Master thesis

Thesis in Industrial Management IN7002 30hp

Business models for charging point operators in heavy battery electric vehicles market: A technological innovation system (TIS) case study in South Sweden

Halmstad 2022-06-19

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Abstract

This thesis combines technological innovation systems with business models in a qualitative case study regarding charging point operators for heavy battery electric vehicles in south Sweden. The heavy battery electric vehicle market is still in early development in Sweden, and the development of public charging stations for heavy battery electric vehicles is low. The case study is developed from several qualitative interviews with relevant actors regarding the system for heavy battery electric vehicle charging stations. The case study delivers an empirical understanding of the heavy battery electric vehicles market system in south Sweden through a technological innovation system, as well as developing the technological innovation system literature to give regulatory and direct recommendations to the actor in focus. These recommendations were based on barriers for charging point operator business models, where the recommendations to charging point operators are on components to business models that can mitigate these barriers. The regulatory recommendations provided are more traditional to the technological innovation system literature. The combination of the technological innovation system and business model literature has also provided the ability to give a more in-depth analysis of business models for actors in new emerging markets.

Keywords: Technology innovations system; Business models; CPO; HBEV

HBEV	Heavy Battery Electric Vehicle
BEV	Battery Electric Vehicle
EV	Electric Vehicle
HV	Heavy Vehicle
TIS	Technological Innovation System
CPO	Charging Point Operator
HVO	Hydrogenated Vegetable Oil
V2G	Vehicle To Grid

Preface

The authors thank our supervisor Eugenia Vico Perez for her support during this thesis. We would also like to thank Mike Danilovic and Simon Sandahl for their assistance and support during and before the thesis.

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1. Introduction

Climate change awareness is increasing and affecting many sectors, not at least the transport sector which is facing significant changes in the coming years to reach the goals set by the Paris agreement. To reach the Paris agreement the Swedish transport sector needs to lower its emission of CO2 by 70 percent by the year 2030 and be total emission neutral by 2045 (MoE, 2018) This can be achieved by completely replacing all combustion engine vehicles with electric vehicles (Monios & Bergqvist, 2020). Passenger cars have come a long way in this transition, but trucks have fallen behind (Ford & Hardy, 2020). Now two Swedish truck manufacturers, Volvo trucks and Scania, have started to produce electric trucks. Volvo trucks offered their first battery-electric trucks to the market in 2021 (Volovtrucks, 2022). Both companies will offer battery and fuel cell electric trucks to the market in the coming years, but problems still need to be solved for the transport sector to reach the Paris agreement. These problems are mainly charging/refueling infrastructure for the new types of trucks and the renewable energy production together with the grid infrastructure needed to make this transition a reality (Monios & Bergqvist, 2020; ACEA, 2021; Furszyfer Del Rio et al., 2020). To tackle these problems, the Swedish government has devised an action plan (elektrifieringslöften) and, together with companies, build infrastructure needed for the transition to carbon-free transport. This thesis will mainly focus on electric truck charging infrastructure, but it will not completely ignore the energy infrastructure since they will affect each other.

For charging infrastructure, there are different technologies and solutions for different types of Heavy battery electric vehicles (HBEV), such as plugin charging and battery swapping. These have been tested and technically work; now, companies that will build the infrastructure have a decision to make, what type of infrastructure to choose and how the business models will look (Danilovic & Liu, 2021; Du et al., 2018). We will in this thesis focus on charging point operators (CPOs) for HBEV and therefore not consider hydrogen or electric road systems. In order to make this decision more than the technical aspects need to be taken into consideration, CPOs must look at the complete business model for these different infrastructure solutions. We will interview companies and organizations in Sweden that are standing in front of these business decisions. This is to gain an insight into the barriers to the electrification of heavy transport.

There have been studies done on different types of electric trucks. However, it lacks studies comparing the different charging infrastructures, especially with the implication of each connected business model from the infrastructure owner's perspective. This study will identify barriers to infrastructure development for electric trucks in South Sweden, more precisely in energy zone three and four. There are two types of charging infrastructures public and private. This thesis will only focus on the public charging/refueling infrastructure.

This thesis combines business models with technological innovation system (TIS) to find barriers for CPOs for HBEVs business models and solutions to these barriers. This is achieved by constructing the TIS to get a system view and related actors that affect CPOs. A technological innovation system is a tool to understand and illustrate the performance and system dynamics of a system. This is done by a analyse of seven different fuctions in the TIS (Bergek, Jacobsson, Carlsson, Lindmark & Rickne, 2008). An analysis of the different functions will find blocking mechanisms that hinder the development of the overall TIS. This thesis has combined the TIS with business models and has based the blocking mechanisms on barriers for CPOs business models. The objective of the combination of TIS and business model is to develop a deeper understanding of what causes the barriers for CPOs in this uncertain and emerging market. With this understanding, we can find components in CPOs business models that will mitigate the barriers in the system. This will be translated to recommendations for CPOs which will be a development of the TIS literature that otherwise only gives regulatory recommendations (Bergek, 2019).

1.1 Problematization

Electric vehicles have been sold and used for years and have improved with time. With higher energy capacity and faster charging, electric vehicles are more viable in modern society compared to the internal combustion engine vehicle (Ford & Hardy, 2020). A specific vehicle that has begun to gain traction is the heavy battery electric vehicle (HBEV). An electric vehicle that can transport materials, food, and others, a change can come to the transport industry relating to emissions. One thing still lacking for electric trucks is the infrastructure that can efficiently charge these vehicles (ACEA, 2021). The technology that enables charging to heavy battery electric vehicles already exists (Monios & Bergqvist, 2020). Even though the technology for HBEV and charging exist, HBEV is not widely adopted in the Swedish context. The report seeks to find out why HBEV has low adoption in Sweden. The report will gather information from actors in the field to understand why and what barriers stand in the way of electrification of heavy transport.

In south Sweden there are energy shortages with increasing electricity prices and unstable power supply. Specifically in the energy zones 3 and 4 in Sweden. The report has this as a focus because energy zones 3 and 4 are similar in energy shortage except in the southern part of energy zone 4, where the shortness of energy peaks in Sweden. From the perspective of transport energy zone 3 and 4 contains the most trafficked roads in Sweden for trucks, these roads being E 20, E6 and E 4. From the infrastructure development perspective for electrified trucks, these roads will be of interest to companies developing electrification infrastructure (ACEA, 2021).

When observing how HBEVs are used today, the routes set for HBEVs are often short and are charged by private charging infrastructure. To be able to compete with ICE trucks public charging infrastructure is required for longer routes. According to ACEA 10,000-15,000 charging points need to be built in Europe by 2025 and 40,000-50,000 by 2030. This is to provide public charging to the projected 270,000 HBEV for 2030. With this realization and information a key actor in the electrification of Heavy transport is the charging point operator (CPO). A CPO is the actor that maintains and profits from public charging stations. The perspective of CPOs on the barriers to establishing public charging infrastructure can give insights into what areas need improvement.

The CPO does not act in a vacuum; some other factors and actors are essential in the electrification of heavy transport. Therefore an approach to gain insight into the barriers facing electrification of transport needs to consider the factors and actors that face CPOs when charging infrastructure is being developed. This is to understand the system that the CPO acts within and the factors that affect them that also consider the new emergent technology.

There are many issues facing the electrification of heavy transport in Sweden. To understand these issues and to be able to provide the infrastructure for HBEV the actor that becomes interesting in the Swedish context is the CPO. To understand how the electrification of heavy transport affects the CPO a technological innovation system will be used. The TIS will provide the system in which the business models will operate to better understand how their surroundings affect them. Bergek (2012) brings up that many empirical TISs lack analyses of three functions: entrepreneurial experimentation, market formation, and development of positive externalities. The solution that Bergek brings up to this problem is to move into a more qualitative analysis to develop the TIS so that the analyzer can genuinely understand the functional dynamics in a TIS and how different mechanisms effects each function; this can only be achieved through case study work. This is what we aim to do in our thesis, where we will use a qualitative case study to gather information to develop a TIS where we do not lose focus on the function's entrepreneurial experimentation, market formation, and development of positive externalities.

1.2 Research question

What barriers for Charging point operators' business models can be identified using a technological innovation system?

1.3 Limitations

- The thesis is limited to the south Swedish context, energy zones 3 and 4.
- The thesis is limited to CPOs for Heavy battery electric vehicles.
- The thesis is limited to public charging infrastructure.

2. Context

2.1 Theoretical context

2.1.1 Business model Innovation

Business model innovation is a novel process of deliberately changing one or more components in a business model to create and capture value (Frankenberger et al., 2013).

According to Cavalcante et al. (2011), there are four business model changes. These are business model creation, business model extension, business model revision, and business model termination. Business model creation is the creation of a new business model, which only includes new ventures. The business model extension is the process of adding activities to an existing BM without changing the core business logic. We will use the same interpretation as used by Chasin et al. (2020) that in addition to the definition by Cavalcante et al. (2011), multiple business models can be created and used in one single company at the same time (Sabatier et al., 2010). This means that an established company that starts a new business model will be seen as a business model extension, including cooperative spin-offs and the accusation of existing venturers. Business model revision is a radical and disruptive change that fundamentally reshapes the business model. Business model termination is the complete elimination of the whole business model or some business activities (Cavalcante et al., 2011). We will use this categorization to look in the literature for business model innovations regarding infrastructure for electric trucks.

