% and the rest is generated as waste heat (IEA, 2012).

On a national level, green house emission levels are also considered a critical issue and are a prioritized matter. The Swedish transportation sector stands for 30 % of the total national emissions, of which cars and heavy-duty vehicles are dominating. The main identified reason

for the high emission levels is similar to the global perspective. Since 2008 the emissions caused by cars and smaller trucks have slightly diminished due the transition towards an extended utilization of hybrid vehicles and diesel. However, the improved efficiency cannot compensate for the increasing number of vehicles in use. Moreover, the efficiency development of heavy-duty vehicles had its peak before 1990 and have thereafter subsided (Naturvårdsverket, 2015).

The Swedish national goals regarding the utilization of fossil fuels and carbon emission levels are considered progressive in comparison to the set targets by the European Commission. The Swedish political ambition is to have a national vehicle fleet which is independent of fossil fuels by 2030 and to have zero-net emissions of greenhouse gas across all national industries by 2050 (Trafikverket, 2012).

Despite the financial resources allocated to R&D and incremental efficiency development by truck manufacturers, emissions from the transport sector are still increasing on a global scale. As a consequence of the extensive green-house gas emissions generated by the transport sector in combination with the lack of sufficient fossil-free alternatives for heavy-duty vehicles, there is a clear sense of urgency for a technology shift towards a sustainable transport paradigm (Tongur & Engwall, 2014).

A widely discussed radical solution for the transport industry is to enter a paradigm of electrified heavy-duty vehicles. For the conventional vehicle segment, the hybrid solution of a combustion engine in combination with an electrical engine and a battery is already an established trajectory of technology development. However, the hybrid solution is not considered to be sufficient due to the low capacity of the battery, which would require a substantial decrease of the cargo capacity of the heavy-duty vehicle (Tongur & Engwall, 2014).

4.1.2 Electric Road Systems

ERS are defined as roads which support dynamic power transfer to vehicles while driving. The vehicle is supplied by an external power source that is integrated in the road infrastructure. There are currently several technological solutions available which are being tested frequently in order to prove their technological feasibility. The available solutions are conductive-based or inductive-based. The conductive-based solution includes two possibilities for transmission; either an overhead transmission to the vehicles or transmission from the ground. In the case of overhead transmission, the vehicle connects to transmission lines by a type of pantograph. In the case of a ground-based solution the vehicle connects to an electrified rail by a physical pick-up which is attached to the vehicle. The inductive-based technology implies wireless charging from a coil in the ground to a receiver in the vehicle. The concept and technique of ERS was originally developed by actors from the railway industry (Tongur, 2013). The different technological solutions are displayed in figure 5.

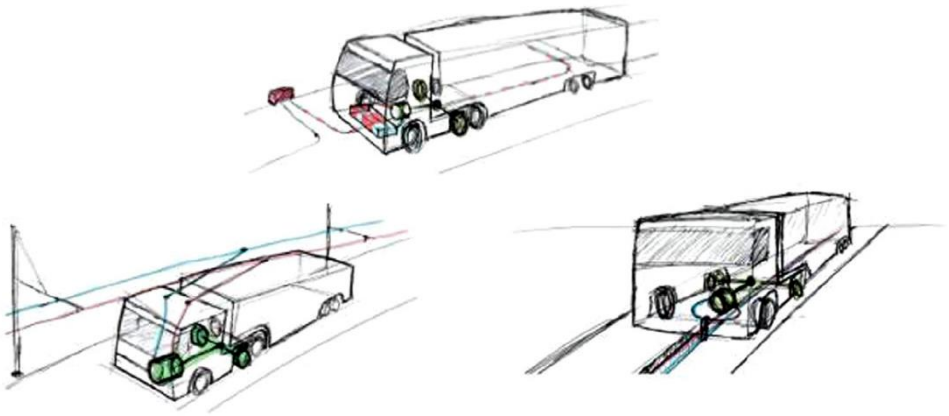

Figure 5: Technological solutions for ERS (Wiberg and Rådahl, 2012)

The opportunity for heavy-duty vehicles to charge electricity while driving implies a compensation for the inadequate capacity of environmentally friendly energy storage systems, such as batteries (Tongur, 2013). The vision is to build an ERS network that connects cities and enables electricity charging for heavy-duty vehicles during transports. Moreover, the vehicles utilizing the system should be equipped with an energy storage system and (or) a smaller internal combustion engine, which allows the vehicle to drive on conventional roads outside the ERS (Tongur & Engwall, 2014). The roads which supports the dynamic power transfer would also be accessible for vehicles that are not ERS-compatible (Tongur, 2013).

A deployment of ERS would imply a technology shift of the transport sector. The conventional transport system is characterized by the many subsystems and components in terms of actors and technologies (Geels, 2002). Many actors that are active in the conventional transport system would most probably be active in the new ERS as well. However, a shift to ERS from the conventional system would have different implications and thereby have an effect on the actors' internal business models. The stakeholders which are necessary to compose an ERS are illustrated in figure 6. Out of the presented stakeholders only road power technology firms and electric utilities are not active in the conventional transport system (Tongur, 2013).

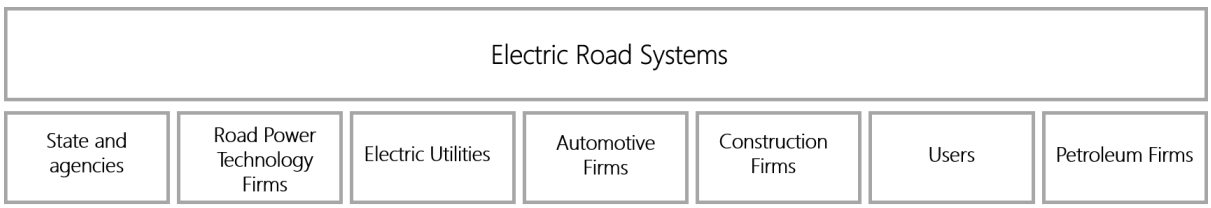

Figure 6: ERS stakeholders (Tongur, 2013)

The different technologies are currently being evaluated in relation to the vision of a future large-scale deployment of the ERS. Hence, the feasibility of each solution is evaluated both from a technological and financial perspective (Lundberg, 2015). The inductive technology is considered to be the least mature of the available solutions as there is still some vital technological uncertainties such as the long-term effects from the magnetic field. Moreover, the implementation of an inductive technology in the current infrastructure would imply huge financial investments, in comparison to the other alternative solutions, which is not considered reasonable. As of today, the conductive overhead transmission is considered to be the most mature technology (Tongur, 2013). However, the conductive ground-based solution is developing quickly and is estimated to be the most financially beneficial solution in terms of implementation in the current infrastructure. Further, the ground-based solutions, both conductive and inductive, allows an additional segments to utilize the infrastructure as well as it is reachable for smaller conventional vehicles (Lundberg, 2015).

There is consensus among the key actors of the transportation system regarding the feasibility of ERS as a concept. The actors may not agree on the timeframe of which a large-scale deployment of the technology is probable to be realized, but there is a join notion that the concept is feasible and a highly probable alternative (Tongur & Engwall, 2014). Despite the large investment required for a large-scale implementation of the ERS, it is considered to be an attractive alternative in order to obtain a fossil free vehicle fleet and thereby reach the set national target of a fossil free vehicle fleet by 2030 (Tongur, 2013).

There are currently several small-scale ERS projects ongoing in different places of the world, with the aim of evaluating the technology and the possibility to commercialize the concept (e.g. Pajala; Los Angeles and Long Beach, California; Arlanda, Sweden; Elväg Gävle, Sweden; Bordeaux, France; McAllen, Texas; Lommel, Belgium; and Stanford University, California (Tongur & Engwall, 2014).

The main identified barriers for a technology shift towards an ERS solution are related to the complex system design as the high number of subsystems would have to change simultaneously and market stakeholders would have to be prepared for a market entry. To manage a shift, the subsystems have to be more closely linked compared to today. A technological shift towards an ERS would imply a change of paradigm for the transportation sector (Tongur, 2013).

Furthermore, a market establishment would require huge investments on the physical infrastructure, which constitutes an initial financial barrier. However, large-scaled deployed ERS are expected to have long-term positive financial implications in comparison to the current fossil fuel dependent system (Tongur & Engwall, 2014).

4.1.2.1 eRoad Arlanda

In June 2013 the largest pre-commercial innovation procurement in Europe was held by the Swedish Transport Administration, the Swedish Energy Agency and the Swedish Innovation Agency (Vinnova) to initiate pilot projects regarding ERS. In June 2015 two out of the eleven consortium applicants, eRoad Arlanda and Elväg Gävle, received permission and financial support for the development and re-building of existing roads into electrified roads. eRoad

Arlanda is one of the several small-scale projects ongoing around the world, with the purpose to probe the feasibility of the ERS technique and the commerciality of ERS (Lundberg, 2015).

The project is working with the ground-based conductive technology from the road power technology firm, Elways, which is considered to be less mature than the conductive overhead technology. The technique will be demonstrated on road 893, between Arlanda Cargo City and Rosersberg Logistics Area, which is heavily utilized mainly by heavy cargo transports but also by local traffic. In total, the road is travelled by approximately 1700 vehicles per day. A two kilometer distance, out of the 10 kilometer distance between Arlanda Cargo City and Rosersberg Logistics area, will be electrified and tested in a commercial setting as a re-built, electrically driven heavy-duty vehicle will be transporting gods between the destinations (RUAB, 2015).

eRoad Arlanda is driven by RUAB which is a development firm with the purpose of demonstrating the ground-based conductive technology from Elways. RUAB is owned by NCC Roads (30%), Elways AB (30%), ABT-bolagen (30%) and Kilenkrysset (10%). The revenues from the transportation will be divided between the owners of RUAB according to a predefined agreement. Furthermore, there are a consortia of actors, which have entered an agreement with RUAB stating their involvement in the project. Members of the different stakeholders have formed a project group and working teams within the project which all work within different areas (RUAB, 2015). The RUAB organization is illustrated in figure 7.

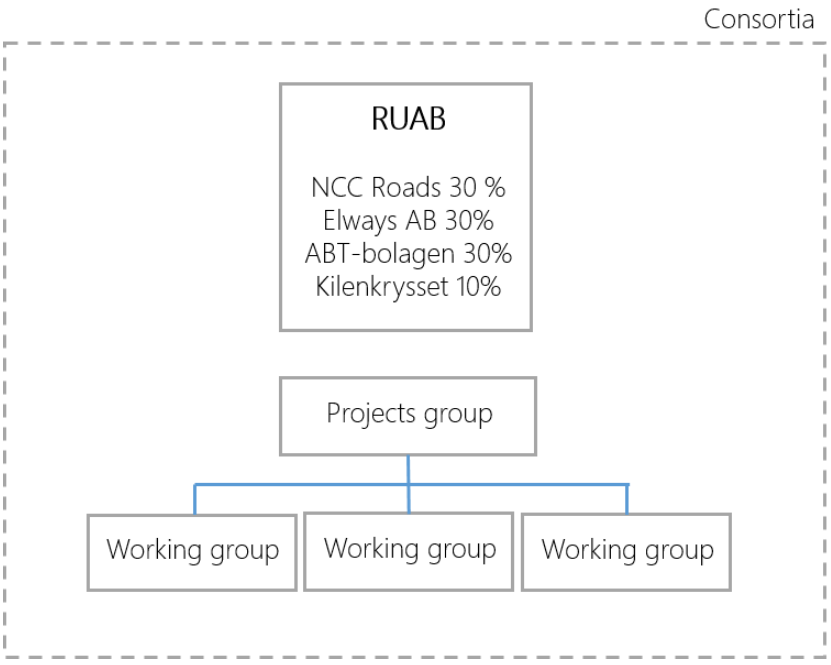

Figure 7: RUAB Organization

RUAB is financing the construction partly from its own capital and also from funding by the Swedish Transport Administration, the Swedish Energy Agency and Sweden's innovation agency (RUAB, 2015). The members of the consortia have different roles in the project and contribute with different competencies. The wide spectrum of both political, commercial and academic actors, among else, creates better conditions to accomplish a successful demonstration. The actors of eRoad Arlanda are described in Appendix B.

4.2 Empirical Findings

A summary of the empirical findings from the interview study has been compiled and can be viewed in table 2. The common opinions and views, thus the trend, within each stakeholder segment can be viewed in the table.

Table 2: Overview of the empirical findings

Summary	Overall incentives	Overall perceived risks and barriers	Future role	Willingness to invest	Ownership structure's effect on ERS development
Agencies	• ERS is strongly in line with their separate governmental missions	• Lack of business models	• Same as today	• High willingness to invest, but during different stages of the development	• Necessary for the government to finance the majority of the system and absorb risk • 100 % private ownership is not possible at scale
Electric Utilities	• Additional electricity segment • New business opportunities	• High risk investment • Immature technology • Market uncertainties • Decision of ERS standard	• Electricity supplier • Service provider • Future role is close to core business (both for PPP and public ownership)	• Differing opinions depending on the individual business models	• Private actors will stimulate the technological development • Necessary with governmental involvement and financing
Road carriers	• Want to contribute to the development towards a sustainable transport system • Lower operational costs • Possible competitive advantage	• Lack of business models • Operational risk	• Users of the system	• Infrastructure – low willingness to invest • Vehicles – high willingness to invest if profitable • In general, an early engagement in the system is preferred	• Public ownership reduces complexity, one actor with overall responsibility • Governmental financing is required • Private actors stimulates the technology development • More expensive for users with private ownership involvement
Construction firms	• Creating an environmentally friendly solution in order to reach the climate goals	• Political risks, including competition for investment • Uncertain number of users	• Partner within ERS projects as a constructor and deliverer of functionality • Involvement in additional business areas connected to ERS	• Non-financial engagement early in the transition • Prefer to invest later during the expansion phase • Willingness to invest increases if there are additional business areas connected to ERS	• Governmental involvement and financing is necessary • A PPP structure accelerates the technology development and the ERS deployment
Road power technology firms	• Environmental benefits • Financial factors	• Political risks • Technology uncertainties • Resistance against new technologies	• Developer and deliverer of ERS technology	• The willingness to invest differs due to different conditions	• Governmental involvement and financing is necessary

4.2.1 Agencies

In the following section the empirical findings within the segment of agencies are compiled. The empirical material has been gathered from six different interviews; four interviews with representatives from the Swedish Transport Administration, one interview with a

representative from the Swedish Energy Agency and one interview with a representative from the Swedish Innovation Agency.

Individual opinions of each agency have been compiled in table 3 in order to emphasize the different views that were raised by the representatives. The content in table 3 should be viewed as a complement to table 2.

Table 3: Overview of individual opinions within the segment of agencies

Specifics	Overall incentives	Overall perceived risks and barriers	Future role	Willingness to invest	Ownership structure's effect on ERS development
Swedish Transport Administration	• Possible solution to increasing emissions within heavy transports • Wants to create a sustainable transport system to the lowest cost • Possibility to further utilize the existing road infrastructure	• European technology standard is necessary • Choosing a standard creates a lock-in effect • Not choosing a standard creates difficulties at scale • Political support • Technological functionality • Chicken and egg dilemma	• ERS administrator • Main financier and risk absorber • Control and responsibility of the future ERS in order to ensure availability	• High willingness to invest in a large-scale ERS if it results in improved public welfare and is in line with the governmental goals, in relation to alternative investments	• Public ownership provides stability • Public ownership might creates a technological lock-in • PPP structure increases complexity • PPP structure creates momentum and dynamics • PPP structure improves the technology development • PPP structure simplifies the dialogue with the industry
Swedish Energy Agency	• In line with their mission to work for a sustainable transport system • Possible solution to increasing emissions within heavy transports	• European technology standard is necessary • Rational of Sweden as a first mover • Political support • Legal barriers for an ERS integration in existing roads	• Stimulates the development at an early stage	• Provides funding early in the development	• The government need to make the first move towards a large-scale system • A PPP structure would be possible • The technology development is independent of ownership structure
Swedish Innovation Agency	• In line with their mission to promote a sustainable growth	• Technological functionality	• Stimulates the development at an early stage	• Provides funding early in the development	• PPP structure is beneficial from a national economical perspective • The Swedish Transport Administration has necessary experience • Public ownership accelerates a large-scale implementation • The government need to make the first move • PPP improves technology development • PPP prolongs the development

4.2.1.1 Overall Incentives for ERS Among the Agencies

Common for all agencies is that working with ERS is strongly in line with their separate governmental missions.

Both the Swedish Transport Administration and the Swedish Energy Agency consider ERS as a possible solution to the current and future issues with heavy transport emissions. Studies have shown that there are limited possibilities to transfer goods from the road to rail and sea. Thus, a different solution is called for. Furthermore, the Swedish Transport Administration wants to create a sustainable transport system to the lowest possible cost and describes ERS as a promising alternative. By building ERS, the existing infrastructure, in which massive capital is tied up, can be further utilized, which both implies a small investment in relation to other options and an increased utilization of the existing infrastructure. As the Swedish Energy Agency works for a sustainable energy system, it would imply a professional misconduct to not investigate the potential of ERS further, means the representative from the Swedish Energy Agency. The Swedish Innovation Agency's mission is to promote sustainable growth. They argue that supporting the development of ERS is strongly in line with this mission.

4.2.1.2 Overall Perceived Risks and Barriers

Common for all interviewed agencies is that they perceive the lack of business models as a barrier that is necessary to overcome in order to build a large-scale system. Further, they enlightened some different opinions.

Both the Swedish Transport Administration and the Swedish Energy Agency argue for the importance of choosing a European technology standard before implementing ERS at large-scale in Sweden. They mean that it would imply a high risk for Sweden if a national implementation of ERS would be realized without a European decision regarding technology standard. Also, choosing a European standard will be a time consuming activity, which constitute a barrier itself.

The Swedish Energy Agency even debates that the decision of a European technology standard constitutes the largest barrier to overcome in order to enable a large-scale deployment of ERS. The interviewee means that Sweden is not a large market for this kind of innovation and that the Swedish conditions, which are considered when evaluating the different ERS technologies, are quite different from the conditions in other European countries. As an example, the environmental benefits from ERS are described as one of the main incentives for a deployment of ERS. The Swedish energy mix is considered to be very environmentally friendly in relation to other European countries. Thus, one could argue that the environmental incentive is not as strong in many other European countries due to the lack of environmentally friendly electricity. Furthermore, the Swedish road system is over-dimensioned in relation to the national vehicle fleet. The situation is different in other countries, like Germany for example, which could potentially imply that the inductive technology could be financially feasible with the large number of potential users. In addition, Sweden has different weather conditions compared to many other European countries. With

these facts in mind, we have to evaluate the rational of Sweden as a first mover within ERS at scale.

The representatives of the Swedish Transport Administration also mean that it is difficult to know when the timing is appropriate to make a decision regarding standard, as the decision will create a lock-in effect. However, the risk with not choosing a standard is that the systems will be incompatible. Moreover, by allowing different standards to develop at small-scale the technologies can reach their full potential.

The Swedish Transport Administration believe there is an uncertainty regarding the number of future users of the system and explains that many road carrier firms have low financing power which the representatives consider as a risk. In addition, they enlighten the chicken and egg dilemma, which implies that users might not find it profitable to convert their vehicles until there is a large ERS in place, which delays the incomes. Furthermore, the question of who will be the electricity supplier and how ERS will affect the grid is still unknown, mean the representatives from the Swedish Transport Administration. Also, they perceive the technological risk as vital and emphasizes the importance to secure the functionality of the system. The Swedish Innovation Agency shares that opinion. The Swedish Energy Agency on the other hand believes that the technology not constitutes a significant risk.

Both the Swedish Transport Administration and the Swedish Energy Agency believes that political support is absolutely necessary before building a large-scale ERS and that resistance is probable as it conflicts with other transport investments. The Swedish Energy Agency means that there are legal barriers that inhibits an implementation of ERS. Also, the security the system needs to be evaluated when integrating electricity into the roads.

4.2.1.3 The Future Role of Agencies and the Willingness to Allocate Financial Resources to ERS

The three interviewed agencies all have different roles and governmental missions. The Swedish Transport Administration is responsible for the long-term planning of the transport system, which includes road, rail, sea and air transport, as well as construction and operation and maintenance of state roads and railways. The Energy Agency works for a sustainable energy system, which combines ecological sustainability, competitiveness and security of supply. The mission of the Swedish Innovation Agency is to promote sustainable growth by improving the conditions for innovations by funding. In June 2013 the largest pre-commercial innovation procurement in Europe was held by the three interviewed agencies in order to initiate pilot ERS projects. As a result of the procurement, they are currently financially supporting the two projects eRoad Arlanda and Elväg Gävle.

As it is not included in the mission of the Swedish Energy Agency and the Swedish Innovation Agency to make large infrastructure investments, they are not likely to be a future investor of a large-scale ERS. However, their roles and funding are vital to stimulate the development.

It is in the Swedish Transport Administration's mission to ensure availability and the representatives predict that the agency will have the same role in a future ERS, since the new infrastructure would be integrated in their roads. The representatives expressed

different opinions regarding including private actors in the ownership of a future ERS, but they all agree that they would have to be in control of the system due to their governmental mission. However, it could be an option to give a private actor concession to build or operate a part of the ERS during a limited period of time. But once again, the Swedish Transport Administration still needs to be able to ensure availability, according to the current legislation.

When considering transport investments, the main evaluated parameters are public welfare and if the investment is in line with the government's goals. They do not discuss in terms of financial risk. According to the Swedish Transport Administrator's prediction of their future role, they will have to absorb the majority of the system risk as the main financier. If there were to be other investors as well they would also absorb a share of the risk.

4.2.1.4 Ownership Structure's Effect on the Development from Small-Scale to Large-Scale ERS

Common for all interviewed agencies is that they believe that governmental involvement is absolutely necessary in order to build a large-scale ERS. They agree that it will be essential for the government to finance the majority of a new, large-scale ERS. They believe that private actors would not prefer to manage the kind of risk that a new capital intensive system like ERS implies. Governmental support has also been vital for the early ERS development, as all of the national demonstration projects have been dependent on governmental funding, mean all of the representatives from the three different agencies. Furthermore, common for all interviewees is that they believe that a totally privately owned large-scale system would be very difficult to accomplish. The Swedish Transport Administration however believes that a privately owned ERS could be possible on a local level.

According to the Swedish Transport Administration, a public ownership structure feels safe and familiar both for them and the industry and implies less complexity. Due to their responsibility to ensure availability, it is necessary for them to control the system and for the government to own the ERS either partly or fully. The Swedish Innovation Agency means that the Swedish Transport Administration has experience of controlling and operating a large-scale system, which they consider as necessary for managing a large-scale ERS. The Swedish Innovation Agency believes that an introduction of a large-scale system could be quicker with a public ownership as they have the required financial resources and the authority. The Swedish Transport Administration however see a risk with public ownership having a negative effect on the development, as they believe that the risk is higher to choose a technology standard too early and thus create a lock-in effect.

The Swedish Energy Agency and the Swedish Innovation Agency believes that it is necessary for the government to show the industry that the ERS deployment is serious by making a large investment and build at large-scale. They believe that it would convert users and make private actors comfortable with making future investments in the system.

The early involvement of private actors has stimulated the ERS development, means the interviewee from the Swedish Energy Agency. After an initial large financing by the government, a PPP-structure can become possible when the industry knows that the ERS conversion is really happening. A PPP ownership structure would be difficult at an earlier

stage of the development as the technology is considered to be immature, which decreases the private actors' willingness to invest.

The Swedish Transport Agency means that a PPP ownership structure is more complex than the conventional structure with only public ownership and it could be far more complex if different actors would be in control of different system components at the same location. The coordination of operation and maintenance could become problematic. However, the representatives also see benefits of including private actor in the ownership. They believe that the involvement of private actors would create a momentum and dynamics in the development. The Swedish Transport Administration would, regardless of ownership structure, have to have a close dialogue with the industry to understand the needs and the incentives to become a user of the system, when making important decisions and dimensioning the system. A PPP ownership structure would perhaps make this dialogue easier. Further, they also believe that the involvement of private actors would improve the technology development and facilitate for finding an appropriate standard. The Swedish Innovation Agency also share this belief. The Swedish Energy Agency believes that the technology development is independent of the ownership structure. The main thing is to not make a decision regarding a technology standard too early.

In difference to the belief of the Swedish Transport Administration, the Swedish Innovation Agency believes that a PPP ownership structure could create longer lead time from today to a large-scale system compared to a conventional ownership structure. However, the Swedish Innovation Agency promotes public and private collaborations and think that a PPP ownership structure would be most beneficial from a national economical perspective.

Moreover, the Swedish Transport Administration and the Swedish Innovation Agency believes that a PPP structure might not be appropriate for every road since private actors are dependent on profitability and might not be interested in roads with lower utilization, which could become a hinder for a large-scale deployment.

4.2.2 Electric Utilities

In the following section the empirical findings within the segment of electric utilities are compiled. The empirical material have been gathered from three different interviews, one with every representative from Fortum, Vattenfall and E.ON. Individual opinions of each electric utility have been compiled in table 4 in order to emphasize the different views that were raised by the representatives. The content in table 4 should be viewed as a complement to table 2.

Table 4: Overview of individual opinions within the segment of electric utilities

Specifics	Overall incentives	Overall perceived risks and barriers	Future role	Willingness to invest	Ownership structure's effect on ERS development
Fortum	• Nothing additional	• Chicken and egg dilemma • Electricity infrastructure must be functional from a grid perspective • Large initial costs for ERS	• Providing a cloud solution could be in line with their current business	• Might not be in their primer interest to invest in the infrastructure • Prefer to engage in the system later in the development process	• PPP structure is most beneficial from a national economic perspective • PPP structure creates stronger driving forces • Public involvement is necessary for reaching large-scaleness
E.ON	• Strongly in line with the company's overall strategy – to contribute to the transition to a sustainable society	• Electricity infrastructure must be functional from a grid perspective • Large initial costs for ERS	• Possible owner of the ERS infrastructure • Operator and maintainer • Energy transfer • Payment system provider	• High willingness to invest • Preferred to invest later in the development process	• Both PPP structure and public ownership create good conditions for reaching a large-scale ERS
Vattenfall	• Nothing additional	• Chicken and egg dilemma	• Possible owner of the ERS infrastructure • Operator and maintainer • Energy transfer	• Medium/High willingness to invest • Preferred to invest early in the development process	• PPP structure creates a momentum in the development • Public involvement is necessary for managing the risk and investment

4.2.2.1 Overall Incentives for ERS Among the Electric Utilities

Common for all three electric utilities is that they see themselves as a natural stakeholder of ERS, if it were to be deployed. They see ERS as an additional segment to sell electricity to, which they perceive as a given opportunity. In addition, all of the representatives express that it would be interesting to investigate if further business could be obtained within ERS, even if they all agree on that it is unclear whether or not such a business would be profitable for the company. All electric utilities are working with products or services related to e-mobility as they believe in electrification of the transport system. Concluding, the electric utilities express clear incentives for participating in ERS if it were to be deployed. The overall incentives for ERS among the different utilities did not vary to any large extent, which can be seen in table 4. The following paragraph present some of the individual opinions that were enlightened during the interviews.