2.1.2 Business models

Business models represent how a company delivers, creates, and captures value in a simplified way. They are a template of a company's business logic and are used to see how a company generates profits from business activities by making them visible, analyzable, and manageable (Osterwalder, 2004; Teece, 2010).

The conceptualizations divide a business model into different building blocks with different value dimensions: value proposition, value creation, value capture, and value delivery (Peters et al., 2015; Günzel & Holm, 2013; Bocken et al., 2014). The value proposition is the core component, including the products and services offered and how these fill the customer needs. Value creation and value delivery include customer channels, customer relationships, and infrastructures such as activities, resources, and partnerships. Revenue streams and cost structure goes under value capture. (Osterwalder, 2004; Bocken et al., 2014)

2.1.3 Technological innovation system

A technological innovation system (TIS) is an analytical construct used to understand and illustrate performance and system dynamics. TIS is built up of three components that contribute to developing, diffusing, and utilizing new goods, services, and processes: actors, networks, and institutions (Bergek et al., 2008; Hekkert et al., 2011).

Functions define the interaction between actors in TIS. There are two different conceptualizations of functions in TIS highlighted by Bergek (2012), Hekkert et al. (2007), and Bergek et al. (2008); we will use the definition developed by Bergek et al. (2008). These functions are knowledge development and diffusion, influence on the direction of search, entrepreneurial experimentation, market formation, legitimation, resource mobilization, and development of positive externalities. Functions help describe what is going on in the TIS so that this can later be analyzed. Only describing how the different functions work currently in the TIS cannot by itself determine if these functions have a positive impact on the overall TIS or not. A weak working function does not necessarily mean that the TIS is lacking this function and that this is a blocking mechanism. The same goes for a vital working function, and this can have a negative impact on the overall TIS. (Bergek et al. 2008; Hekkert et al. 2011)

It is not until after the TIS has been developed that the analysis of the different functions can begin, where the functions are being analyzed on how well they fulfilled the desired functional patterns. The desired functional patterns in this thesis will be based on the needs of CPOs for HBEVs (Bergek et al., 2008; Hekkert et al., 2011).

After the analysis of the different functions, the authors can identify different blocking mechanisms that hinder the development of the TIS towards the desirable functional patterns. This is then followed by the final part of the TIS, which is suggestions and regulatory recommendations to remove or mitigate the blocking mechanisms in the TIS. We desire to develop this final part of the TIS further and provide recommendations directly to the core actors in the TIS. Since the blocking mechanisms will be based on components for business models for CPOs, changes to these business models can remove or mitigate these blocking mechanisms. We will examine changes to business models that can mitigate the different blocking mechanisms to provide recommendations directly to the core actors. These recommendations will be based on components in business models for the core actors, in our case, CPOs business models. Both recommendations for regulators and actors are to mitigate the blocking mechanism's effects to stimulate the TIS's development (Bergek et al., 2008; Hekkert et al., 2011).

2.1.4 Functions

As mentioned previously, we will use the definitions of functions developed by Bergek et al. (2008). In this section, we will explain each one of these seven functions.

Knowledge development and diffusion are how well the TIS performs in the overall knowledge base and how knowledge is diffused in the TIS. The knowledge can be distinguished between different types such as scientific, market technological, and production. Knowledge can also come from different sources such as R&D, production, and learning from new applications.

Influence on the direction of search is the combined strength of incentives and pressures for organizations to enter the TIS. This also covers the direction the overall TIS is heading in competing technologies, applications, and business models. Influence on the direction of the search will be measured by qualitative factors such as beliefs in growth potential, incentives, and regulatory pressures.

Through trial-and-error experimentations, entrepreneurial experimentation reduces uncertainty around technologies, applications, and markets. There has been a misunderstanding about the meaning of entrepreneurial experimentations, leading scholars to believe that this only refers to new and small firms (Bergek et al., 2012). In this context, "entrepreneurial" means acting under uncertainty (cf. Kirzner 1997; Schumpeter, 1934). Established firms can also participate in entrepreneurial experimentations such as demonstration plants, pilots, and exploration of new applications or technologies. This function is essential for a TIS not just in the early phases but also has a vital role in the later phase of developing a TIS.

The market formation is how the market around the TIS develops and what the drivers are for the market formation. The market formation will take time, and for an emerging TIS, the market can be underdeveloped with no apparent customer demand and with a poor price/performance of the new technology. We will gather qualitative data from the different actors in the TIS to find what drives the market formation.

Legitimation is referred to the social acceptance and compliance with core institutions. New technology and its advocators need to be suitable and desirable to the relevant actors in order for them to mobilize resources toward the technology, demand to form, and gather political strength. Legitimation influences actors in the TIS and therefore also influences the direction of search. In order to measure the legitimation in the TIS, we need to analyze both the legitimacy of the stakeholders and relevant actors, as well as the actors in the TIS that increase the legitimacy.

Resource mobilization is referred to the different resources that need to be mobilized for a TIS to develop. We will focus on the resources, finance capital, and complementary assets such as infrastructure products and services.

The development of positive externalities is an essential function of the development and growth of a TIS. This function refers to the creation of resources on a system level. This ranges from complementary technologies, pooled labour markets, and specialized suppliers, which are available to the system actors but were created from the system itself, therefore not contributing to building the system up in the first place. The development of positive externalities positively influences legislations and other functions such as resource mobilization, influence on the direction of search, market formation, and entrepreneurial experimentation. (Bergek et al. 2008)

2.1.5 Business models with Technology innovation system

TIS gives the system understanding on a macro-level that affects a business operating on a micro-level (Lamprinopoulou et al. 2014). TIS gives greater knowledge and understanding about the system that business models are operating in. To further link the connections between business models and TIS, the barriers that exist for CPOs business models will be translated into blocking mechanisms in the TIS. Business models will not construct the TIS itself. However, the blocking mechanisms will be based on barriers that exist in the TIS for CPOs business models. The reason for this is that from a business model perspective identifying barriers for existing business models new blocking mechanisms can be identified and provide a new perspective on a TIS.

TIS gives the ability to look on a deeper level for barriers regarding business model and how these effects the business model of the core actors. If the study were only in the scope of the core actors, in this case CPOs, it would be hard to investigate what causes the barriers for nearby actors. The TIS involves the nearby actors, which gives a greater understanding of how these barriers occur and gives the analysts the ability to find solutions to the underlying problem causing the barriers. This can then be translated into business models and how they can solve the underlying problem causing these barriers. This would not be possible without the system understanding that the TIS brings. (Bergek et al. 2008)

2.2 Empirical context

2.2.1 Electric vehicles and charging technologies

Electric trucks are a growing trend, and many truck manufacturers are committed to completely switching their production to only electric trucks. The trucks are not all the same just because they are electric; there are two main designs, battery-electric and fuel cell electric trucks. Fuel cell electric trucks use hydrogen as an energy source and get this from refueling stations, much like diesel and petrol. For battery electric trucks there are three subgroups of electric trucks, and these differ from each other in the way they are being charged. First, there is the plugin battery-electric trucks that use a physical cable to charge the batteries. Battery swapping trucks are the second type of battery-electric truck, and these can physically change their empty battery in a battery-swapping station to a fully charged one. Finally, there are inductive charging battery trucks that are continually charged by an electric road system as it drives. Battery swapping and inductive charging battery trucks can use plugin charging. This means that they are not completely locked into their charging solution and can be seen more as a plugin battery truck with complimentary charging solutions. (Monios & Bergqvist, 2020; Danilovic & Liu, 2021)

2.2.2 Charging infrastructure

Plugin stations have become the standard for electric cars. These charges the vehicle thru a physical cable, the time it takes for a truck to be fully recharged varies from 2,5 to 9 hours, dependent on the charger's capacity and how big the truck's battery is. The time it takes to fully recharge a truck is the biggest downside of plugging charging (Monios & Bergqvist, 2020). V2G is a new emerging complementary that can be used with plugin charging. V2G sends energy back to the grid from the battery when energy is expensive; this lowers the stress on the grid and gives the users some income (Calabrese et al., 2018; Chasin et al., 2020; Ford & Hardy, 2020). Technically electric trucks can use plugin stations built for electric cars; the only two problems are space and capacity of the chargers. Some of the existing plugin stations that are built for electric cars have parking spaces with chargers making it hard or impossible for trucks to use these for charging (Monios & Bergqvist, 2020). The capacity of the chargers built for electric cars vary, which is a problem for electric truck though they need a high capacity to charge their bigger battery faster. Existing charging stations can be built out to include trucks, or new stations could be built to serve both trucks and electric cars. Plugin stations need much space, especially if they are built to serve electric trucks, because of the parking space required to charge multiblade trucks simultaneously. The types of electric trucks they can serve are plugin, battery swapping, and electric road system battery trucks. It is only the service of plugin charging they can offer, and they will not have battery swapping ability or be connected to an electric road system but can still serve trucks built for these systems(Danilovic & Liu, 2021; Du et al., 2018).