The representative of E.ON expresses that ERS are strongly in line with the company's overall strategy, which is to contribute to the transition towards a sustainable society. This fact also opens up for an intention to engage financially in ERS, if it also would imply a good business. The representative from Fortum expresses that the company is looking for diverse

businesses within the energy sector. Therefore, it would be of interest to obtain business beyond selling electricity within an ERS as well. This reason was also mentioned by E.ON.

4.2.2.2 Overall Perceived Risks and Barriers

All of the interviewed representatives agree that there are several barriers to overcome before ERS can become a large-scale system. Common for all interviewees is that they emphasize the importance of choosing a technology standard. They express that this will require a lot of time and imply an uncertainty regarding the optimality and suitability of the future chosen technology, if Sweden would become a first mover within ERS. Furthermore, the perceived risks described by all interviewees are technology and market related. They all agree that the technology is immature, which they perceive as a risk.

A number of different views on ERS was enlightened when they were asked to speak freely about the barriers for ERS. The representatives from Fortum and E.ON both emphasize that the initial, large investments for the system constitute a barrier for ERS. Also, Fortum and E.ON states that the electricity infrastructure must be functional from a grid perspective. The questions of how the electricity infrastructure will be designed and how to balance and control uneven power outputs are perceived as unresolved. The interviewees from Fortum and Vattenfall chose to enlighten the chicken and egg dilemma, which they think implies an uncertain market at an early stage of the deployment with a lack of knowledge of the number of users.

Common or all interviewed representatives from the three different utilities is that they do not perceive any considerable risks for the company itself to participate in an ERS if it was to be publicly owned. They all agree that the risk substantially increases if they were to invest in the infrastructure. In the case of a PPP solution, it would be required that the government took a larger share of the risk, according to the representative of Fortum. Similarly, Vattenfall describes that private actors are not interested in managing that kind of financial risk as they are highly dependent on their profitability. As the government has different incentives than purely financial, it would be more suitable that they absorb a larger share of the risk, according to the representative from Vattenfall, which is also described by the representative from Fortum.

4.2.2.3 The Future Role of Electric Utilities in ERS and the Willingness to Invest

All three of the electric utilities are currently following the development of ERS and are still learning about the concept. Vattenfall is participating in several ERS projects in order to contribute to and closely follow the development. When asking the interviewees about their future role within ERS the answers vary among the representatives.

The Future Role of Electric Utilities in a Publicly Owned ERS Infrastructure

In the case of a publicly owned infrastructure they all predict that they will have the role of an electricity supplier and would like to provide other services as well, which would be procured by the Swedish Transport Administration. Common for the electric utilities is that they suggest that their future role would remain close to their current core businesses, implying small requirements for change of their internal business model. Vattenfall expresses that their current portfolio consists of producing and selling electricity, electricity

transfer, operation and maintenance and means that these services would be possible to provide in an ERS system as well. E.ON provides operational service on charging infrastructure for electric vehicles and can thus see themselves providing operational service on the electric infrastructure for ERS, in addition to selling electricity and providing a connection point. If not, their role within the system would be very limited in their opinion. Also, like Vattenfall, E.ON would be interested in providing further services such as payment systems, energy transfer, operations and maintenance. Since Fortum currently provides a cloud service for charging infrastructure and electric vehicles, a similar service for ERS could be in line with their current business. The interviewees all agree on that their role will be heavily controlled by the government and the Swedish Transport Administration.

The roles described by the electric utilities, in the case of a publicly owned infrastructure, is also applicable for the case with a PPP ownership structure. Additional implications for a PPP ownership structure are described below.

The Future Role of Electric Utilities in ERS with a PPP Ownership Structure

When discussing the electric utilities' role in a PPP solution and whether or not they would consider to engage financially in the road and electricity infrastructure, the opinions differed. E.ON, which also owns the grid at some locations, believes that they could benefit from owning a part of the ERS infrastructure at these locations. The main reason is that it would imply a quiet small effort since they are already in full control of the grid. Since they are responsible for the grid, it means that they would have to keep close contact with the owners of the infrastructure, regardless of who the owner is. This utility is the only one who expresses a clear will to own the road and electricity infrastructure. However, they express that it is important to have a clear demarcation of the different ownerships and roles. Controlling a larger part of the value chain, by owning infrastructure, would be the most preferable ownership structure from E.ON's point of view. Currently, E.ON has a solution for electrical buses where they operate and maintain the charging infrastructure. In this case, it would be beneficial for the utility to own the charging infrastructure as well, as it would imply a small additional effort but an ability to provide additional services such as first and second line support. E.ON perceives this as a suitable reference case when discussing the future ERS. They point out that a PPP-structure, where they own a part of the infrastructure, would imply a larger risk for them than with a public ownership where they only would provide their services. However, they perceive this risk as a manageable.

Fortum, who does not own any grid, expresses that it might not be in their primary interest to have ownership of the road and electricity infrastructure. They consider ERS to be an immature concept that would be risky to invest in during the early stage of the development.

The interviewee from Vattenfall believs that there are benefits to obtain from having a shared ownership of the ERS infrastructure, as ERS fundamentally consists of components which are within the company's portfolio. However, they clearly expressed that it is currently uncertain if such a business would be profitable or not. However, if it were, it would not be such a large step for the company from a business model perspective.

Concluding, there is a consensus among the utilities that ERS would imply a new segment for them to provide their existing products and services to. However, regarding the

involvement in a PPP and thus engaging financially, they have differing opinions. Common for all of the interviewees was that they believe that there still are a lot of uncertainties and challenges regarding the ERS concept and technique and that it is therefore difficult to predict if a PPP would be preferable for them or not.

Timing for an ERS Engagement

The timing for investing in ERS, alternatively engaging in the system, varied among the utility representatives. Fortum argues that the risk of entering the system at an early stage could become much more costly than entering the system at a later stage, as higher costs would have to be allocated to the unknown risks. Likewise, E.ON argues that it would be preferable to engage financially in the system at a later stage when the development of ERS has reached large-scale and the infrastructure is in place. However, E.ON also talk about their current project with electric busses as an example of the opposite opinion. The project comprises of a consortium of actors which all cover their own costs within the project. Even though a pilot project implies a larger financial risk the actors within the consortium get the privilege to acquire knowledge about risks as well as the opportunities in an early stage of the development, which is beneficial if the technology and concept would to be deployed further. It is easier to be involved later on and manage the risks if one has knowledge about risks and opportunities. Vattenfall argues that they would like to engage at an early stage of the development in order to verify the technique for their own sake but also for the sake of society. Furthermore, Vattenfall see it as absolutely necessary to be involved at an early stage of the development if they were to engage in a PPP structure, in order to gain knowledge and experience early on. However, they point out that the engagement more likely would be focused on operations and providing services rather than a financial involvement. It is also enlightened that it would probably not be profitable to participate financially at an early stage of ERS when there is only a few established, and perhaps short, locations, means the representative from E.ON.

4.2.2.4 Ownership Structure's Effect on the Development from Small-Scale to Large-Scale ERS

Fortum argues that a PPP-structure would be most beneficial from a national economical perspective as it will be necessary that the investment is reasonable from a financial perspective and not only from a public welfare perspective. If private actors are not willing to invest, internally nor externally, it might not be the right timing for the technology. The representative from Fortum also emphasizes that the government have to be financially involved in order to achieve a large-scaleness. Furthermore, Fortum argues that having both public and private owner would create stronger driving forces. On the other hand, the interviewee believes that the development towards a large-scale system could be a quicker process if the infrastructure was publicly owned. Even if a PPP-structure would be more complex and time consuming, it would be more beneficial from a long-term perspective.

The interviewee from Vattenfall believes that the involvement of private actors would create a momentum in the development and also create a confidence-building environment between private actors and the government. It is also pointed out that the ability to make such a large investment requires access to large capital, which the government has. They are uncertain of the amount of risk that private actors are willing to take in an early stage of the development.

The representative of E.ON believes that both a public ownership and a PPP structure would create good conditions for reaching a large-scale system.

Common for all interviewed representatives is that they believe that the involvement of private actors will stimulate the technological development of the ERS technique. E.ON emphasizes that with a governmentally owned system a certain standard could be forced and there is a risk for not choosing the most appropriate technique, which is a result of not letting the different techniques mature. On the other hand, Vattenfall believes that the government can accelerate the development by financing, alike the pre-commercial innovation procurement in 2013.

4.2.3 Road Carriers

In the following section the empirical findings within the segment of road carriers are compiled. The empirical material have been gathered from three different interviews, one with each of the companies PostNord, ABT-bolagen and Schenker Consulting. At the interviews with PostNord and ABT-bolagen, two representatives from each company participated. At the interview with Schenker Consulting one representative participated. Individual opinions of each road carrier have been compiled in table 5 in order to emphasize the different views that were raised by the representatives. The content in table 5 should be viewed as a complement to table 2.

Table 5: Overview of individual opinions within the segment of road carriers

Specifics	Overall incentives	Overall perceived risks and barriers	Future role	Willingness to invest	Ownership structure's effect on ERS development
PostNord	• Nothing additional	• High initial costs for converting vehicles, which smaller firms might not afford • The necessity of ERS depends on other technologies • Too small shares of profit • Competition for governmental funding	• User • Supplier of test-vehicle during the development phase • Possible owners on a local level	• Nothing additional	• Private actors lack technology neutrality, thus it is difficult to find the most suitable standard
ABT-bolagen	• Nothing additional	• Load capacity when driving on electricity needs to be sufficient • Integration of infrastructure in existing infrastructure • Time consuming to set a standard	• User • Active during the next step of development of enabling heavy load capacity on ERS • Possible owner of stationary infrastructure	• Nothing additional	• One actor should have the overall responsibility, some ERS could be 100% publicly owned ERS and some 100% privately owned • Include private actors to stimulate innovation and development
Schenker Consulting	• Nothing additional	• High initial costs to convert vehicles • Competition for governmental funding • Source of electricity	• User • Lobbyist during the development of the system	• Nothing additional	• The actor who can deliver the system in the best way should deliver it and perhaps own it

4.2.3.1 Overall Incentives for ERS Among the Road Carriers

The overall incentives for ERS are similar among the interviewed road carriers. Common for all is that they believe in a future sustainable transport system and want to contribute to this development. ERS are in line with the vision of a sustainable transport system, which is presented as the main incentive for working with ERS. Furthermore, the financial benefits of a shift towards ERS are put forward by all the company representatives. For example, PostNord argues that ERS imply an opportunity to lower the overall operational costs substantially within the haulage contractor industry, even if the share of profit would be limited for every company. PostNord also means that there is a clear customer demand for fossil free transportation.

All interviewees agree that ERS could mean a competitive advantage for those who utilize the system, since it implies the possibility of decreasing operational costs and lowering the offered prices to customers. However, the possibility for creating a competitive advantage by utilizing ERS depends on a number of parameters which are still unknown, such as cost of converting vehicles, electricity price and the load capacity of the vehicle when driven on electricity.

4.2.3.2 Overall Perceived Risks and Barriers

The company representative all believe that there are barriers to overcome before ERS can be realized on a national level. All representatives emphasize the current lack of business models for ERS and stress the question regarding funding and infrastructure ownership. Common for all companies is that they perceive an operational risk with the ERS system. It is absolutely vital for haulage contractor firms to be able to secure the delivery of goods in time for their customers, as this is one of the core within the business. The new technology of electrically driven vehicles on an electrified road constitutes an uncertainty.

PostNord expresses that even if there are large profits to be made within the industry, it has to be shared between numerous actors which results in a limited share of profit for each actor. PostNord is uncertain if the limited profit will create enough incentive for private actors to engage financially to any larger extent. Furthermore, both PostNord and Schenker Consulting mean that there is large competition for governmental funding, which also constitutes a barrier for the realization of ERS. ABT-bolagen emphasizes the risk of integrating a new infrastructure in an existing infrastructure and certainly if the integrated infrastructure have a different owner than the existing infrastructure. They mean that nobody would have an overall responsibility for the system and the complexity would be too advanced.

Both PostNord and Schenker Consulting argue that there is a risk of high initial costs for converting vehicles to electricity driven vehicles and that there is an uncertainty regarding if the conversion will be profitable or not. PostNord argues further that there is a risk that smaller firms of haulage will not afford the initial conversion of vehicles and thus will get a competitive disadvantage in relation to the larger companies with lower operational costs. ABT-bolagen also argues that a deployment of ERS could imply structural changes in the

transporter industry. If smaller companies might not afford the conversion of vehicles, larger companies might be forced to own a larger share of their own fleet of heavy-duty vehicles. Today, the transporter industry is very fragmented as there are a lot of small firms on the market. This might change.

Furthermore, ABT-bolagen means that the limited load capacity with electricity drive constitutes a technological barrier since the profitability within the industry is dependent on the load capacity. ABT-bolagen also thinks that it will be time consuming to take a national decision regarding a suitable ERS standard.

4.2.3.3 The Future Role of Road Carriers in ERS and the Willingness to Invest

PostNord and ABT-bolagen are both participating in eRoad Arlanda and thus have a clear role in today's ERS movement. PostNord describes that Rosersberg is an important connection point for them as it is close by to both the airport, railway and highway. In the demonstration project, ABT-bolagen transports the goods for PostNord who decides the transport criterias. Schenker Consulting describes their current role within ERS as an observer of the development as they are not currently active in any demonstration project. They are however active in the area of e-mobility and are participating in a project where they are developing a hybrid heavy-duty vehicle.

Regarding the road carriers future role within ERS, they all agree that they will be users of the system. In addition, PostNord would like to be an early user of the system and a supplier of converted vehicles early during the development. ABT-bolagen expresses that they would like to participate in the next step of the development with enabling heavy load capacity when using ERS. Schenker Consulting thinks that they will have the role of a lobbyist during the development of a large-scale system on a national level, in order to affect the dimensioning of the system.

Moreover, they all agree on that they are not likely to invest in the road and electricity infrastructure. However, PostNord believe that there could exist some locations which would be profitable for them to own, but only in the case of a local, small-scale system. ABT-bolagen believes that they will own stationary charging stations, if ERS would be deployed and they would be users of the system. They will however not become owners of the infrastructure that provides dynamic electricity to vehicles in motion. Schenker Consulting is determined that they will not become an owner of the system but wants to remain open for the possibility that there could be certain beneficial locations. Since the interviewed companies see themselves mainly as users of a future ERS system, with small variations, their role within ERS will probably not be dependent on the ownership structure of ERS.

Timing and Type of Engagement

The future financial engagement of the road carriers will be related to converting the vehicle fleet. All of the interviewed representatives have a more or less positive attitude towards converting their vehicles. PostNord expresses that they would be willing to convert their vehicles if it did not imply decreased profits over time, compared to the current situation. Due to the environmental benefits of having electrically driven vehicles, the costs over time could be allowed to become somewhat higher, but not much. As ABT-bolagen believes that electrification is the future of the transport sector they would like to convert their vehicle

fleet incrementally when the timing is right. Schenker Consulting expresses that is it difficult to answer the question whether or not they would consider to convert their current vehicle fleet as there is no business case for it at this point. If a conversion would be profitable, they would probably do it.

Regarding the timing of the engagement they all wish to engage at an early stage of the development as they think that it is important to be a part of the leading edge. By participating at an early stage there is an opportunity to learn.

4.2.3.4 Ownership Structure's Effect on the Development from Small-Scale to Large-Scale ERS

Common for all interviewed road carriers is that they all have a positive attitude to a public ownership of ERS. They all emphasize the importance of having one actor that holds the overall control of the infrastructure and that an ownership involvement of private actors would increase the level of complexity, which they believe constitutes a risk. Another common opinion among the road carriers is that a PPP structure could imply higher user fees as they think that private actors would be more inclined to have higher profit goals. Furthermore, they believe that governmental capital is necessary for reaching a large-scale system as the initial investment is large and private actors would be unwilling to take that risk.

However, all interviewees also agree on that the technology development probably would be stimulated in a better way with a PPP structure than with a publicly owned system. They explain that the presence of private actors probably will create a momentum in the development. However, ABT-bolagen emphasizes that during the telecommunications infrastructure development in Sweden, the government took a firm grip which resulted in a quick expansion, which private actors might not have been capable of. PostNord thinks that the momentum of the development also will depend on the regulatory framework decided by the government.

As ABT-bolagen stresses the importance of someone having the overall responsibility of the infrastructure, the representatives explain that ERS locations either should be totally publicly owned or privately owned. Their suggestion is that a larger part of the ERS should be publicly owned while a smaller part should be privately owned. This way the private actors could stimulate the innovation and development of the system. Private actors should be involved on these terms from the beginning of the development.

Furthermore, the interviewees from PostNord chose to enlighten some additional risks with having a PPP structure. Private actors might not be technology neutral since they are dependent on their own financial gain and thus might prioritize a certain technology for their own financial gain. They argue that the technology research should be made during governmental arrangements, such as a pre-commercial innovation procurement, since it will create an openness regarding the technology which is a condition for reaching a large-scaleness. A risk with private actors leading the development is that the future system might become highly dependent of one actor patented solution. Thus it could be difficult to reach an appropriate standard, which could inhibit the development towards a large-scale system.

4.2.4 Construction Firms

The empirical material has been gathered from two different interviews with representatives from two different construction firms; NCC and Skanska. Individual opinions of each construction firm have been compiled in table 6 in order to emphasize the different views that were raised by the representatives. The content in table 6 should be viewed as a complement to table 2.

Table 6: Overview of individual opinions within the segment of construction firms

Specifics	Overall incentives	Overall perceived risks and barriers	Future role	Willingness to invest	Ownership structure's effect on ERS development
NCC	• Gain knowledge about the future transportation sector • Cost-efficiency	• Infrastructure investments are mainly allocated to high-populated areas • High maintenance costs • Global technology standard is necessary	• Nothing additional	• Nothing additional	• PPP structure enables the construction of more sustainable systems
Skanska	• Possibility of delivering a total infrastructure solution • Additional business opportunities	• Demand of ERS is dependent on the subsidizing of fuels Reaching a critical mass of users • Chicken and egg dilemma	• Nothing additional	• Nothing additional	• PPP structure could result in the construction of only profitable roads

4.2.4.1 Overall Incentives for ERS Among the Constructions Firms

A common incentive for the construction firms to engage in ERS is the environmental benefits and thus the possibility to reach the national and international climate goals. Both firms believe that solutions such as ERS are necessary in order to reach the set targets. Skanska is currently working with an e-mobility project, which is a larger infrastructure project connected to public transportation. NCC began working with electrified roads six years ago, before the pre-commercial innovation procurement held by the Swedish Transport Administration, the Swedish Energy Agency and the Swedish Innovation Agency. The reason for the early cooperation with a road power technology firm, Elways, was to gain potential advantages in the future by learning about the future transport sector. Hence, they perceived it as an investment for future business. Also, the related risks were considered to be few and non-substantial.

The representative from NCC concludes that from a national economic perspective, there are several advantages with ERS since it is not a high-cost technology and is predicted to be cost efficient for the road carriers. The representative from Skanska believes that there will be additional business areas connected to ERS, for example the delivery of total solutions with well-operated infrastructure. Another possible business area is new building opportunities on the surrounding land to ERS, that otherwise would not be attractive areas for building.

With more silent, electrically driven vehicles, construction of buildings could be enabled the closer to the roads.

4.2.4.2 Overall Perceived Risks and Barriers

Common for the construction firms is that they perceive a political risk connected to ERS. They agree that there is competition for funding with other transport infrastructures, as increased investments are necessary in several transport segments in order to reach the climate goals. The representative from Skanska means that the stakeholders' willingness to participate in ERS could be dependent on which type of fuel that in the future will be subsidized and how the regulatory framework will be designed. It is important that the government makes a long term decision to promote the deployment of the technology, since large investments are necessary in order to reach large-scale. The representative from NCC is concerned that the focus on infrastructure investments is mainly on high-populated areas. According to the representative, it is often easier to identify problems and solutions in these areas than on highways and country roads which carry heavy traffic. They mean that ERS could be a solution to this problem.

The interviewee from Skanska mentions the uncertainty of reaching a critical mass of users, which represents an enough volume of users to justify the investment and is beneficial for the technology development. When forecasting the future volumes of user, the pricing of other fuels in other countries have to be considered as well, since it affects the Swedish market. A sufficient regulatory framework have to be created by the government in order to make the ERS technology economically beneficial. Skanska also emphasizes the chicken and egg dilemma as there is a necessity for an infrastructure to convert users and vice versa.

Additionally, the representative from NCC perceives the risk of the decision regarding ERS technology standard. To maintain the mobility and flexibility of the transport sector, a global standard of ERS is necessary. Political decisions on an international level will be important.

Furthermore, the interviewee points out a global risk of generating electricity with fossil fuel in order to supply the ERS, which would eliminate the environmentally advantages of ERS.

4.2.4.3 The Future Role of Construction Firms in ERS and the Willingness to Invest

The construction firms both discussed the benefits of working with partners in projects as it often implies higher efficiency, decreased costs and lower risks for the involved actors. The construction firms expressed that different ownership structures are possible for ERS, both publicly owned and PPP structures. The construction firms agreed on that their future role will include responsibility for the functionality of ERS. If they were to invest in the system, it is important for both firms that the investment is profitable.

According to the representative from Skanska, the willingness to invest in ERS increases if there is a possibility for additional businesses, such as building real estates in areas close to the ERS. Skanska´s willingness to invest increases if a larger part of the infrastructure needs to be constructed, as they would prefer to deliver whole systems in cooperation with partners which are responsible for the electric infrastructure. Skanska could also conduct smaller constructions ordered by the government. The representative also describes that they could have a future ownership in ERS, where they are responsible for the functionality. On a local

level, especially for public transportation, Skanska is willing to invest to a larger extent since it is easier to forecast the future utilization.

The representative from NCC also perceives the possibility of additional business areas connected to ERS. If they would build new roads, they could include new technical solutions such as absorbing energy from vibrations in the road and gathering information about current traffic and emissions through built-in sensors. Furthermore, the representative believes that NCC has a low willingness to invest in the beginning of the deployment of ERS. In general, the risk is perceived to be higher if having an ownership but it depends on the business model. However, they are quite certain that their role will include maintenance and functionality, in addition to the construction of the roads.

The Future Role of Construction Firms in a Publicly Owned ERS Infrastructure

In a publicly owned ERS infrastructure, both construction firms enlighten that they will be hired by the government to construct and maintain the roads. They would prefer that the government hires them with a functional focus rather than giving them a specification of what should be done in a certain order. This role enables the actors to plan the construction, which can increase the optimization of the system. This flexibility enables sustainable innovations, since their core competences can be used properly. The representative from Skanska adds that it is beneficial if the government owns the ERS during the initial expansion phase, when the utilization is uncertain.

The Future Role of Construction Firms within ERS with a PPP Ownership Structure

In a PPP structure, the construction firms both believe that they can be responsible for the functionality and maintenance of the ERS. The government will still be the actor that in some way order what they should deliver.

The representative from Skanska discusses the scenario where they could deliver a suitable and economically feasible total solution and have full responsibility for the construction and functionality of the infrastructure. The government still has to be involved since they are not willing to be responsible for demand. Thereby, their risk would be limited and allocated to the area of their core competence. They believe that they would be able to manage the risks connected to functionality in a better manner than the government. It would thus be favorable for them to own that risk. Moreover, they are not willing to own a risk which they cannot influence. They are therefore certain that a completely privately owned system is not possible.

Regarding other financing solutions, the representative from NCC believes in new solutions rather than the traditional way for infrastructure investment. Though, NCC has negative experiences from PPP-projects, but are willing to try it as they have gained new knowledge. In general, a higher risk is perceived if the company is the owner. If NCC would own the ERS infrastructure they would need to change their business model. After owning the road for some years, it could be sold to the Swedish Transport Administration, according to the representative. They are willing to own the ERS during the construction phase and possibly for a maintenance and service period, but would thereafter consign the ERS. They also see themselves in a role where the Swedish Transport Administration gives them an existing road which they update to an ERS. The road would then be given back to the Swedish

Transport Administration when NCC has gained the profits. The interviewee does not believe that their role in a PPP structure would differ in the different phases of an ERS transition.

Timing for an ERS Engagement

Since the construction firms probably would build large parts of the ERS infrastructure, their timing for an engagement is during the planning phase. Regarding a national system, the interviewee from Skanska believes it is beneficial if the government owns the infrastructure and hire construction firms to build the infrastructure. Continuing, both representatives from Skanska and NCC express a higher willingness to invest in small-scale projects early on, compared to investing during the expansion phase of a large-scale system.

4.2.4.4 Ownership Structure's Effect on the Development from Small-Scale to Large-Scale ERS

Both Skanska and NCC agree on that a PPP structure enables them to be involved in projects on a functional level, rather than according to a given specification. With a PPP structure, they both believe that the development of the technology and the deployment of ERS will be faster. Both interviewees mention that political decisions will have a great impact on the development from small-scale to large-scale ERS. The representatives agree that governmental involvement is necessary in order to obtain a large scale system.

The interviewee from Skanska expresses that the expansion from small-scale to large-scale ERS would happen sooner if the government decides to build the system. The interviewee predicts a risk with private ownership where only the most profitable roads will be electrified. The interviewee does therefore see the importance of the government's role as the responsible authority of ERS in a PPP structure as well.

A PPP structure would create a momentum in the development from small-scale to large-scale ERS, according to the representative from NCC. However, they do not believe that the construction of the ERS infrastructure would be affected by the ownership structure. They believe that the development would be affected more by the level of focus on functionality during the procurement process. The interviewee is also certain that alternative financing solutions, such as PPP, would create a more sustainable system compared to the traditional financing. The reason for not considering traditional financing as equally beneficial is the restricted governmental budget allocated to infrastructure investments.

4.2.5 Road Power Technology Firms

The empirical material has been gathered from two different interviews with the representatives from Siemens and Elways. Individual opinions of each road power technology firm have been compiled in table 7 in order to emphasize the different views that were raised during the interviews. The content in table 7 should be viewed as a complement to table 2.

Table 7: Overview of individual opinions within the segment of road power technology firms

Specifics	Overall incentives	Overall perceived risks and barriers	Future role	Willingness to invest	Ownership structure's effect on ERS development
Elways	• ERS is their core business as a development corporation	• Main barrier is to initiate a large-scale deployment	• Deliverer of the ERS technology • Licensing possibilities	• Could only invest if they would be financially supported by other actors, otherwise not	• Beneficial with PPP structure due to less competition with other infrastructure investments
Siemens	• Has been working with electrification of road transports since 1882 • Export potential of the technology • ERS is considered as beneficial compared to other technologies	• Long time horizon of infrastructure budgets • Legislation of current road system has to change • Finding new business models • Extreme development within battery technology	• Deliverer of the ERS technology • Could be responsible for operations, maintenance and financing at a local level	• Could invest in local systems • Low willingness to invest in a large-scale system	• Beneficial if the government owns the system • Risk that only profitable roads will be electrified with a PPP structure • Legislation of road system affect which ownership structure that is beneficial

4.2.5.1 Overall Incentives for ERS Among the Road Power Technology Firms

A common incentive for the road power technology firms to engage in ERS are the environmental benefits and the possibility to reduce the fossil fuel dependency in the transportation sector. Another shared incentive is connected to financial factors. According to the representative from Siemens, it is beneficial for them if fossil fuels are replaced by electricity. The reason is that they are delivering other types of equipment and technology to the electricity producers and since more electricity have to be produced and distributed the demand for these products and services will increase. The representative from Elways discusses the potential for actors within ERS to be more profitable due to decreased overall transportation costs.