Battery swapping stations are a new emerging charging solution that is starting to come to Europe for electric cars after being highly adapted in China (Danilovic & Liu, 2021). Even if battery swapping stations were first adapted for electric cars does not mean that there is no future for swapping stations for electric trucks. In fact, the business model of battery swapping is more suitable for trucks than cars, and trucks are more accessible designed to implement battery swapping (Danilovic & Liu, 2021). Battery swapping stations bring many benefits, such as faster charging time and less space needed than plugin stations. Instead of having much space for parking, a swapping station only needs space for one truck and the batteries in the station. This is because a battery change only takes a couple of minutes instead of hours, and therefore they can serve one truck at a time (Du et al., 2018; Monios & Bergqvist, 2020). When the batteries are in the battery swapping station, there is no need to charge them up as fast as possible which extends the life of the batteries compared to charging them fast. This also allows battery stations to charge the batteries when the energy demand is low, which lowers the energy price. They can also use the same principle as V2G, where they can sell energy back to the grid when the price is high or help stabilize the grid. (Danilovic & Liu, 2021; Naor et al., 2018) The most significant limitation of battery swapping stations is the different amounts of batteries and vehicle types they can handle. Different types of batteries could have different charging standards and designs, limiting each battery-swapping station to only work for one or a few different models (Danilovic & Liu, 2021; Monios & Bergqvist, 2020).

2.2.3 Business models for CPOs

Each new charging infrastructure technology has its own opportunities and limitations for the owners; this gives the owners new possibilities to capture and create value, giving rise to business model innovation.

Plugin charging stations' business model is providing charging to the trucks by fast chargers to charge the trucks as fast as possible. For this service, the truck owners will pay the charging station. The price of this service will fluctuate a lot over the day because of the changing energy price. These stations will need many high-power cables to be able to provide the charging, and this could increase the prices of the service even more. (Biancardi et al., 2021; Monios & Bergqvist, 2020; alabrese et al., 2018; Chasin et al., 2020; Ford & Hardy, 2020). These stations will need much space to provide charging to many HBEVs simultaneously (Du et al., 2018).

Plugin charging provides the ability of V2G, but this service is best suited for private charging stations, not public. The charging time is the biggest problem for public charging stations, which takes time from the truck operators where the trucks stand still and do not provide money. There will not be time to send energy back to the grid when trucks leave the station as fast as possible. (Monios & Bergqvist 2020). The only scenario where V2G could be an option is if trucks stay overnight when the driver sleeps. The benefits of plugin charging stations are that they could be combined with charging stations for passenger vehicles and can provide service for many different battery-electric trucks. In the future, the charging time could be lower if fast chargers continue to evolve, these could then be added to plugin charging stations (Biancardi et al., 2021; Furszyfer Del Rio et al., 2020; Monios & Bergqvist, 2020).

Battery swapping is very dependent on a business model where the whole vehicle or only the battery is rented to the user. The owner of the battery will most likely be the owner of the battery swapping service or the provider of the vehicles (Danilovic & Liu, 2021). This is because users will change between different batteries and will not keep their original battery. This allows the battery swapping stations to use the batteries for V2G services when they are in the station, giving an additional revenue stream. This will lower and help with grid stress (Ford & Hardy, 2020). The most extensive offer to the customers is how fast the service is, compared with plugin charging (Danilovic & Liu, 2021; Monios & Bergqvist, 2020). However, battery swapping will also offer lower energy prices because they can charge up the batteries overnight when the price is low. This will also make it easier to offer renewable energy to the customers because they can store it when it is produced. Each battery-swapping station can only operate a few different batteries and therefore can only offer the service to limited models (Danilovic & Liu, 2021; Du et al., 2018; Monios & Bergqvist, 2020; Naor et al., 2018). This is a limitation for battery swapping stations, but it should be noted that each station needs fewer customers per day than plugin charging stations to be profitable (Du et al., 2018).

3. Method

3.1 Research philosophy

Saunders states that when choosing a research philosophy, if there are issues in adopting a single philosophy of conducting the research, that would guide you to the position of pragmatism. Pragmatism is chosen because we consider the research question to the report's philosophy (Saunders, 2007).

3.2 Research approach

Induction is the research approach of building theory rather than testing theory. With induction as the research approach, the data guides the theory. The currently formed research question: *What barriers for Charging point operators' business models can be identified using a technological innovation system?*

The primary data gathered will guide the thesis, and modifications can be made to allow for changes in theory based on the findings. The research question also depends on the context, and according to Saunders, the induction approach is more appropriate when the context is an essential factor (Saunders, 2007).

3.3 Research strategy

The research strategy chosen is a Case study, where the phenomenon studied is the electrification of heavy vehicles. More precisely, the case being studied is the infrastructure development for heavy vehicles. A gap was observed when reading literature in the field of business models for electrification. There was a lack of literature on business models for infrastructure development and the owners of infrastructure for electrification. This phenomenon needs to be observed and analyzed to provide researchers and industry insight into this area. According to Saunders, a case study allows the researcher to understand a phenomenon that few have considered before (Saunders, 2007).

3.4 Research choice

Mono-method was chosen for the thesis because the data collection and analysis are qualitative methods. The authors believe that qualitative data collection is best suited for answering the research question. This is because what question usually is used for quantitative research and the question has an element of subjectivity. The subjectivity being the perspective from CPOs. To gather and analyze these subjective perspectives the authors chose a qualitative approach.

3.5 Time horizon

Cross-sectional studies are when a moment in time is being analyzed. The time horizon for this thesis will be cross-sectional because the data collected investigates the current time and what the current time tells us about the future (Saunders, 2007).

3.6 Techniques and procedures

3.6.1 Primary Data

To get a systematic understanding of the system surronding CPOs in the south Swedish context 17 interviews were conducted with different actors in the system. This ranges from HBEV manufacturers, station operators, energy producers HBEV operators, research intuitions, industry partnerships, and governmental institutions. The data were collected using semi-structured interviews, and the interview questions were different depending on what type of company that was interviewed. When interviewing a CPO, the questions were business model oriented to gain insight into how the CPOs business model was constructed in the areas of Value proposition, Value Creation, and value capture. This data was used to create a general overview of how a CPO business model was constructed. This is to get a system understanding from different perspectives to give a holistic perspective. The primary data was collected from actors in the electrification of heavy transport. The actors included infrastructure developers, truck manufacturers, energy providers, and electrification institutes. These data are a collection of actors that are a part of the system for electrification of heavy transport, primarily actors for infrastructure development. The criteria for selection for interviewees were that they were actors in the field of electrification of transport, specifically actors relating to infrastructure development for electrification. These interviews were conducted to get insight into how the company relates to the evolution of electric vehicles and how the company sees new trends and opportunities in the electrification of transport.

Interview Number:	Company/Institution:	Position:	Time:
1	ABB		53.42
2	Haulage Company		50.22
3	Haulage Company		30.54
4	Circle K		48.31
5	Energy provider		1.14.48
6	Electrification HUB		35.38
7	Göteborgs Energi		45.12
8	East Sweden Battery-Swapping Initiative		1.27.16
9	Nima Energy		28.09
10	OK Q8		43.11
11	Pathway Coalition		58.54
12	Scania		1.04.22
13	Svensk Fordonsladdning		51.28
14	Swedish Electromobility Centre		57.31
15	Swedish Electric Transport Laboratory		56.22
16	Trafikverket		42.40
17	Volvo Energy		1.00.17

Table 1 Interviews

Interview procedure: When interviewing another actor in the system, the questions were primarily focused on how their operations affected CPOs, and the system of electrification of heavy transport. The questions in these interviews were changed over time because of the interviews with CPOs. When a CPO proposed a barrier or a problem, questions were asked to actors to which this problem was related. The companies that were contacted were gathered from a publication from the Swedish government institute called "elektrifieringslöftet”. When reading the report, the companies working with infrastructure development and electrification of heavy transport were contacted per e-mail. A date was set for an interview and before the interview, a document was sent to the interviewee to explain the subjects that were going to be discussed. At the beginning of the interview there was an introduction of the research team and the interviewee and a discussion about how the material would be used. What followed was a semi-structured interview divided into three parts. The parts were value proposition, value creation and delivery, and value capture. These parts were used because of Osterwalders' definition of business models (Osterwalder, 2004). Other than the different parts, a few questions were prepared to not obstruct the discussion. The reason for this was to get as many thoughts and perspectives from the interviewees as possible.

While interviewing, the authors were assigned a primary interviewer and a secondary interviewer. The primary interviewer's role was to lead the interview and ask the prepared questions and engage in discussion. The secondary interviewer's role was to take notes during the interview and ensure that the transcription and recording were working. At the end of the interview, when all prepared questions had been asked and answered, the secondary interviewer ensured that all questions had been answered. This division of labour was done to guarantee that our software for recording and transcription didn't malfunction and to make sure that all questions were asked.

3.6.2 Secondary Data

The secondary data is collected from articles regarding electrification. This is done to provide hard data such as numbers to give perspective to different issues that are discussed in the TIS.

3.6.3 Analysis

The interviews were conducted over electronic communication tools such as Zoom and Microsoft teams. The authors were present at the University when the interviews were conducted so a discussion could take place after each interview. The discussion was done to reflect over the topics discussed and a summary of what was discussed was written for each interview. The summary contained the perceived problems and solutions for barriers and information relating to the TIS. If any new information emerged from the interview, a discussion was conducted to see if and how we could formulate a question regarding that topic to get more information from later interviews.

The information gathered from the interviews was synthesized and discussed among the authors. After each interview, a primary discussion was held to determine important information regarding business models. The moment all interviews were conducted a secondary verification process was held to verify the information previously gathered and the identification of new information. After the business model processes were gathered, they were categorized into value proposition, value creation, and value capture.

These were then summarized into a general business model for CPOs. A general business model was chosen because the industry for infrastructure development for HBEV is still in its infancy, and the business models do not differ much. The text describes these differences to provide different perspectives of business models for CPOs. The interviews used for this section are 4, 7, 9, 10, and 13.

The information gathered from the interviews was then discussed between the authors to determine the relevance of the information provided and then transcribed into the TIS in its respective areas. The criteria for inclusion in the TIS is that the information is related to identifying barriers in the system.

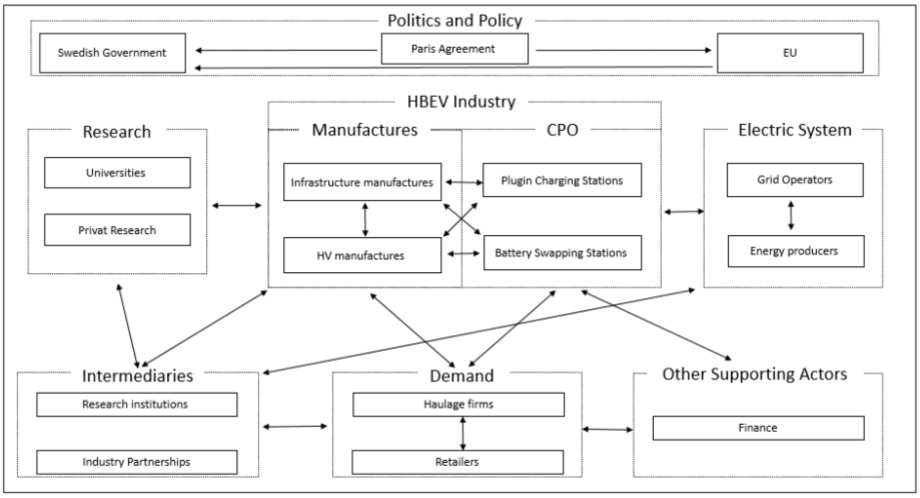

Image 1: TIS

Actors within the TIS. The layout is according to Kushnir et al. (2020) and Hekkert et al. (2011), based previously on Kuhlmann et al. (2001).

The TIS is developed from the context of CPOs for HBEVs in south Sweden. We have used interviews with these different actors in the TIS to develop the TIS. The TIS with the different actors and their relationships are represented in image 1 TIS. CPOs were represented by interviewees 2, 4, 5, 7, 8, 9, 10, 13 & 17. Interviewees 9 and 13 are not directly CPOs but develop charging stations for CPOs and represent the development of charging stations. HBEV manufacturers are represented by interviewee 12 and 17. Interviewee 1 represents infrastructure manufacturers. Haulage firms are represented by interviewee 2 and 3. Energy producers are represented by interviewee 5 and 7. Research institutions are represented by interviewee 6 and 15. Industry partnerships are represented by interviewee 8 and 11. Universities are represented by interviewee 14. Swedish

Government is represented by interviewee 7 and 16. These actors are not fixed, and some interviewees represent two different actors in the TIS because their companies or organization are active in several different parts of the TIS and can therefore represent more than one actor.

The different functions were analyzed from the questions and discussions in the different interviews. The information for the first function, knowledge development and diffusion, was gathered from the question "Who provides you with information about HBEV" where the responses from CPOs and haulage firms played the most significant role. Influence on the direction of search was based on the overall discussion with the interviewees with follow-up questions on how they believe the future will evolve. The information on the third function, entrepreneurial experimentation, was gathered from the question "What service do you provide and with what product?", where the interviewees told what they have and currently provide. Where they also explained what they have tested and are currently experimenting with regarding HBEV. There also accrued discussion in several interviews about what different actors have or are currently experimenting with. The market formation function was gathered from the first part of the question "What is needed for this market to grow from our perspective". And a discussion with the different actors on why they are moving in the current direction that accrued from the question "What service do you provide and with what product?". The information about legitimation was gathered from the question "How do you feel about the other products and its benefits and drawbacks?". Where the focus was to bring up the different solutions or products that the actor does not use, to understand why and if they do not believe in them. Resource mobilization was gathered from the question "What is needed for you to provide this service?" where the interviewees described what is needed from different resources to provide different services regarding HBEV. Finally, the information regarding positive externalities was gathered from the question "Will you have any additional revenue streams?" where new products and services were presented to help new actors in the TIS in the future.

The barriers were gathered from the interviews with questions relating to the system or business models. The questions were created to identify the issues facing the electrification of transport. When the interviewee identified an issue during the interview, a discussion was conducted to explore the issue further to identify the reason why the issue occurs and what impact it has on the industry.

The authors collected these barriers and discussed regarding relevance to the research question and the scope of the report. The barriers were then bundled into more significant and overlapping barriers and then related to either the output of a traditional TIS or business model solutions. This is to give different solutions to the same barrier from different perspectives. This was highly relevant because the TIS and information gathered were primarily from a business model perspective.

An analytical process was conducted to identify the barriers and convert them to blocking mechanisms. Interviews were conducted with CPOs and the areas where the implementation process was slow or bottlenecks were considered possible barriers. The barriers from the business model perspective were areas where other factors impeded the development process. To identify these areas, questions such as "What is halting the progress of charging stations in Sweden" were asked. The answers that were provided were analyzed from the perspective of the TIS to get a concrete blocking mechanism that later was analyzed, and solutions were proposed.

Then we did one qualitative data collection by interviews divided into two parts. One to collect data for CPOs business models and one for data collection regarding surrounding actors in the TIS to develop the analysis of the different functions in the TIS. The CPOs business models were then used as a filter to analyze the functions in the TIS to find barriers to CPOs business models. These barriers were then combined into five different blocking mechanisms. Because the blocking mechanisms are grounded in barriers to CPOs business models, changes to these business models can mitigate the effects on the blocking mechanism. This provided the ability to develop the TIS to not only give regulatory recommendations but also give recommendations to the central actor in the TIS. We provide this recommendation to CPOs thru changes or additions to their business models. Business models and TIS have a symbiotic relationship where the TIS provides the system where the business models exist. The business models then provide the blocking mechanisms based on the TIS functions. The business model recommendations can be made to the core actor in the TIS.

3.7 Research Quality and Ethics

During a research process the quality aspects that need to be considered are reliability, validity and ethics (Saunders, 2007). Reliability is the aspect that considers if the data collection and analysis have provided consistent results. To ensure reliability in the thesis the same core questions have been asked to all the participants, the only deviation being follow-up questions. In the analysis a summary was made of all the interviews to not let a single actor dictate the findings, instead a general overview was provided from actors in the south of Sweden. This was done to get an industry view rather than one company's perspective.

Validity in a thesis is that the information gathered, and findings are about what the thesis seeks to analyze (Saunders, 2007). To ensure this was all the interviews recorded and transcribed. The interviews could then be listened to again and read to not confuse any statements and to make sure that the answers were related to the question. The information provided from the interviews was also crossed checked with secondary data to confirm certain pieces of information.

During the data collection process all the participants were asked if the company name could be used in the thesis. Information relating to the answer of one participant was also checked with that participant after the interview before being used in the thesis. This agreement was made with all the participants to ensure that they could speak freely and give an honest perspective.

4. Data

4.1 Business models

The industry of infrastructure development for HBEV is still in its infancy; therefore, the business models focus on the core essence of the service they provide. The core essence is providing their customers with fast and reliable charging solutions.

4.1.1 Value proposition:

The most given response to what the companies wanted to provide the customers was availability. This term kept resurfacing when questions relating to value proposition were asked. This value proposition was defined in different ways, availability in the sense of a charging station being available so the customers do not need to wait and have available capacity so the vehicle can be charged fast. Both definitions of availability were a part of the second most used term in value proposition, booking. Providing booking services to charging stations would allow consumers to guarantee that there was a spot available for them. A system for this service has not been widely adopted yet, perhaps because of the current low utilization of charging stations in Sweden. The benefits of booking systems collected from the interviews were: additional revenue stream, guaranteed charging for customers at a defined time, and possible higher utilization.

Other core aspects of business models for infrastructure for HBEV are reducing CO2, Parking space, and semi-public charging stations. Reducing CO2 as a value proposition is nothing unique and is being used by all industries working with electrification. Some infrastructure developers have this as a higher focus where integration of their own sustainable energy production and storage can ensure that the energy charging the HBEV is green. Parking space can be vital for a charging station for HBEV because lack of space and inefficient layout can make it harder for customers to charge the vehicle. A charging station with a clear driving pattern, easy-to-access stations, and separation between HBEV and BEV can make a charging station more appealing, especially to haulage contractors.