Developing the ERS technology is the core business of Elways, which is a development corporation registered in 2009. It is therefore natural for them to be involved in an ERS project. The representative from Elways also adds that one incentive for working with ERS is from a strategic perspective as oil have caused several difficult situations in the world over time.

Siemens have been working with electrification of road transports since 1882 starting with the trolley bus. Due to the forecasted, future increased transport demand and the uncertain solutions for reducing fossil fuel dependency in the heavy goods transport sector, Siemens chose to develop their existing technology to ERS. Since Siemens already has knowledge about the technologies for both the road infrastructure and vehicles, they saw a potential in ERS. Another incentive for choosing ERS is the comparison with other technologies. It is not realistic that batteries can carry heavy goods and biofuel are currently too expensive. According to the representative, Siemens also identifies a potential export possibility with their ERS technology.

4.2.5.2 Overall Perceived Risks and Barriers

Commonly, the representatives perceive several political risks. The question of how ERS should be commercialized has to be answered before the system can be deployed, argue both Siemens and Elways. According to the representative from Siemens, one of the major questions is how the investment should be financed. The representative believes, due to the long time horizon of the infrastructure budgets, that a governmental decision has to be made regarding separating the ERS investment from the existing infrastructure budget. The representative from Elways believes it is important to promote the advantages of ERS as it creates more incentives for an implementation. The representatives commonly mention the risk regarding the technological functionality in certain types of weather, but they both consider this risk manageable.

In addition, the representative from Siemens discusses the legal issues with a change of the traditional ownership structure as the current legislation does not facilitate for this. The barrier is to get a political decision to change the legislation and to shorten the time frame of the amendment of the law. A challenge to enable a self-supporting system is to discover new business models and ideas for how revenue should be collected, according to the representative. In the case of a PPP structure, this challenge is particularly crucial. The representative also identified the possibility of an extreme development of batteries. The representative is certain that transports will be powered by electricity in the future, how the electricity will be supplied to the vehicles is however less certain. Furthermore, some considered manageable risks are person safety related, since a new object will be located in the road area. New regulations will be needed for this. They also believe that there is a risk for possible resistance against the ESR technology. The representative from Elways agrees that there often is resistance against new technology, which have to be overcome. The representative means that the main barrier for ERS is to reach a deployment of the system.

4.2.5.3 The Future Role of Road Power Technology Firms in ERS and the Willingness to Invest

The perceived future role of the road power technology firms within ERS are common for Siemens and Elways. The perceived role is independent of the ownership structure. They will continue to develop and deliver the ERS technology, both for the road infrastructure and vehicles.

According to the representative from Siemens, the company will continue to be a system supplier if ERS were to be deployed at a large-scale. When discussing local, smaller projects Siemens can also deliver the system to a private actor and could then have full responsibility for operations, maintenance and perhaps financing. Independently of the ownership structure, Siemens will be a supplier of the system and also a supplier of ERS technology to the vehicle industry. They believe that a privately owned system is possible from a financial perspective, as there is already private actors who are interested in investing in a system. The representative expressed that ERS imply a secure revenue stream and it would therefore be a safe investment. The representative means that there is a clear demand for the system.

The representative from Elways believes that licenses on the technology will be common in the long-term perspective. Currently Elways does not have the necessary financial means to invest in a system, according to the representative. If Elways were to obtain owners of their own and thereby more available capital, they could possibly invest and own a share of the

system. However, the representative express that it would be beneficial if previous participants of a local projects engaged financially during a large-scale deployment since they have knowledge and experience within ERS.

The representative from Siemens adds that it would be more beneficial for all stakeholders if the government owned the system. The representative from Siemens does consider it as possible with a PPP ownership structure, if the juristic obstacles and the challenge of how revenue is to be made are solved. A solution could be to form a holding company and apply for funding from pension funds and venture capital companies and thereafter receive a concession to build ERS on certain roads. If a PPP structure would be applied, it is not likely, but possible, that Siemens would be a part of the company which operates the system. The representative perceives financial risks when owning the system, but are not certain of how large it would be.

The representative from Elways compares the PPP structure within ERS to the PPP structure during the deployment of the GSM system where the government sold rights for building the system to operators. The operators could collect the profits if they assured to build and operate the system. Common for both ERS and GSM are the chicken and egg dilemma. The representative argued that the government could legislate different aspects of the deployment of the system and thereafter sells rights to other actors who will construct it.

As the firms would be system suppliers, they would have to engage in the development during the initial deployment, whether if the firms are owner of the system or not.

4.2.5.4 Ownership Structure's Effect on the Development from Small-Scale to Large-Scale ERS

The representative from Siemens presents the potential situation where a PPP structure results in that only the roads which carry heavy traffic will be electrified since these roads would be the most profitable to electrify. Depending on the business model of a PPP structure, the government may not be allocated a share of the profit in order to enable construction on less profitable roads. A solution for this would be if it was stated in the procurement that a share of the revenues has to be re-invested in the infrastructure. The representative believe that a PPP structure has the potential of reaching a large-scale deployment more rapidly compared to a public ownership, but only if the current legislation of the road system was to be radically changed.

The representative from Elways considers a PPP structure to be beneficial due to the restricted governmental budget and the competition with other infrastructure investments. At first it may be favorable if the government is responsible for the local systems, before the system is expanded. When it is time for implementing the system at a large-scale, the government can initiate a procurement for private actors, inviting them to finance the system and letting them operate and collect revenue from the system. In addition, it is believed that the total cost of the system would be lower if a PPP structure were to be applied. Though, requirements for functionality and for electrifying less profitable distances have to be included in the procurement.

4.2.6 RUAB

The empirical material has been gathered from three different interviews, one with each owner of RUAB, except for Kilenkrysset. The reason for interviewing the owners of RUAB is to investigate the owners' incentives and perceived risks for engaging financially in the demonstration project and whether or not the current ownership structure would be applicable for a large-scale system, according to the interviewees. Common opinions and views among the interviewees have been identified and summarized in table 8.

Table 8: Summary of opinions within RUAB

Summary	Incentives and advantages with RUAB's ownership structure	Risks and disadvantages with RUAB's ownership structure	Opinions regarding current ownership structure and future applicability at scale
RUAB	• The structure facilitates the communication with the Swedish Transport Administration • The structure of RUAB is familiar and the risks are clear as it is a stock corporation	• No general risks	• The current ownership structure would be applicable for a large-scale system with some differing opinions regarding certain adjustments

In addition, further individual opinions have been compiled in table 9 in order to emphasize the different views that were raised by the interviewees. The content in table 9 should be viewed as a complement to table 8.

Table 9: Overview of individual opinions within RUAB

Specifics	Incentives and advantages with RUAB ownership structure	Risks and disadvantages with RUAB ownership structure	Opinions regarding current ownership structure and future applicability at scale
NCC	• Networking and establishing relationships with the stakeholders • Good investment for the future • Gain knowledge about ERS	• Nothing additional	• Could possibly become too bureaucratic
Elways	• Gain influence in the consortium and to show their commitment	• Nothing additional	• RUAB's ownership structure is applicable at large-scale, but the purpose of the company will be different
ABT-bolagen	• Gain knowledge and good PR	• The necessity for companies to be profitable could lead to unbeneficial short-term decisions from a research perspective • Risk of not gaining the expected advantages	• Uncertain if ownership structure is applicable for a large-scale system • Main incentives of the company might change which probably will affect current structure

4.2.6.1 Incentives for Investing in RUAB and Advantages with the Company Structure

RUAB was initiated after the pre-commercial innovation procurement held by the Swedish Transport Administration, the Swedish Energy Agency and the Swedish Innovation Agency. RUAB is the formed corporation that takes care of the ERS research and demonstration project eRoad Arlanda's businesses. One corporation enables simple communication with the Swedish Transport Administration, since they do not have to coordinate with several parties. Further, RUAB facilitates for dividing costs, revenues and responsibilities among the owners, according to the representatives from ABT-bolagen. The owners of RUAB are comfortable with the company structure as RUAB is a stock corporation, which is perceived as familiar. Hence, all the owners can easily foresee and understand the risks of their engagement since they have invested limited capital in the project.

NCC started working with Elways before the pre-commercial innovation procurement and the representative from NCC mentions that if the procurement had not been held, RUAB would probably not exist. The representative from NCC saw the potential in Elways' solution and decided to initiate a collaboration. They perceived the advantages as many and the risks as small. The representative from Elways believes that there are several benefits with the ownership structure of RUAB. Since the involved companies have different incentives for engaging in ERS and have different financial situations, it is preferable to have a joint connection through the company in order to align the goals. The representative also adds that all important stakeholders are part of the consortium which is highly beneficial for the development of ERS.

Elways incentives to invest in RUAB was to gain influence in the company and to show their commitment. The small capital investment does not affect how the project is conducted. The representatives from ABT-bolagen identify two major incentives for investing capital in RUAB, to gain knowledge and to obtain good PR. The representative from NCC enlightens the advantage of networking and establishing a relationship with the other stakeholders in the consortium, which could enable a future joint collaboration towards the next step in the ERS development and expansion. NCC does not consider their investment in RUAB as significant, but consider it as an investment for the future. NCC wants to gain knowledge within ERS and does not expect to gain any financial profit from the project. Furthermore, the representative believes that the current ownership structure, with a mix of both large and new, smaller companies, are beneficial when working in contact with agencies and other companies.

4.2.6.2 Risks and Disadvantages with the Company Structure

In general, the owners of RUAB do not perceive any risks regarding the ownership structure.

The representative from Elways expresses that the risk of investing capital in RUAB is minor compared to other risks they have. One potential disadvantage according to the representatives from ABT-bolagen is the companies' drive to be profitable, which may result in short-term decisions and thus not be beneficial from a research project perspective. However, this is not an existing issue within RUAB. The representatives from ABT-bolagen consider the risk of not gaining the expected advantages from the project. They also express the uncertainty of possible risks later on, since there are difficulties in measuring all possible risks within a research and demonstration project, such as person injuries and material damage. The representative from NCC does not perceive any risks. All members of the

consortium have an agreement with RUAB and the importance of trust and collaboration is essential when handling a research and demonstration project connected to large capital investments.

4.2.6.3 Opinions Regarding Current Ownership Structure and Future Applicability at Scale

Since the research and demonstration project is financed by the government, the members have continuous meetings with the Swedish Transport Administration. This structure could be compared to a PPP structure, when private and public actors cooperate. All RUAB owners consider the communication with the Swedish Transport Administration as easy. The representative from NCC considers it to be too bureaucratic occasionally but admits that they also can be bureaucratic at times.

The representative from Elways believes that a similar ownership structure can be appropriate for a future large-scale system. However, the structure would have other characteristics as the purpose of the company would be different from today. The purpose of today is to deliver knowledge and in the future it will regard performance and time plans. Since Elways currently is a development corporation, other financiers are necessary in order to enable their involvement in a larger project. They can offer licenses and knowledge, but cannot stand for the financing as the situation is today.

The representatives from ABT-bolagen are not certain if this ownership structure could be applied on a large-scale system since the structure is created for a research and demonstration project. The main incentives for the company might change from being related to knowledge and PR to financial factors. Thus, adjustments may be necessary to the current structure.

According to the interviewee from NCC, several actors should cooperate regarding road infrastructure investments, instead of the traditional model where the Swedish Transport Agency or a municipality procure the construction of a road. Their opinion is that one actor should be responsible for the construction and another should be responsible for operation and maintenance. Further, they believe that the traditional model will probably still exist in the future, they are positive towards new business models which include several actors and collaborations. This way, various services and additional business possibilities could be connected to the road system. A structure like the current consortium would be applicable on a larger system. The representative from NCC believes that the procurement process has to be different in order to open up for these new business models. The representative is not certain that NCC would be willing to invest more capital in an expansion phase, they may find another ways to be involved. NCC is not a venture capital company, but in the future they might be possible to open up for additional investment solutions.

5 Discussion

A transformation of the traditional transport system by implementing ERS is reasonable to discuss based on the sociotechnical perspectives described by Geels (2002) and the Large Technological System framework described by Hughes (1987). Political, environmental targets are creating a demand for new solutions as the traditional ways are insufficient from the environmental perspective. Analyzed from a multi-level perspective, the new set political targets correspond to changes at the sociotechnical landscape-level, creating tensions at the sociotechnical regime-level as it changes the conditions of the industry. Consequently, a window of opportunity for new solutions and innovations are created. It would therefore be fair to argue that the initial conditions for ERS to be considered are right, which is why a discussion regarding the subject has emerged. The demonstration projects of ERS are located at a niche-level where the projects are protected from ordinary market forces.

According to Geels (2002) and his multi-level perspective, it requires an aligned development over the three levels, as the system is deeply rooted at all levels, in order to create a transition within the transport system. Mosca (2008) argues that environmental impact creates the strongest incentive for such a transition.

5.1 Stakeholders' Future Roles and Their Willingness to Invest

When analyzing the findings from the conducted interviews, a number of trends were identified. In the following text a discussion follows regarding the incentives for participating in ERS, including the stakeholders' future role and willingness to invest in ERS.