4.1.2 Value Creation:

To create value for the customer, the interviewed companies focused on providing a service with an emphasis on comfort and amenities. This will include providing other services such as facilities, food, and a safe resting place for overnight visits. This has been a focus for new charging stations to provide the value of comfort for truckers, and this is because the interviewed parties have gathered this information from their users and the industry wants it. Another important aspect is to provide the core value of a charging station which is fast charging. To ensure fast and reliable charging the interviewed companies had solutions for this in the form of ensuring capacity, energy storage, and energy production.

4.1.3 Value Capture:

The essential value capture process gathered from the interviews was the location. The location where a charging station is will impact all parts of the business model, the difference is that from the value capture perspective, it will reach new customers. This will drive traffic towards stations, which was also an answer the interviewees provided.

The cost structures also vary between the companies interviewed. The main cost structure that the majority agreed on and have implemented is that the price is based on KWH charged. The opposition to this was a fixed price per charge. When it comes to payment, there is a mixed batch, implemented in both card payment, apps, and tags for charging stations. All the companies are interested in future payment technologies such as Plug and Charge.

4.2 TIS

4.2.1 Actors and networks

The actors and networks in the TIS can be seen in "Image 1 TIS" these are the regulatory actors and networks that act on the rest of the actors; these are the Swedish government and the EU. The core of the TIS are manufacturers for both HV and infrastructure together with charging stations; both plugin charging and battery swapping that are operated by CPOs. In the electric system there are two different types of actors. First, the grid operators that have a closer connection to charging stations because they provide the power needed for the stations. The second is energy producers. Some of these actors are currently expanding their services by building their own charging stations. The demand comes from retailers that need the service that HBEV provides. Haulages is the owner of the HBEV and provides retailers with the service. Haulage firms are closely connected to HV manufacturers that provide the firms with their HBEVs, and they are also connected to the CPOs charging stations where they charge their trucks. Other supporting actors, such as financial actors, are mostly connected to charging stations and haulage firms, where both types of actors need finical support to fund their investments. Intermediaries are networks with different actors in such as industry partnerships that connect actors from different parts of the TIS. Research institutions also connect the different actors with research projects. Finally, there are two different reach actors, universities and privet research. Many different actors from the different sectors are planning to move into charging stations such as HV manufacturers, energy producers, haulage firms, and even industry partnerships.

4.2.2 Institutions

Institutions include informal and codified to give the rules of the game and the expectations (Bergek et al., 2015). The codified aspects that are the most relevant, and are acting on the TIS, come from the Swedish government laws surrounding both climate and HVs. The Paris Agreement and the European Union Fit for 55, which refers to the EU goal to reduce the greenhouse gas emission by 55% by 2030, this will be achieved with new EU legislation towards this goal (EU, 2018; Fitt for 55, 2022). Sweden is characterized with a high degree of public support for environmental policy and with high trust in overall state institutions. (Harring & Jagers, 2018; Harring et al., 2018) There is a high willingness from the public to support and also punish firms in order to achieve environmental goals (Kushnir et al., 2020).

4.2.3 Knowledge development and diffusion

Knowledge diffusion

The overall knowledge surrounding HBEV is relatively low due to the newness of the HBEVs. The majority of the knowledge in the TIS comes from the HV manufacturers that spread the knowledge to CPOs, energy producers, and especially haulers. CPOs and energy producers have some prior knowledge surrounding BEVs but not all of this knowledge is useful for HBEVs. Haulers usually do not have any prior knowledge of BEVs and are used to getting their information regarding HV from the different HV manufacturers.

4.2.4 Influence on the direction of search

Charging standards

There is a clear focus on plugin charging in the overall TIS. The HV manufacturers and charging manufacturers have committed to the CCS standard. This is the same standard that is used for EV charging. This gives the ability to use EV chargers to charge HBEVs. For many actors, the next step in the evolution of chargers for HBEVs is mega chargers that are categorized at 500-3500 kW. These will be made for HBEVs and will have a new standard that is under development right now. Many actors in HV and infrastructure manufacturers are on the same page and want one standard. They believe that a standard in mega chargers will help everyone. Where there is no standard in sight is where on the HBEV the charging outlet is placed. This leads to that public charging stations need more space for HBEV to access the charger from different sides.

Firms entering public charging stations

The strength of entry in the TIS is strong, especially for actors entering the public charging stations. Ther are actors from HV manufacturing, haulers, intermediates, electric system, and new ventures. The general belief in the market's growth potential is strong and is what is driving most of the entry right now. Many actors have stated that they know that public charging stations for HBEV are not profitable right now. However, they believe that it will be profitable in the future and are willing to lose money right now to get a better position for the future and to reap the rewards later. The other push into the public charging stations market is from actors that need public chargers for their primary business and sees these investments into public charging stations as secondary to their primary business. These are primarily actors from HV manufacturing and haulers.

Energy storage & Energy production

Energy storage combined with HBEV charging stations is a strong trend that many actors see as beneficial. The primary energy storage system is with batteries which can help the station with peak power and lower the price of electricity for the customers. The grid cost will be lower if part of the peak power is taken from the energy storage system and not the grid, and it can also help build a bigger station where grid power is a problem. V2G is seen as a possible revenue stream but not from HBEV public charging stations, but the same technology can be used for the battery energy storage where actors see the potential. In this case, public charging stations can have an additional revenue stream from energy arbitrage and frequency control from the battery storage to the grid. When it comes to energy production connected to the charging station, this is seen as mainly an addition for publicity and will not significantly affect the charging station. The total production and peak demand needed for a charging station are hard to produce on-site with both wind and solar energy.

Hybrid solutions

Especially new actors in HBEV charging stations are considering combining HBEV charging with EVs to increase the utilization of the chargers and therefore the profit potential. This means that HBEV chargers must not only be used by HBEV but can also be used by EVs. This is possible because they use the same standard CCS, which is considered a short-term solution when the HBEV is still relatively small.

Payment solutions

The industry wants to learn from the mistakes of EV charging stations and create an easier way to pay for charging to avoid over ten different apps depending on which charging stations are being used. Work is being done for plug and pay charging where the payment will occur automatically when plugged into the charger. In contrast to EV charging stations, many actors see that a booking system is needed for HBEV charging stations and are working on a booking system. This is to ensure that when an HBEV arrives at the station, it does not need to wait for a charger to be available.

Battery

HBEV differs from diesel HV; the engine is less important because of the relative simplicity of an electric motor. This shifts the focus of HV manufacturers from engines. Batteries will be very impotent for HV manufacturers, and the battery will give a competitive advantage for HBEV.

Rest time

Regulation around driving rest time is a prominent factor that influences the market. This regulation directs how fast a recharge needs to be and how long the gap between charging stations needs to be on longer transporting roots. To minimize unnecessary time where the HBEV stands still charging should co-occur when the driver needs rest time.

Government

Several actors have moved into the HBEV industry but have not fully committed due to uncertainty regarding the market's direction. Several actors are looking to the government to take the leading role and show the direction that the industry should take. Governmental actors such as government institutes and governmental owned companies do not want to close any doors and have many options opened in order for the market actors to lead the way forward. This leads to a stand where government and market actors expect the other to lead the way forward.

Battery swapping

Battery swapping has not broken ground in Sweden or Europe for HEBVs mainly because no manufacturer provides HBEVs with battery swapping capabilities. However, there are some actors that want battery swapping

HEBV and are planning to order them from China together with five battery swapping stations.

Competitive technologies

There are two competitors when it comes to other fossil-free solutions: hydrogen HEV and diesel trucks that run on HVO diesel. Many actors believe that hydrogen will be part of a larger ecosystem with both HBEV and hydrogen HEV but that the dominant design will be HBEV. Hydrogen HEV still has some years left before they will be available to purchase from the HV manufacturers. Diesel trucks that run on HVO are a significant competitor to HBEV though they can be seen as a fossil-free transport. Instead of purchasing HBEV, Haulers can use their existing diesel trucks to fuel them with HVO diesel to deliver fossil-free transport. HVO diesel transport is considered to be cheaper today than transport with HBEV.

4.2.5 Entrepreneurial experimentation

Charging system

HBEV has not had much experimentation in Sweden or the rest of the world. However, the plugin charging system CCS that is used for HBEVs has existed for a long time and has had much experimentation. Not much experimentation is needed or ongoing regarding the technology of CCS charging. However, much work is being done regarding mega chargers that are considered the next step for HBEV chargers.

Grid flexible contracts

There have been some experimentations and pilot testing regarding flexible grid contracts in the TIS. Flexible grid contracts differ from regular grid contracts because they do not grant the user a predetermined power from the grid. This means that the user can get a lower power output from the grid than what was set from the beginning if the power is used by someone else. The benefit of a flexible contract is that a higher peak power can be achieved where it otherwise could not.

Public charging stations

The Swedish government has offered 1,5 billion Swedish kr for experimentation pilots regarding HBEV public charging stations. These stations will be operational for at least five years and give public information about user time, power use, and degree of use, with more. There have not been any dedicated charging stations for HBEV in Sweden as of right now. All public charging stations that will receive support for pilots have to be finished before September 2023. This will provide much information regarding the use case of public charging stations for HBEVs.

Haulers

Experimentation from haulers is low, especially regarding public charging. Most of the few HBEV that exists in the TIS only charge overnight by private charging stations. There are some HBEVs that have used public charging stations, but that is meant for EVs.

Battery swapping

There is no experimentation regarding battery swapping for HBEV in Sweden; this could change in the upcoming years, though some actors have this goal. Experimentation has started for battery swapping EVs in Norway in 2022 by NIO.

4.2.6 Market formation

HBEV & charging stations

The most significant need for the market to grow for public charging stations is more HBEVs, and one of the most significant needs for the market to grow for HBEVs is public charging stations. Many actors call this a "catch-22" scenario where the markets are in a limbo where no market can grow because the other market needs to grow first. However, haulers do not necessarily need public charging stations. Public charging stations will help increase the degree of use and the use case for HBEVs. Many actors in the TIS, even CPOs believe that haulers need private chargers first, in order for the HBEV market to grow. HBEVs can charge overnight with private chargers and serve local distributions on the day. Then public charging stations can start developing to offer fast charging with short breaks to increase the degree of use and use case for HBEV so that more extended transport can be possible. Finance for public charging stations is not a big problem; many actors have and are willing to spend much money to provide public charging for HBEV. When it comes to haulers, finance is a bigger problem. With already tight profit margins are buying an expensive HBEV a significant risk. Haulers express that they need lower the risk in order to choose HBEVs. Today this is achieved by leasing the trucks from the HV manufacturers. The last big factor for the HBEV market is their customers procuring willingness for fossil-free transport with HBEVs. Because of the risk and uncertainty for HBEV, a higher price is needed to provide the service with fossil-free electric transport from haulers.

HBEV uses cases

The first HBEV that enters the market will transport goods locally or regionally from point to point. Shorter local transport will not necessarily need public charging stations if haulers have their own private chargers. However, public charging stations can provide faster charging that can increase the root of the HBEV. More extended regional transport needs public charging stations to reach the destinations. Regional transport will most likely also charge on private chargers overnight and use public chargers as a compliment to increase their range. Long haulers stand for the more extended transport that needs night stops on the way. These need public chargers during the day and at night combined with several hours of rest time. HBEV long haulers will not enter the market for some years.

Additional emphasis

Several CPOs want to have their charging stations close to facilities to provide the drivers with food and restrooms to make the charging stop more convenient for the driver. However, several haulage firms think these facilities are a bonus but not the determining factor for choosing a charging station. The determining factor for haulage firms is the location and that the stop fits nicely in with the timing for the driver's rest time and the driving root of the HBEV.

Battery swapping

One of the big HBEV manufacturers needs to provide HBEVs with battery swapping capabilities for battery swapping stations to break through. Many actors believe that public battery swapping stations need a standard in batteries for HBEV to succeed. This can be true for a market with many different HV manufacturers, but two HV manufacturers are dominating the Swedish HV market. This allows one of these HV manufacturers to offer HBEVs with battery swapping capabilities and together with other actors, or on their own, build a network for battery swapping. Battery swapping will still only be considered complementary to plugin charging which means that battery swapping HBEVs does not need battery swapping stations because they can use plugin charging stations. Public battery swapping stations depend on the degree of use to be profitable; the degree of use does not need to be as high as for public charging stations. This allows one manufacturer with a large market size to make their own battery swapping standard and not need to partner up with competitors.

4.2.7 Legitimation

HBEV

HBEVs have gained much acceptance over the last years, with the biggest HV manufacturers starting to produce HBEV and wanting to completely change their HVs to electric over the coming years. Haulers do not question the technology around HBEV but have concerns about the profitability of HBEV and its flexibility. The degree of use for a HBEV is lower than for a diesel HV and more logistics are needed. Matching to time and finding charging stations is more crucial for HBEVs. The cost is a factor for legitimation regarding haulers, where a significant upfront cost for HBEV is repulsive.

Retailers

Retailers that buy the transport service from HV operators are willing to pay extra for fossil-free transport. The fossil-free transport can be achieved by diesel trucks with HVO fuel and with HBEVs. Retailers are less willing to pay more for transport with HBEV than diesel trucks with HVO fuel.

Battery swapping & HV manufacturers

Battery swapping has a low legitimation in the TIS, especially from HBEV manufacturers. The belief is that battery swapping HBEVs needs a standard battery for all HBEV manufacturers, which is not something HBEV manufacturers want. It is not only the competitive disadvantage that is repulsive regarding battery swapping, but also that it could look in HBEV manufacturers to one technology regarding batteries which could be outdated fast. There are also safety concerns with battery placements and an overall stigma towards “China technology”. The legitimation from infrastructure manufacturers regarding battery swapping is also low with no known R&D projects regarding battery swapping towards HBEV.

Battery swapping, haulers & CPOs

Haulers are under the impression that battery swapping is a technology that does not work; however, if they were presented with the option, they see several benefits with battery swapping. CPOs see battery swapping as an opportunity if HV manufacturers start to deliver the HBEV in the future. Some have even stated that they would be willing to partner with one of the big HBEV manufacturers to provide battery swapping services for just that brand. This is because the Swedish market is dominated by two more prominent brands. If one of these were to offer battery swapping, it would be large enough of a market share to consider offering battery swapping.

Flexible grid contracts

There are mixed opinions on flexible grid contracts from CPOs. Several CPOs highlight that it is essential for them always to be able to deliver the high-power charging that they promise their customers. This makes station operators uncertain about the use case regarding flexible grid contracts.

4.2.8 Resource mobilization

Grid infrastructure

Grid infrastructure is a core component for all public charging stations. With high-power chargers of 350 kW each, there need to be high power cables that provide the power. These are not cheap and take a long time to provide from the grid operators. The grid operators cannot by law build the grid based on predictions and can first start the process of building the grid when a request for power is received. Only the process of asking if there is available power in the vicinity of a proposed charging station to receive an answer can take a long time. If there is no power available, it can take five years for the grid operator to provide the power needed.

Location

Location is essential for charging stations. It is vital to have a good location where there is a need and traffic from HBEV and space to provide charging for many vehicles. It is hard for station operators to find a location with power from the grid available, high traffic flow of HV, and the space needed. Battery swapping stations do not need as much space as plugin charging stations and do not require as much peak power from the grid. However, battery swapping stations do still require space and power from the grid.

Finance

Finance is needed for both station operators and haulers. It seems more critical for haulers to lower their finical investments than for station operators. Serval CPOs are large cooperations with financial support, where they see public charging stations for HBEV as a side business and not their primary business. Haulers on the other hand do not have another business that will generate them money. This combined with small profit margins makes it hard for HV operators to convert their HV fleet to HBEV without financial support.

4.2.9 Development of positive externalities

Batteries

Second-life batteries for battery storage have been proposed to reuse the batteries from HBEV that are not performing sufficiently but can still provide value. This will lower the price of battery storage in the future which will be very beneficial for station operators that are considering using battery storage.

Market growth

The development and growth of the HBEV market will positively affect future CPOs and haulers. More HBEV will give rise to more public charging stations, increasing the willingness for haulers to convert to HBEV. The market and new ventures entering the market will benefit from the early market growth.

4.3 Blocking mechanisms

4.3.1 Grid infrastructure

The grid greatly impacts CPOs and is vital for value proposition and value creation. The grid has several barriers connected to it from a CPO standpoint. A grid connection is crucial for a charging station, the problem is that these connections take a long time, can be costly and locations with available power are becoming scarce. This is connected to Swedish regulation that prohibits grid operators from building the grid on expectations which makes the grid infrastructure fall behind. This, combined with a large area that is needed for charging stations and that the station also needs to be close to a road with a high traffic flow, complicates the process of finding a location for a station even more complicated. If the proposed location does not have available power in the grid, a long process needs to be started to build out the grid. To avoid this lengthy and sometimes costly process station operators want to find locations where power is available. This leads to the second problem connected to the grid: companies must ask if the grid operators have power available at a particular location. It is tough to know if power is available in the location, and only the grid provider can get a clear answer. Only getting an answer if an attractive location has available power can take a long time, dragging out the process of developing a charging station from the beginning.

4.3.2 Grid cost structure

The cost structure for using grid power is not beneficial for CPOs. The cost is based on the highest peak power per month, even if this peak only occurs for a few hours per month. Charging stations have a low degree of use over a day; however, if many HBEV stays on the same time around lunchtime to combine the driver's rest time with the charging time, the peak use and, therefore, peak power will be high even though the total degree of use and power use will be relatively low compared to the peak demand and power.

4.3.3 Adoption

In order for charging stations to capture value they need users and the degree of use for charging stations is currently low in the TIS. There needs to be more HBEV for charging stations to be profitable. The mechanisms that are hindering the adoption of HBEV are the high cost and uncertainties from HV operators. The upfront for HBEV is high and the value added for HV operators is low in comparison. The benefit of providing fossil-free transport can be provided cheaper and more manageable with HV fueled with HVO than with HBEV. Retailers value fossil-free transport but do not seem to value HBEV transport over HVO transport. This leads to slower adoption of HBEV because diesel HV with HVO can, from a market standpoint, fulfill the need that HBEV provides.