All interviewed segments have stated environmental and financial benefits as main incentives for their current or future participation in ERS. The possibility to decrease the emissions from fossil fuels in the transport sector and thereby reach the environmental goals are the most vital environmental arguments. The financial incentive is based on the prediction that ERS would generate lower transportation costs. Existing literature argues that environmental issues are one of the main incentives for initiating an infrastructure transitions (Mosca, 2008). As the environmental issues of the transport sector are prioritized on the political agenda, and it is mentioned as one of the main incentives among the actors, the authors of this thesis argue that there is a window of opportunity for a transition in the transport sector. Furthermore, the other mentioned incentives for engaging in ERS varied between the different segments as they were strongly connected to the actors' own businesses. A conclusion from the interview study is that the stakeholders' overall incentives to participate in ERS are independent of the ownership structure of the system in general.

The incentives for actors to participate in demonstration and research projects early in the development of ERS are mainly to increase knowledge about ERS and the possible future transport system, according to the stakeholders in RUAB. In addition, some of the involved actors in RUAB mention the good publicity and branding possibilities that an engagement in this sort of research and demonstration projects provides. However, the incentives among the private actors for participating in an ERS research and demonstration project, such as RUAB, and the incentives for participating in a large-scale ERS have been found to be very different when analyzing the empirical findings. In a large-scale system, the incentives for

participating in ERS will be commercially based in contrast to today's demonstration projects. The representatives from Elways and Siemens argue that there is a need to prove how ERS can be commercialized before the system can be deployed. Business models are absolutely necessary in order to reach a commercialization and the lack of ERS business models has been mentioned as a great barrier for reaching a large-scale deployment among the stakeholders, independently of stakeholder segment.

Since the stakeholders' overall incentives to participate in ERS are based on environmental and economic benefits, it is important to discuss the influence of national energy mix and energy price on these incentives. Using ERS will only be more environmentally friendly than using the traditional combustion engine if the electricity powering the ERS is produced by renewables or other non-fossil fuels. As the energy mix varies substantially between different countries, the environmental incentive will not be equally strong in every country. The argument regarding energy mix was also enlightened by the representative from the Swedish Energy Agency. The financial benefits of using ERS will heavily depend on the energy price, which was discussed by all the road carriers and the representative from NCC during the interviews. If the energy price increases, the financial benefits of using ERS will decrease. Further, the prices of other types of fuel, such as diesel, will also have an impact on the financial incentive as it effects the level of financial benefits with ERS. If there would be a drop in fossil fuel prices at a time when the electricity price is high, the economic benefits of ERS might become nonexistent.

When analyzing the interviews, it was important to consider the different perspectives of the public and private actors. The actors of private companies answered the interview questions from a perspective with the financial benefits of their own company in mind. On the other hand, a public actor such as the Swedish Transport Administration did not refer to any financial gain in their answers. The Swedish Transport Administration refers to other gains when evaluating potential investment than strictly financial, in contrast to many of the private actors where economic profitability determines if an investment should be done or not. The Swedish Transport Administration aims to increase public welfare and their duty is to assure availability of the national infrastructure. As a result, these arguments are more essential during investment decisions than strictly financial aspects.

When analyzing the empirical findings regarding the stakeholders' future roles within ERS, it is clear that all actors predict a future role which is in line with their current business model. The future roles of the actors are, on the contrary from the overall incentives, dependent on the ownership structure of the system. If the actors are willing to own a share of the infrastructure it also affects their future role within the system. The empirical findings have shown that the willingness to invest in the infrastructure is dependent on the current business model of the company.

Several actors discussed the potential of expanding their current business within areas connected to ERS. The electric utilities are interested in new business opportunities connected to ERS which does not only include selling electricity per kWh and Skanska is interested in business opportunities of building real estates in areas close to the ERS.

There is a higher willingness to invest in small-scale systems among the private actors. The main reason is that the utilization of the system would be easier to forecast and the allocation of benefits are clearer in a small-scale system. This simplify the evaluation of the investment. On a national level, the private actors find it difficult to estimate the number of users of the system, which implies uncertainties and an increased investment risk. The public actors, on the other hand, are willing to invest in a large-scale system if the investment results in increased public welfare. The willingness to invest also vary between the different phases in the development process among the actors, there is no obvious trend among the actors to invest early or late in the development process. The stakeholders which refer to invest early in the development value the learning that comes from an early engagement rather than the financial risk related to an early engagement. Vice versa applies for the stakeholders that prefer to invest later in the development.

5.2 The Necessity for Cross-Sectorial System Suppliers

The increased demand for investments in Swedish transport infrastructure and the political environmental ambition, challenge the traditional transport system and create a window of opportunity for the establishment of new innovations. The deployment of new innovations, such as ERS, would imply a sociotechnical transition within the robust transport sector. According to Tongur and Engwall (2014), the main barriers for a transition is connected to the complex system design of the transport system. They state that there is a need for more closely linked system components in order to enable a transition of the system. Thus, there is a necessity for a decreased level of complexity in the system in order to facilitate for a transition.

The current transport system can be conceptualized by figure 8, which is inspired by Tongur (2013). The system designers of the current system are the government and the Swedish Transport Administration. The Swedish Transport Administration is responsible for the procurement process for various products and services connected to the transport system. The providers of these products and services are referred to as sub-system suppliers, which are active in a certain segment.

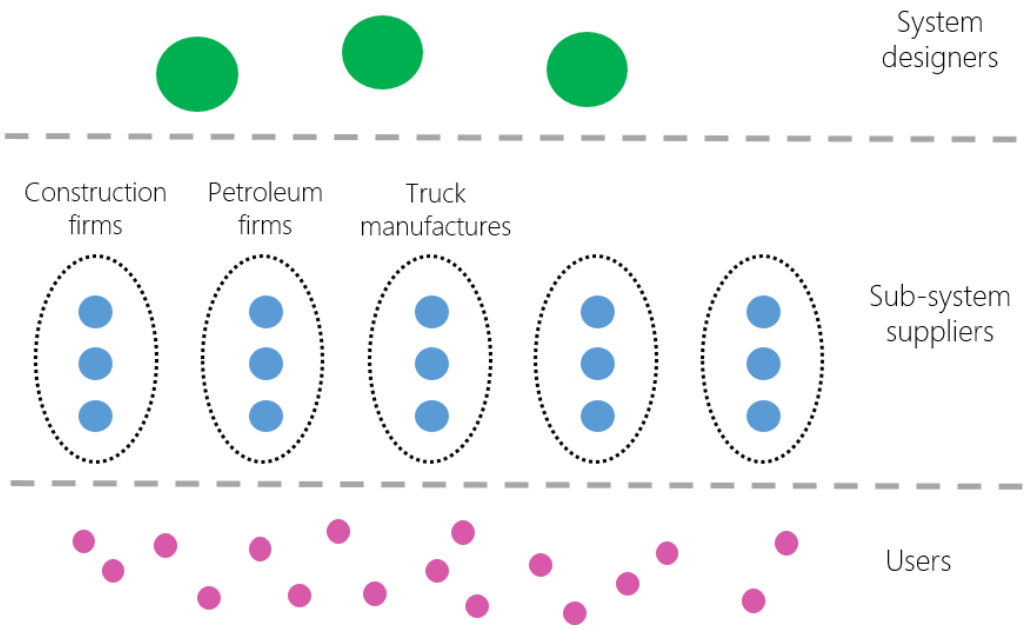

Figure 8: Conceptual model of current transport system

As the transport system is being questioned, and alternative solutions are being discussed, the traditional financing and procurement are being challenged as well (Carbonara, et al., 2015). According to the empirical findings, the traditional procurement has recently been re-evaluated in Sweden and there is a drive to focus more on procuring functionality rather than according to a specification, in order to properly utilize the level of competence of the sub-system suppliers. Hence, the interface between the system designer and the sub-system suppliers have developed from being sharp to more flexible and versatile.

The authors of this thesis argue that an establishment of new technology, in the transport sector which is characterized by a high level of systemness, requires competence and knowledge of actors within the current system, but also actors within the development of the new technology. Hence, procuring a functionality will be even more important when procuring a new system, such as ERS, as there is a lack of competence within the area in general. Hence, business as usual and procuring according to a specification will not be applicable during a system transition. Thus, there is a requirement that the sub-system suppliers of the current transport system approach the role of co-system designers.

The stronger need for procuring a functionality and the need for a decreased level of complexity call for a restructuring of the many system components, including the sub-system suppliers, in order to facilitate for an infrastructure transition. When investigating the case of a transition to ERS, it was found that competence from the infrastructure sector, the transport sector and the energy sector is vital for obtaining a functioning system design. Creating a functioning system thus depends on and requires the cooperation of numerous actors. In order to decrease the complexity, the authors argue that it is time to increase the cooperation between the current, sector specific sub-system suppliers and form cross-sectorial system suppliers instead, where the cross-sectorial system suppliers approach the role co-designers. This idea is conceptualized in figure 9. In the case of ERS, the cross-sectorial system suppliers can be referred to as ERS suppliers. The authors believe that this idea makes sense from a complexity perspective, competence perspective and innovation perspective and implies a closely linked system.

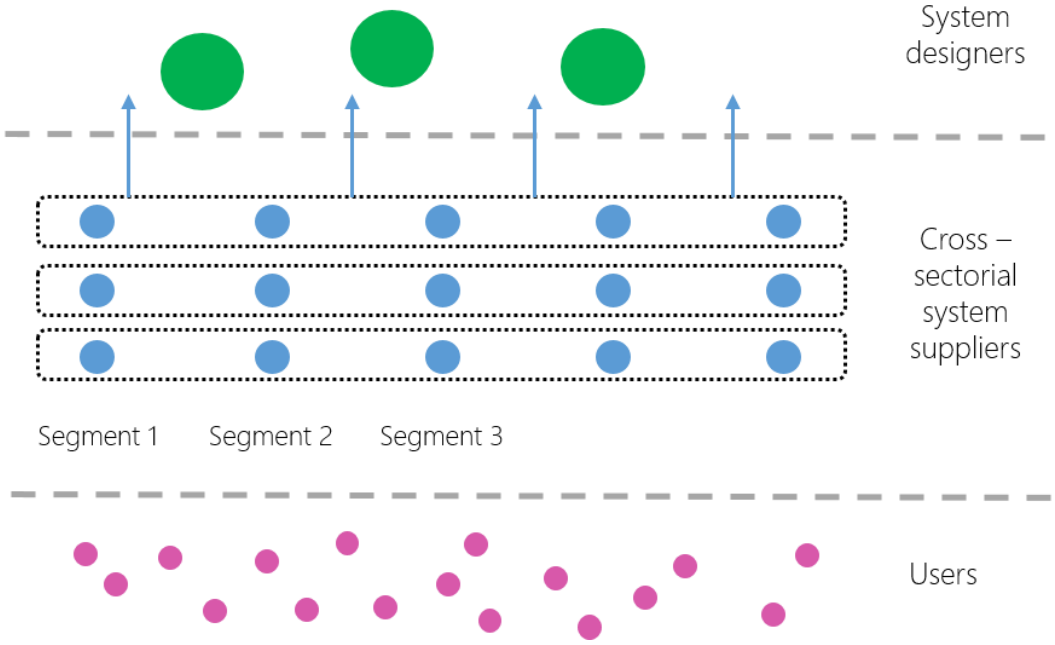

Figure 9: Conceptual model of future ERS stakeholder structure

The authors of this thesis believe that the cross-sectorial system suppliers will resemble the consortiums of the ongoing ERS demonstration projects, such as eRoad Arlanda, as they include many different stakeholders within different segments. Consequently, these consortiums would obtain a competitive advantage if the suggested structure would be realized as they have an established business relation and have obtained knowledge within ERS.

The authors believe that the structure with cross-sectorial system suppliers will be applicable for both local and national constructions and operations of ERS. However, the combination of stakeholders within the cross-sectorial system suppliers will have to be somewhat different depending on if it is a local or national ERS. For example, the local cross-sectorial system suppliers will be dependent on involving local stakeholders to a larger extent, such as the

municipality, local grid owners and energy suppliers. Many of the stakeholders will however be the same for local and national constructions of ERS.

During an initial deployment of ERS, towards a national, large-scale system, it is suggested by the authors to only have one cross-sectorial system supplier which manages the constructions and operations of ERS. This would decrease complexity and facilitate for increasing and establishing knowledge during the initial phase, which is vital. Furthermore, it would be difficult to obtain competition on a cross-sectorial system supplier level during the initial deployment, as there are a limited number of actors which possess competence within ERS at such an early phase. Also, assumed that the government has decided on a technological standard before initiating the deployment of a large-scale system, there might be one road power technology firm who owns the rights of the technology. At an early stage it would be vital to include this firm in the cross-sectorial system supplier in order to increase the knowledge regarding implementation at scale on a national level.

As the system and technology matures and knowledge regarding ERS has been established, it is suggested by the authors to introduce competition at the cross-sectorial system supplier level, as it is not as crucial to obtain knowledge and decrease complexity. It would require the ERS technology to be open, or licensed, or that the road power technology firm became a subcontractor to the cross-sectorial system suppliers rather being a part of them. By letting several ERS suppliers form on a free market a competitive and market-like environment could be approached. Moreover, it is also possible that the traditional sector specific procurement will become sufficient when the technology has become mature.

It is important to consider the risks with the suggested structure of cross-sectorial system suppliers. One risk that the authors of this thesis foresee is lower sector-specific competition. As consortiums will compete during the procurement, rather than individual companies, the sector-specific competition will occur before the procurement when consortiums are formed. It is fair to believe that once a consortium is created and as the relations grow stronger, the included actors will probably not be exchanged to a large extent. Consequently, a barrier will be formed for individual actors who want to enter the market and participate in the procurement, as it is impossible without a consortium. As mentioned, it could be possible to re-introduce the traditional and sector-specific procurement in order to increase the sector-specific competition when the system has matured if this were to be a problem. Another risk that the authors foresee is non-compatible business models and differing goals between the consortium and the participating, individual actors. This can result in inefficiency, among else.