The uncertainties regarding HBEV for haulage firms are if the dominant design is not set, new driving patterns, where to be able to charge and what the end-of-life value of the HBEV is. Uncertainties regarding if the dominant design is not set and the end-of-life value is connected to the newest HBEV and the belief that HBEV will improve over the coming years. In order to lower the unnecessary time, when the HBEV stands still, more focus for haulage firms needs to be put on driving and charging patterns.

4.3.4 Battery swapping

Battery swapping needs one of the big HV manufacturers to provide HBEV with battery swapping capabilities. Why HV manufacturers are not providing battery swapping or considering it soon has several factors: unwillingness to have an industry-standard battery, low customer demand, and overall disbelief in the technology. The battery is an essential part of the HBEV for HV manufacturers, where large parts of the competitive advantage will come from. Therefore, HV manufacturers do not want to create an industry standard. An industry-standard can also create a standard that will be outdated fast due to technological advancements regarding batteries, discouraging HV manufacturers from a battery standard. The benefits battery swapping bring are beneficial for haulage firms; however, battery swapping is still not demanded. Haulage firms do not trust or believe in battery swapping technology. This skepticism comes from HV manufacturers that spread negative information about battery swapping to other actors, especially haulage firms. This influences haulage firms and creates a belief that battery swapping is unreliable; thus, the demand for battery swapping remains low. There is no entrepreneurial experimentation in the TIS regarding battery swapping, which could increase the legitimation from HV manufacturers and haulage firms.

4.3.5 Interoperability

Several actors in the TIS want a standard payment system so that HV operators do not need a particular app for a particular charging station and end up with several different apps. Several actors are also procuring booking systems for their charging stations. In contrast to the payment system, there does not seem to be much effort in developing one booking system or several with interoperability. This can lead to several different apps for different booking systems that are needed for different charging stations, the very problem many actors want to avoid. This may not seem to be a big issue; however, it complicates the use of HBEV even more for haulage firms, leading to lower adoption of HBEV and lock-in users to a few stations.

5. Discussion

5.1 Business models

Electrification of heavy vehicles in Sweden is an immature industry. With a low amount of electric trucks being used by haulage firms in Sweden. With a low adoption of HBEV, CPO business models focus on the core value of a charging station. To still be operational and make a profit, charging stations for HBEV have found two solutions. These solutions are semi-public charging stations and public charging stations for HBEV that can also accommodate BEV. The owner primarily uses semi-public charging stations but also allows other actors to charge their vehicles. These charging stations are being built by haulage companies to charge their fleet during the night and when the vehicles are not in use and can be used by other haulage firms or private actors when not in use or at a set time. The other solution, letting BEV:s charge at public HBEV charging stations, increases the utilization of the charging stations and further assists the station in reaching the break-even point of approximately 20% utilization according to one of the CPOs interviewed.

Solutions for when a higher adoption of HBEV has been reached are more focused on primarily serving HBEV. The activities discussed during the interviews can be categorized into three different types of activities. Firstly, increase the charging stations' utilization, energy solutions, and complimentary services. Solutions to support this includes booking systems to provide a plannable availability to the haulage firms and increase the utilization for the CPOs.

5.2 Technological innovation system

The TIS goes down on a more detailed level than other TISs such as Blum (et al. 2015) that also include a qualified data collection with a case study. This can be related to the combination of business models and TIS. In order to understand barriers to CPOs business models, a data collection on both a micro and meso level was conducted. This could then be translated into a TIS with a more in-depth meso analysis that gives a greater understanding of the market formation and the influence on the direction of search. The developed TIS describes these functions from different actors' perspectives and is necessary to understand how CPOs are affected by the different actors.

The TIS is dominated and controlled by the HV manufacturers, who are the big established companies that know the technology regarding HBEVs. Their product, HBEV, is the core of the market. Other actors in the TIS adapt to the HV manufacturers and do not question them.

5.3 Blocking mechanisms

The blocking mechanism is based on CPOs business models but affects the entire TIS. Charging stations are vital for the development of HBEV on a large scale, therefore are barriers to charging station blocking mechanisms for the entire TIS. The grid provides two different blocking mechanisms, both grid infrastructure and grid cost structure. These emerge from the disruption that charging stations brings to the grid infrastructure. They demand high peak power irregular, which differs from other connections to the grid with more steady power demand. Regulations regarding the grid have not had time to be adapted for charging stations, which has led to the blocking mechanisms regarding the grid for the TIS. A market needs users, this market does not differ, the market is still very new and is developing, but more is needed to incentive new adopters to choose HBEV. Both battery swapping and interoperability could help to mitigate other blocking mechanisms. There are today barriers to both battery swapping and interoperability that need to be solved before they can be part of the solution for the other blocking mechanisms.

5.4 Recommendations

5.4.1 Business models

Grid infrastructure

The blocking mechanism regarding grid infrastructure is based on regulatory factors and these are hard for individual companies to impact. However, there are still adjustments that can help CPOs to tip the scale in their favor. Battery storage can lower the peak power needed to form the grid, making lower power grid connections also suitable for charging stations. Battery storage combined with a flexible grid contract will also increase suitable grid connections where the battery assures that the station can deliver sufficient peak power even when the grid is throttled. To increase locations with sufficient space, a suitable grid connection, and close to large traffic flows, station operators can focus on several small stations rather than a few big stations. Smaller stations require less peak power and space, increasing suitable locations for charging stations.

Gird cost structure

To avoid using peak power from the grid charging stations can use battery storage for peak shaving. This will lower the peak power and therefore the cost to the grid operators based on the peak power every month. The battery storage can also be used for energy arbitrage and frequency control which will be an additional revenue stream for the charging station. Battery storage will increase the initial cost for the charging station but lower the running cost. Finance for starting capital seems to be a minor problem for charging operators; therefore, additional battery storage should not hinder charging station operators. What is a hindrance is the degree of use that is needed to break even, which is also connected to the blocking mechanism of adoption. Lower running grid cost will lower the break-even point for the degree of use.

Adoption

To lower the investment cost for haulage firms charging stations can provide semi-public stations where the stations are public during the day and booked at night. This allows haulage firms to not invest in private charging stations and lower the initial cost. It also gives charging stations an additional revenue stream. This will be beneficial at the beginning of the market where haulage firms have not invested in private charging and where long ha that needs night charging has not converted to HBEV; therefore, should the stations be relatively empty. To lower the uncertainty for haulage firms on where to be able to charge, an option to book a charging point in advance can be helpful. There are two other approaches that station operators are considering to lower the uncertainty on where to charge. The first is to build a large station to always have available charging points for the users. The second is to build several smaller stations to spread the users to several charging stations. Smaller stations can also favor haulage firms with lower demand on optical driving patterns though charging stations will be denser. Hybrid stations where the charger can be used by both EV and HBEV will increase the degree of use for the chargers. Hybrid stations should be combined with a booking system that prevents EVs from taking over the charging spot meant for HBEV. In this case, HBEV book the time they want to charge, and in the other free time where the chargers are not booked, EVs can use the charger to increase the degree of use of the charger.

Battery swapping

Collaborations between CPOs and HV manufacturers are needed to provide battery swapping stations. The CPOs depend on batteries from the HV manufacturer because there is no standard in batteries for battery swapping.

Interoperability

Instead of developing their own booking system CPOs should collaborate to create one standard booking system. If each CPO develops its own system without interoperability with other booking systems, they will create the same problem with several different systems they want to avoid.

5.4.2 Regulations

Grid infrastructure

Locations with sufficient power from the grid are hard to find and are slowing down the development of charging stations. This is predicated on the regulation regarding grid development, which states that grid operators cannot build the grid based on predictions. Changes to the regulation about grid development to make it possible for grid developers to build the grid based on forecasts will help the development of public charging stations. The process of finding a location with a suitable grid connection is long and can slow down the development of a charging station from the beginning. Several charging station operators have stated that a grid power map would be beneficial for finding suitable locations and that this would make the process faster. A grid power map to show where there is available power in the grid and where the power is lacking could be developed by governmental institutions together with grid operators.

Gird cost structure

In order to help charging stations break even, a new cost structure for grid power use should be developed for charging stations. The current cost structure is based on peak power use each month even if that use is only reached for a couple of hours per month. Charging stations have a low degree of use and use the grid at a low percentage overall; therefore, a new cost structure more suitable for the use case of charging stations should be developed. This will lower the degree of use needed to be profitable and therefore increase the likelihood of more charging stations.

Adoption

The Swedish government has subsidies HBEV public charging stations but has not focused much on subsidies for HBEVs or private charging stations for haulage firms. It is crucial for the market that haulage firms get incentives to pursue HBEVs. The upfront cost is one of the biggest hindrances for haulage firms to convert their HV to HBEV. They need to buy HBEV that is more expensive than a regular HV and they also need to invest in charging points in order to charge their HBEV over the night. Developing new grid cost structures and regulations about grid development can also have a smaller positive effect on private charging stations and thereby haulage firms that will have their own private charging stations. Subsidies for both HBEVs and private charging stations would lower the upfront cost for HV operators and increase the number of users of HBEVs. A distinction should be made between HBEV transport and HVO transport, where incentives towards HBEV transport would make HBEV transport more valuable for retailers. This is to increase the demand for HBEV transport from retailers and to insentience HV operators to provide HBEV transport.

Interoperability

If every actor develops their own booking system haulage firms need to have the software for every system, this is what several actors want to prevent. The focus has been on the payment system and creating a standard payment system so that haulage firms do not need several different payment systems. The same focus needs to be put on the booking system otherwise the problem will still occur, but for booking systems instead of payment systems. This will favor haulage firms and can positively affect the adoption of HBEVs.

Battery swapping

Battery swapping has many benefits for the development of the TIS and can help with the blocking mechanisms of grid infrastructure, grid cost structure, and adoption, as shown in 4.2. The biggest problem with battery swapping is the lack of legitimation of the technology in the TIS. There is low user demand and inessives from HV manufacturers to develop HBEV with battery swapping capabilities. To increase the legitimation of the technology in the TIS battery swapping tests should be funded. This combined with spreading information about the opportunities with battery swapping will help legitimize battery swapping in the TIS from haulage firms and HV manufacturers. Some actors believe that there needs to be a state-regulated standard for batteries in order for battery swapping to be viable. However, this is not something HV manufacturers want.

5.5 Theory

This thesis has provided three theoretical contributions, the first is the development of the TIS to include recommendations to actors in the TIS. This was provided with recommendations for components in business models that could mitigate the blocking mechanisms. The second theoretical contribution was developing a TIS with a qualitative data collection which was recommended by Bergek (2019). This was done with the focus on business models to further increase the understanding of the different functions in the TIS. The final theoretical contribution was combining the TIS and business models to evaluate and find important components in business models for actors in a new a developing market. This is a new method to understand better the system in which the business models will act. This gives the ability to understand better what different components in business models will be important in new emerging markets where no standard business model is set.

6. Conclusions

6.1 Findings for CPOs business models

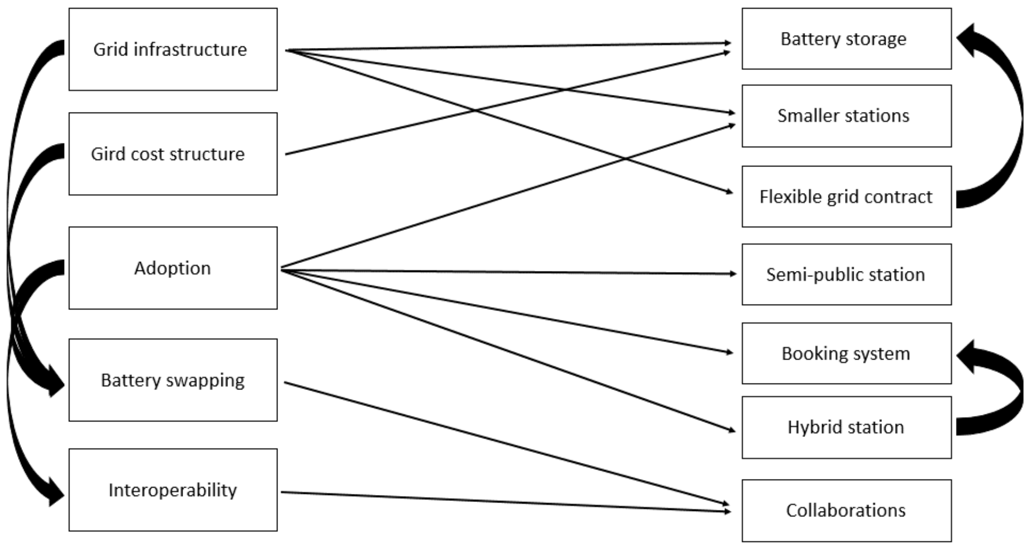

Image 2: Recommendations for CPOs

This thesis has identified five key blocking mechanisms and several components in CPOs business models that can help mitigate these blocking mechanisms. First is the implementation of *battery storage* which will help with *grid infrastructure, grid cost structure,* and with *flexible grid contract. Smaller stations* will both be beneficial for *adoption and* help with lower demand on *grid infrastructure. Flexible grid contracts* can together with *battery storage* lower the demand on the *grid infrastructure* even more without losing the available peak power. *Semi-public stations* will benefit from *adopti*ng HBEV and at the same time increase the degree of use for the stations. Implementation of a *booking system* can both increase the *adoption* and enable *hybrid stations. Hybrid stations* will increase the use case of the charging stations and therefore increase the degree of use, which is the underlying problem for the blocking mechanism *adoption. Collaborations* will help increase *interoperability* and be crucial if a CPO wants to invest in a *battery swapping* station. *Battery swapping* stations do not entirely solve the blocking mechanisms of *grid infrastructure, grid cost structure,* and *adoption.* However, they provide better conditions and lower this blocking mechanism's overall obstacle for CPOs. Finally, *interoperability* will simplify and increase the number of users that can use the charging stations and therefore increase the degree of use, which once again is the underlying problem in *adoption* of CPOs.

6.2 Findings for regulators

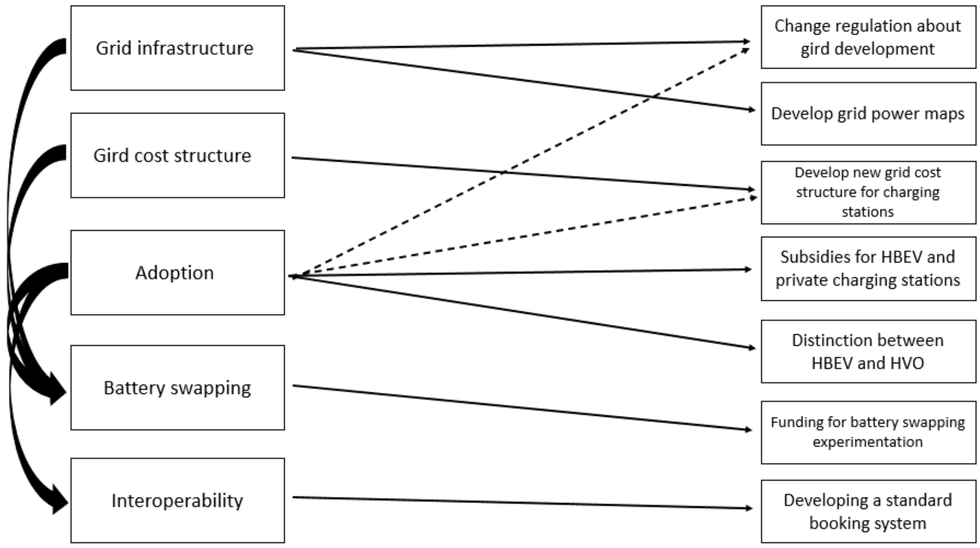

Image 3: Recommendations for regulators.

This thesis has also identified essential components of CPOs business models also identified seven regulatory recommendations that will help the overall TIS develop and grow. Firstly, *change regulations about grid development* so grid operators can build the grid based on predictions. This will significantly help with increasing location with available power, which is the obstacle regarding *grid infrastructure.* This can also be beneficial for haulage firms that own private charging stations and therefore increase *the adoption* of HBEV. *Developing grid power maps* will also help with *grid infrastructure* and increase the speed of finding suitable locations with available power. *Developing a new grid cost structure for charging stations* will lower the cost for CPOs. This will help with the *grid cost structure* that is toady not beneficial for charging stations, especially in the early stage of the market when the overall utilization of the chargers is low. This will also be beneficial for haulers' private chargers and can increase the *adoption* of HBEV. *Subsidies for HBEV and private charging stations* will further increase *the adoption* of HBEVs by lowering the financial burden for haulage firms. *The distinction between HBEV and HVO* transport can further increase the *adoption* of HBEVs, where HBEV transports becomes more profitable than HVO transport for haulers. There needs *funding for battery swapping experimentation* to increase the legitimation for *battery swapping* by showing that the technology work. *Battery swapping* can have, as mentioned in 6.1, mitigating effects on the blocking mechanisms of *adoption, grid cost structure,* and *grid infrastructure. Developing a standard booking system* is essential to building a complete system with *interoperability.* Increased *interoperability* will benefit haulage firms and, therefore, increase the *adoption* of HBEVs.

6.3 Future research

This thesis has combined business models with the TIS literature to better understand the TIS, especially in the functions of market formation and influence of search. However, more research is needed to test and verify that this combination can better understand the functions of the TIS. The combination of TIS and business models is also believed to give a greater understanding of what affects business models for actors in new emerging markets where different business models have not been tested. To honestly know if this statement is correct more research is needed. Both hypotheses can be tested by conducting two separate research studies, one with a traditional approach and one with the one we have conducted. These can then be evaluated to verify if our proposed hypothesis holds up.

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Appendices

Interview questions:

Value proposition:

What service do you provide and with what product? Why do you use this product?

Customer needs:

What are the most important customer needs and how do you deliver these?

Are you providing any extra service? Examples?

Value creation and delivery:

What is needed for you to provide this service?

Are there anything that is blocking these needs?

Are you planning to have editions that create value for you?

Value capture:

How will your payment structure look like?

General:

Will you have any additional revenue streams?

How do you view the government involvement in the HBEV industry?

What is needed for the HBEV market to grow from our perspective?

What are the biggest hurdles for charging operators?

Who do you fell about the other products and its benefits and drawbacks?

Who provides you with information about HBEV?