5.3 The Implications of Cross-Sectorial System Suppliers as Infrastructure Owners

The authors of this thesis mean that infrastructure financing and ownership could be a possible additional step for the cross-sectorial system suppliers and would in that case imply additional system control and new, possible business opportunities.

Both existing literature and the empirical findings indicate that the suitability of different ownership structures depends on the size of the system. Mosca (2008) has discussed transport infrastructure as natural monopolies due to the capital intensity of a large-scale system. Similarly, Hasselgren (2013) described transport infrastructure assets as difficult to manage on a market-basis. Furthermore, the Swedish historical railroad development showed that once the system and the transport flows became national rather than local, a change in ownership structure was required in order to increase efficiency and obtain an overall control and coordination in order to manage the increased complexity of a national system (Hasselgren, 2011). There was an overall trend among the interviewed actors that the government should play a key role in a large-scale, national ERS, as the main financier, the main risk absorber and the overall coordinator, while many of the interviewed stakeholders would consider to invest in the infrastructure on a local level. Since PPP tends to increase the system complexity (Carbonara, et al., 2015) as additional actors are financially engaged and thereby obtain increased system control, both literature and interviewed actors point out the possible insufficiency of a PPP structure in a large-scale, national system. Furthermore, an increased level of control among private actors, through financing, could interfere with the governmental mission of the Swedish Transport Administration of securing availability of the national infrastructure, according to themselves. In addition, investments in a large-scale, national system are considered as high risk among the interviewed private actors due to the large investments and unclear allocation of benefits.

However, the authors of this thesis mean that the complexity level is considerably lower in a closed, small-scale ERS system. In the case of a closed system, the allocation of benefits is clear and the government does not need to be as involved in the system, since the large-scale implications, such as the necessity for advanced coordination, overall control and public availability, do not apply. The empirical findings have also pointed to this fact. The authors mean that the user itself could become the procurer and designer of the system in the case of a closed system. Therefore, there is a greater possibility for a cross-sectorial system supplier to become both a supplier, co-designer and an infrastructure owner in a closed system. A closed system could possibly be entirely privately owned as well. As a closed ERS system still would imply environmental benefits, the authors believe that it is possible that the systems would be subsidized by the government. Due to the less complex system design in a closed system, the authors argue that a PPP structure would be more suitable in such a system. In addition, the empirical findings show that the trend among the interviewed private actors is that the willingness to invest is greater if the system is small and the allocation of benefits is clear.

When evaluating the potential of a local, or national, system to be 100 % privately owned, there are still a lot of additional investigations that are necessary in order to make conclusions. However, existing demonstration projects, such as RUAB, could be viewed as an example of a small-scale system, according to the authors. The empirical findings have showed that existing demonstration projects in Sweden have been dependent on governmental financing, which indicates that the drive among private actors to build ERS with only private capital is low. However, the purpose of the small-scale demonstration projects is scientific rather than commercial at this point, which makes the demonstration projects of today incomparable to future commercial, small-scale projects.

Concluding, the suitability for a PPP structure is dependent on the size and level of complexity of the system in question, among else. In a large-scale, national system, where a governmental agency is the procurer, a cross-sectorial system supplier can become both a supplier and a co-designer, but should not become an owner of the infrastructure during an initial expansion phase. In a closed, small-scale system, where the user is the procurer, a cross-sectorial system supplier can become both a supplier, co-designer and an owner as the level of complexity is considerably lower.

In relation to the case study regarding a transition to ERS, the authors of this report argue that the transition increases complexity in addition to the existing system complexity. A national, large-scale ERS system requires an overall coordination (Hasselgren, 2011) and decreased complexity in order to manage a transition (Tongur & Engwall, 2014). The authors of this thesis thus argue that competence from each relevant system (infrastructure system, energy system and transport system) and closer cooperation among system actors should be in focus, rather than private ownership and control on a national level, as it adds complexity to the initial expansion phase. In a closed, small-scale system a PPP structure, or private ownership, can be in focus, where the complexity level is lower.

Furthermore, according to the historical perception described in literature and the empirical findings, a PPP structure, or private ownership, facilitates for innovation (Bogart, 2009). The authors', of this thesis, conclusion is therefore that closed systems, with a PPP structure, or private ownership, could help to drive innovation within the technology area of ERS. Thus, it would be beneficial from a socio economical perspective to have both open, national, large-scale systems owned by the government and closed, small-scale systems owned by private actors or with a PPP structure, in order to drive the development while still obtaining a national and robust system.

The authors of this report believe that it is possible that the suggested stakeholder structure with cross-sectorial system suppliers could facilitate for PPP on a national level as well, since a consortium-like structure including several private actors is identified as one of the success factors for a PPP arrangement (Osei-Kyei & Chan, 2015). However, the authors of this thesis believe that PPP on a national level would be more suitable after the transition when the system is mature.

5.4 The Ownership Structure's Effect on the ERS Transition

The literature study and the empirical findings have shown that the infrastructure ownership affects system transitions to a large extent and in different ways depending on the characteristics of the system. An analysis has been made based on investigating the implications of system transitions within the infrastructure sector, historical cases and the current state of ERS, in order to predict the ownership structure's future effect on the development. Furthermore, the authors argue that an important part of the analysis is to include opinions and views of stakeholders within the segments which will be affected by a future ERS transition, since they have valuable competence within their systems. Knowledge within the current systems, such as the transport system and the energy system, is of great importance in order to understand the specific implications of a system change. Therefore,

the findings from the case study is compared to existing literature and the historical cases in the following discussion.

Systemness, capital intensity and asset durability, which are the characteristics of infrastructure systems, are highly important to take into consideration when discussing the ownership structure's effect on the development of ERS (Markard, 2011), as a lot of the ownership structure effects, enlightened in literature and during the interview study, originates from these factors.

5.4.1 PPP's Effect on the Development from Small-Scale to Large-Scale ERS

When speaking of a large-scale, national system, the authors of this thesis refer to a system which is publicly accessible and utilized. In order to be large-scale and national, the system should connect several regions. An example of a large-scale, national system is if Stockholm, Malmö and Gothenburg were to be connected with electrified roads. If a large-scale ERS were to become a solution to the environmental issues in the transport sector, which constitutes the source of the emerged discussion according to Tongur and Engwall (2014), the authors of this report argue that the infrastructure needs to be deployed widely over the country, independent on user frequency and thus profitability.

The reviewed literature within the area of the ownership structure's effect on infrastructure development presents distinguished theories and views on the matter. This study has mainly compared PPP to the traditional ownership structure of infrastructure in Sweden. The literature presents a number of benefits with PPP within infrastructure, such as higher efficiency, better quality, reduced costs and a more reliable public infrastructure. At the same time, a lot of literature question the same benefits and promotes an opposite thesis. The mentioned benefits by literature was also strongly enlightened during the interview study as an argument in favor of PPP.

There are a lot of positive aspects of having a PPP structure during the development of a new infrastructure system, which are enlightened in both the interview study and literature. Existing literature as well as the empirical findings strongly agree that PPP drives innovation and creates a more dynamic environment, which could be preferred when developing and implementing new technology. Many of the interviewed actors mean that the profitability incentive of private actors is necessary during the development of a new infrastructure since there also should be a financial rationale behind the decision to build a new infrastructure. The focus of profitability is also believed by the interviewed actors to foster an efficient environment and thereby reduced costs. Thus a private financial engagement could be beneficial from a socio economical perspective.

The authors of this thesis argue that the difference in public and private incentives and goals is a key factor to discuss in relation to the ownership structure's effect on the development from small-scale to large-scale systems. The empirical findings show that public incentives are in general focused on public welfare, while private incentives are financial. An opinion raised by many interviewees, which also is presented by Mill (1849), is that a private owner would mainly like to invest in the most profitable locations for ERS where the forecasted utilization is high. The authors of this thesis mean that if an infrastructure is to be accessible

for the majority of the Swedish population, it requires implementation on the less profitable locations as well. The authors thus argue that private ownership involvement could create a barrier for reaching a large-scale system in that sense. A second negative aspect regarding the private profitability incentive is that the road carriers, hence the future users of the system, are expressing a concern that the user fees might become more expensive with private ownership than with a strictly public ownership. It is also emphasized that a private owner would try to maximize the return of investment in a different manner than the government, which could affect the development in a negative manner as capital is not re-invested to the same extent. Existing literature also emphasizes the concern regarding private profits being prioritized before functionality and that the profits instead could be obtained by the government (Yescombe, 2007). Literature also highlights that private ownership is not suitable since infrastructure have natural monopoly characteristics and a private owner would take advantage of that role (Mosca, 2008). One example of how to limit profits in a PPP constellation is by using the NPD structure, which has been described in existing literature (Hellowell & Pollock, 2009).

Concluding, there are risks with PPP which are emphasized in both existing literature and in the interview study. According to the empirical findings, it is believed that a governmental owner, with the public welfare benefits in focus, would manage the expansion in a way that creates a large-scale system, available to a majority of the population, independently of the profitability of different locations. This is however also perceived as a risk from the private actors' perspective, as the public tax money should be managed in a financially responsible manner as well.

Both literature and the empirical findings enlighten the issue of the governmental restricted budget. There is a certain budget allocated for infrastructure investments which are considered to be insufficient in relation to the demand for maintenance and new infrastructure investments (Carbonara, et al., 2015). The authors of this thesis thus argue that the necessary large investment for an ERS infrastructure expansion is a barrier for the development from small-scale to large-scale. The discussion regarding alternative financing has as a result occurred. In the literature, PPP is discussed as such an alternative and that PPP is used when governmental investments are limited (Carbonara, et al., 2015). However, there are also literature which argues that the total investment does not necessarily increase with PPP as the governmental investments tend to decrease in that case (Yescombe, 2007). The empirical findings present scattered opinion regarding if PPP accelerates the development or not. Several of the interviewees express the belief that it will take a lot of time before such large amounts of governmental capital is allocated to ERS and that a PPP structure would accelerate the process by the additional private financing. On the other hand, several of the interviewees believe that ERS implies great risks and that private actors are unwilling to take any larger financial risk at an early stage of the development. They all agree that the government has the necessary capital to build ERS but that there is a lot of competition for funding with other transport investments. Some believe that the profitability focus of the private actors, through a PPP, would accelerate the development since a faster development is considered more profitable by the interviewees. At the same time other interviewees think that a public owner would make a decision faster and then have the possibility to finance the implementation.

Furthermore, the authors of this thesis argue that from a stakeholder perspective, a PPP structure could mitigate the entry barrier that is due to the large initial investments in infrastructure as the different stakeholders are allowed to invest in a limited share of the infrastructure. PPP could thus foster competition as several stakeholders would have the possibility to enter the market.

5.4.2 A Historical Perspective on the Ownership Structure's Effect on System Transitions

It is important to study historical cases in order to better understand the dynamics of a sociotechnical system transition and the ownership structure's implications during the development. The railroad and telecommunications development have several similarities and differences, according to the authors of this thesis. Both the telecommunications system and the railroad system are large and complex sociotechnical systems, where technology, institutions, organizations and other system components are deeply interrelated. The industries are totally dependent on its infrastructure, which is the core of the system's functionality (Markard, 2011). When investigating how the ownership structure might affect the development of a transition to ERS, the authors of this report found it to be of great interest to study the historical emerge of other sociotechnical systems due to the similarities in system characteristics.

The large-scale systems of telecommunications and railroads were both deployed by the government, due to the risk, capital intensity of the systems and the fact that they were "public good", among else. Hasselgren (2011) argued that even if private actors had been constructing and managing many local railroads, they were dependent on governmental support and financing. From the point of the public initiative of a large-scale deployment, the development and ownership structure of telecommunications and railroads took different paths. The telecommunications standard was from the start developed with the purpose of enabling competition on the operator and ownership level by developing an open system standard with lower capital intensity (Dunnewijk & Hultén, 2007). After the governmental agency had built and operated the infrastructure for a while, the agency was converted into a public utility and the market was deregulated. At first, the cost for entering the industry was high which resulted in very limited competition. However, due to regulatory changes, the financial barriers were mitigated and competition was thus stimulated (Hultkrantz, 2002). Hence, the authors of this thesis conclude that the level of capital intensity and the regulatory framework were the main factors that enabled a proper deregulation of the industry. The development of the railroads was the opposite as they went from having many privately operated railroads to an entirely nationalized system. Railroads continued to be capital intensive and are still owned and operated by the Swedish government (Hasselgren, 2011).

At an early stage, the telecommunications industry aimed for obtaining a high level of competition on an operator level, unlike the railroad industry in Sweden where the company "SJ" had the monopoly on operating the trains for a very long time (Alexandersson, et al., 2012). The authors of this thesis argue that competition on the operator level require an infrastructure which is easy to utilize and connect to. The operators of ERS would in comparison be the road carriers, which is already a highly competitive market. This has to

be taken into consideration when designing the system and the regulatory framework. The authors argue that it is reasonable to believe that it will take time to create a high level of competition on an operator level within ERS due to the initial financial barrier of converting vehicles. This has been emphasized by the interviewed road carriers as well. When studying the empirical findings, it is fair to believe that larger companies will initially dominate the system as they have the necessary financial resources. As some of the interviewed road carriers have indicated, it is possible that governmental subsidies might become necessary in order to stimulate a higher level of competition on the operator level in an initial phase.

After studying the historical cases, the authors conclude that it is fair to argue that the government have to build and finance the large-scale deployment of an ERS due to the high level of capital intensity and risk. As the system and technology matures, it might be possible to initiate PPP and enable the cross-sectorial system suppliers to have an ownership in the large-scale infrastructure. However, this possibility will be dependent on future regulatory system and the capital intensity of the infrastructure, similarly to the telecommunications development. Today, the capital intensity of a future, national ERS is unknown as it is dependent on the standard. Hence, the decision of standard might affect the future share of private ownership.

In both historical cases, private actors have been involved during the early stage of the development of the technology and the system, which is similar to the current ERS development, according to the authors. As the demonstration projects within ERS, such as eRoad Arlanda, are driven and financed by both public and private actors, the authors argue that the structure resembles a PPP structure. Since the development phase requires competence and innovation, it can be argued that such a structure can be suitable during this phase. This argument is also reasonable when considering the historical cases.

Moreover, the authors found it important to investigate and consider the arguments for the nationalization of railroads, as it concerns a shift in ownership structure during the expansion of the railroad system. According to existing literature, the increased transportation flow on a national level made the earlier ownership structure insufficient. The main arguments for a nationalization were based on higher efficiency, economies of scale and the requirement of overall control. It was also believed that it was difficult to implement innovations in the fragmented system. These arguments were driven by both the government and private actors (Hasselgren, 2011). Existing literature also shows that the global transition towards governmental ownership increased the efficiency of the industry (Bogart, 2009). If a future ERS should be a national system, with national transport flows, these arguments are important to take into consideration when deciding on ownership structure. The empirical findings also point to the necessity of overall control of the system, which is compromised by shared ownership with private actors.

Another important aspect, which have had a great impact on the railroad and telecommunications development, is the timing for choosing a national standard. There are several different standards that are currently being developed and evaluated within ERS. According to the empirical findings, there is a dilemma regarding the appropriate timing to choose a national standard as a decision creates a lock-in effect while the lack of a decision prolongs the development and creates incompatibility when there is time for an integration

of the different systems. It is found that the interviewed stakeholder segments find this problematic. During the telecommunications development, the standard was chosen early during the development which became a success and facilitated for the development (Gandal, et al., 2003). However, the literature still enlighten that this was risky (Fuentelsaz, et al., 2008). During the railroad development different standards were built which created difficulties when it became time to integrate the systems (Kullander, 1994). Thus, the authors of this thesis argue that it is difficult to predict the appropriate timing for choosing a standard within ERS. This regards both the case of a publicly owned system and a PPP structure.

The procurement of a future ERS system with a PPP structure, when the technology is considered as mature, could be inspired by the "beauty contest" within the telecommunications industry, where not only price was an evaluated factor but also the connection range (Wessel, 2007). By making the connection range a factor of evaluation during procurements of PPP projects, the authors of this thesis believe that it is possible to also make less profitable locations a subject for PPP.

The authors of this report believe that the historical case of the construction of Saltsjöbanan is a good example on a privately owned, local construction. The incentives for building Saltsjöbanan was to profit from the increased land value as the sufficient connection by railway made the area attractive for residents and visitors (Svallhammar, 2008). The interviewees within the segment of construction firms have expressed a similar incentive for ERS, as the construction of ERS could increase the attractiveness for residents in a new area which would enable new constructions and thus imply a good business for them.

Concluding, both the historical cases indicate that a large-scale infrastructure initially needs to be constructed and financed by the government. In both cases, private actors were involved early during the development and contributed with competence and innovation. Due to enabling governmental regulations and a decreased capital intensity, it was possible to deregulate the telecommunications market. The same barriers were not mitigated in the railroad industry. The historical railroad case showed the importance of having a coherently controlled system in order to manage the national transportation flows and increase efficiency.

The authors of this thesis argue that a PPP structure can be sufficient during the initial phase of the research and development in order to maximize competence and innovation. During the expansion phase, from small-scale projects to a large-scale system, it is essential to have a publicly owned infrastructure before the technology and the system has matured. Later, when the technology and system is considered as mature, a PPP structure can be phased in.

5.5 Future Work

Since ERS are a relatively new phenomenon, there are several queries that needs to be further investigated before a large-scale system can be deployed. There are both technical and commercial aspects that have to be examined in order to create beneficial conditions for a deployment. In the following section, some future work within the area is suggested from the authors' point of view.

- It would be interesting to investigate how and to what extent electrified heavy-duty vehicles could be used as energy storage within the energy system when powered by ERS. Heavy-duty vehicles powered by ERS might be able to balance the grid. When production is high or the demand is low the heavy-duty vehicles could store more electricity from the grid, and when the production is low or the demand is high the heavy-duty vehicles could be powered by their batteries to a larger extent or even supply the grid. An investigation of the possibilities for such a system and its storage capacity would be highly interesting. If such a system could increase the balancing capacity of the grid it could facilitate for the expansion of intermittent supply, such as renewable energy.

- It is necessary to investigate the effect on the power grid and the necessary grid requirements in order to manage a large-scale ERS with various levels of power outtakes. The dimensioning of the electricity system needs to be further studied in order to optimize outtakes and know how to manage the local and national peak demand.

- In the interview study, several stakeholders mentioned the decision of an ERS standard as one of the major risks. According to the interviewees, it is important to choose a European ERS standard in order to enable cross-country transports and thereby maximize the utilization of the system. However, the decision process is complex and time consuming. Further, the decision regarding standard depends on numerous factors which vary between the European countries. Hence, the most favorable ERS standard for Sweden might not be the most favorable for other European countries. One factor in Sweden that could affect the choice of ERS standard is the weather and temperature conditions, which are not the same in most other countries. Another aspect is the amount of traffic on the roads. The Swedish national road system is over-dimensioned in relation to the size of the national vehicle fleet, while other European countries, such as Germany, have a substantially larger vehicle fleet in relation to their road system. As a result, a standard could be financially feasible in some countries due to the number of possible users, but not in other countries. Thus, a future work on how these different factors affect the decision and suitability of ERS standard and how these factors vary between the European countries, would be of interest. Also, it is important to investigate how a joint, European decision process should be conducted. It should be investigated if Sweden has the appropriate conditions to take the first step in deciding an ERS standard.

6 Conclusions

A summary of the main conclusions of the study and the author's recommendations are presented in this chapter, which also answers the research questions of the thesis regarding the effect of infrastructure ownership on the development from small-scale to large-scale ERS and the foreseen future roles of the stakeholders within ERS.

The foreseen future roles among the stakeholders are dependent on the ownership structure of the system and their own current business models. Agencies foresee that they will have the same role as they have in the traditional system. Road carriers see themselves mainly as users of the system. Electric utilities, construction firms and road power technology firms see new business opportunities related to ERS besides their current roles of electricity supplier, constructor and technology provider, which most often imply an expansion of their current products and services. Most of the stakeholders foresee that they will become system suppliers mainly, rather than owners of the system. However, several of the stakeholders mentioned their interest in being a possible owner of the system and engage financially in the infrastructure, even if it requires a lot more investigations before knowing if such an involvement would be profitable. The willingness to own and invest in the ERS infrastructure is dependent on current business model and the size of the system. Most stakeholders find it preferable to invest in a smaller, local system, rather than in large-scale systems due to the large investment and risk.

The classical characteristics of an infrastructure system such as a high level of complexity, capital intensity and asset durability applies to the ERS infrastructure, which makes it difficult to create a market-like environment. Further, as the construction of a new, large-scale, technological system is connected to high risks and uncertain return of investment it creates a limited willingness to invest in the infrastructure among private actors. ERS are considered as "public good", similarly to other national infrastructures and there is a consensus that there is a necessity to have an overall control of a large national system. By investigating historical cases of infrastructure development, it is clear that the government needs to play a key role, both as a coordinator and financier, in the initial phase of an ERS expansion.

Competence from both the private and the public sector will be vital for the development of ERS. The required competence can be obtained by close cooperation between the government and private actors during the technology and system development phase. Today, this takes place in the small-scale demonstration projects, such as eRoad Arlanda, which are partly financed by the government and partly by private actors. Thus, the ownership structures and financing will look a lot like PPP during the technology and system development phase.

During the expansion phase, towards a large-scale system, it is inevitable to notice that there are numerous barriers for a PPP structure due to the initial large investment, the high risks related to an immature technology and the necessity for overall control. The initial phase of constructing a large-scale ERS is connected to a lot of risks such as utilization and maintenance among else, which makes an early investment in a large-scale system unattractive for private actors as it does not ensure profitability. It is however still vital to obtain competence from private actors. In order to obtain a high level of competence it is

important with close cooperation between different stakeholder segments and to have a procurement process which is strongly focused on functionality. The authors suggest that in order to decrease the complexity level in the system, which is key for enabling a system transition, there is a necessity to form cross-sectorial system suppliers. By restructuring the supplier-level like this, the system components become more closely coupled.

During an initial deployment of ERS, towards a national, large-scale system, it is suggested to only have one cross-sectorial system supplier which manages the constructions and operations of ERS. This would decrease complexity and facilitate for increasing and establishing knowledge during the initial phase, which is vital. Furthermore, it would be difficult to obtain competition on a cross-sectorial system supplier level during the initial deployment, as there are a limited number of actors which possess competence within ERS at such an early phase. Cooperation and competence should thus be in focus during the expansion phase, rather than competition and a private financial commitment. As the system and technology matures and knowledge regarding ERS has been established, it is suggested by the authors to introduce competition at the cross-sectorial system supplier level nationally, as it is not as crucial to obtain knowledge and decrease complexity. This will however be dependent on the level of capital intensity. It would require the ERS technology to be open, or licensed, or that the road power technology firm became a subcontractor to the cross-sectorial system suppliers rather being a part of them. The suggested stakeholder structure with cross-sectorial system suppliers facilitates for a possible future PPP structure.

A PPP structure or private ownership is suitable in closed systems as the level of complexity is much lower in comparison to a national system. These systems should be encouraged financially by the government as the dynamics of private ownership and involvement will drive innovation and stimulate the development.

The initial financing dilemma however remains and is central in the discussion about ERS. Due to the limited budget and the large demand for investments in new infrastructure and maintenance, private capital might be necessary in order to enable the initial implementation. However, as PPP implies an increase level of complexity it might not be the appropriate choice for alternative financing during the expansion phase of new infrastructure. It is suggested to investigate other options such as financing through pension funds.

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Appendix A: List of Conducted Interviews

Actor	Description	Length of interview	Number of interviews
NCC Roads	Vice president and head of business development	80 min	1
Elways	CEO	60 min	1
PostNord	2 interviewees: Environmental director and environmental specialist	60 min	1
ABT-bolagen	2 interviewees: CEO and team leader	70 min	1
The Swedish Transport Administration	Development strategist	100 min	1
The Swedish Transport Administration	Contract manager	45 min	1
The Swedish Transport Administration	Contact for eRoad Arlanda	50 min	1
The Swedish Transport Administration	Group treasurer	30 min	1
Vattenfall	Head of E-mobility R&D	45 min	1
Fortum	R&D manager	50 min	1
E.On			
The Swedish Innovation Agency	Program manager	60 min	1
The Swedish Energy Agency	Administrator and ERS specialist	90 min	1
Siemens	2 interviewees: Head of rail and road electrification Sweden and business developer at mobility services	60 min	1
Skanska	Nordic development director	60 min	1
Schenker Consulting	CEO	35 min	1

Appendix B: Description of eRoad Arlanda Actors

Actor	Description
Elways	An industrial company which develops and provides the ground-based conductive ERS technology. The electricity is transmitted from the electrified rail in the ground to the driving vehicle. The company has 17 approved patents.
NCC Roads	One of the leading construction companies in Sweden. The company has experience in construction of transport and electricity infrastructure. NCC Roads are developing a technique for integrating the electrified rail into the roads.
e-Traction Europe B.V.	An industrial company which provides e-mobility technology. e-Traction develops and provides an in-wheel powertrain technology which allows and enables heavy-duty vehicles to drive on electricity.
WSP Sverige AB	A consulting-firm which provides services within technology and analysis.
Kilenkrysset	Land owner of Rosersberg Logistics Area.
Sigtuna kommun	The demonstration of eRoad Arlanda is located in the municipality of Sigtuna. Sigtuna kommun provides the project with political guidance and support as the project I considered to be in line with their environmental policies. Sigtuna kommun handles the communications with locals.
Swedavia	Owns, operates and develops Arlanda Airport.
KTH Royal Institute of Technology (ITRL)	KTH will test the electricity installations and the electricity driven vehicle and analyze the testing results. KTH has experience from doing analyses as they have been a part of other small-scale ERS projects.
Gävle Container-terminal	Operator of the intermodal terminal at Rosersbergs Logistics Area.
ABT-bolagen	Delivers services within the construction sector. ABT-bolagen will operate the electrically driven vehicle in the project by handling the transportation and selling services to companies which are based in Rosersberg.
PostNord	Owner of goods. PostNord are in need of large and frequent transports between Arlanda Cargo City and Rosersberg Logistics Area.
Airport City Stockholm	A development corporation, owned by Swedavia, Sigtuna kommun and Arlandastad Holding, which works for a developing an airport city nearby Arlanda Airport.
Arlandastad Holding	Land owners of the Arlanda Airport area.
Swedish National Road and Transport Research Institute (VTI)	Research institute within the transport sector. Responsible for project management.
DAF	A heavy-duty vehicle manufacturer which provides the vehicle used in the project.
Vattenfall	An electric utility. Provides electricity to the road and contributes to the electricity planning.
Bilprovningen	A vehicle inspection company. Participates in order to facilitate for the inspection of the transformed vehicle.

(RUAB, 2015)