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SCHOOL OF BUSINESS, ECONOMICS AND LAW

Powering the Future:
Unveiling the challenges associated with planning of charging infrastructure for heavy electric vehicles

A master thesis on the future planning
of heavy charge infrastructure in Sweden

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Abstract

The transport sector is currently transitioning into a more sustainable use of fuel. The current aim of the European Commission is to reduce the greenhouse gas net emissions by 55% by 2030 compared to 1990 levels. Electric trucks are considered an important aspect in this transition. However, the development of charging infrastructure for heavy electric vehicles in Sweden faces challenges associated with large scale investments and long term power grid infrastructure development. This thesis provides a deeper understanding of the challenges through the aspect of institutional theory with a qualitative analysis of different stakeholder experiences. By identifying power dynamics within institutions and regulatory frameworks the reader is provided with essential insights into navigating this challenging landscape. This analysis generates an understanding of how stakeholders are affected by industry norms and political tradition when planning for new heavy vehicle charge infrastructure and an insight to what institutional changes might be necessary in order to meet the demands of the sustainable transition. These findings offer an important outlook on the planning process of heavy vehicle charging infrastructure in Sweden.

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1. Background

The electrification of freight transport has emerged as an environmentally sustainable solution with advantages over traditional transportation methods (González Palencia et al., 2020). Transitioning from fossil fuel-powered trucks to more efficient electric cargo trucks can reduce global-warming pollutants by removing harmful emissions caused by the burning of fossil fuel. Governments around the world are aware that meeting ambitious sustainability targets within transport will require bold and decisive action. An example of this is when, in July 2021, the European Commision proposed several changes for future regulation by law that affects the usage of fossil fuel called Fit For 55 (Gannedal and Wadmark, 2023). This proposal aims to reduce greenhouse gas net emissions by 55% by 2030 compared to 1990 levels, and net emission neutrality by 2050 (Store and Pausch-Homblé, 2023).

The transition into a more sustainable transport sector does not only involve building trucks with batteries. Re-fueling the battery driven trucks will require charge stations adapted for heavy vehicles. These charge stations are in turn connected to the power grid network, supplying the necessary energy to the charge stations (Lindgren, 2021). Between 2021 and 2045, investments in the Swedish power grid network is estimated to reach 668 billion SEK and the demand of the transportation sector is one of the driving factors behind the investments (Krönert and Bergerlind, 2022). Several projects are involved in the power grid network expansion. However, investments of scales such as the power grid development are usually considered mega projects (Flyvbjerg, 2014). Characteristics of the typical mega project is that it overruns budget and lead time schedule, and in order to generate positive outcome from the mega project there is a need for recognition of the economic and societal impact of the project as well as adaptation and organisational learning during the progression of the project (Ansar, 2022).

Research suggests that policy instruments such as subsidies and tax reliefs can be very effective in spurring sustainable growth within the transport industry (Wang et al, 2021). The development of infrastructure for charging electric trucks is progressing in Sweden with multiple projects underway in order to adapt for the Alternative Fuel Infrastructure Regulation (AFIR) that is part

of the Fit For 55 proposals. The AFIR directive is an attempt to increase the volume and density of charge stations available for trucks and cars throughout Europe (European Commission, 2021). The Swedish Transport Administration is investing funds to construct new rapid charging stations designed for larger vehicles like delivery vans, buses, and trucks. These new charging points will allow electric truck drivers to recharge their vehicles in just 20-30 minutes at key locations along major highways (EY, 2020). Private enterprises are also contributing to this growing infrastructure; energy provider Vattenfall and truck manufacturer Scania are cooperating to create a network of electric truck charging stations. According to Person (2021), the placement of charging stations at Scania's manufacturing and logistics facilities, as well as on highways, demonstrates private investment in electric truck charging infrastructure.

The government aims to have all new automobiles sold in the country be electric by 2030; a plan that requires a significant investment from both public and private sectors. To address this issue, various incentives and subsidies have emerged including grants for companies looking into purchasing zero-emission trucks alongside financial aid for constructing charging stations across different locations across Sweden also available through government programs established by the Swedish Energy Agency designed specifically as one pillar part contributing towards aiding reduction of national carbon footprint targets.

According to Hatzigeorgiou (2022), various organisations are working in Sweden with an aim to construct 10,000 electric car and truck charging stations by 2025. This ambitious target is complemented by government programs and private initiatives supporting the electrification of fleets in various sectors. ICA, a prominent grocery retailer, plans to switch all its delivery vehicles to electric power by the end of the decade. Meanwhile, PostNord has already begun to use electric trucks for last-mile deliveries (Volvo Trucks, 2021). These developments collectively signal Sweden's pursuit of a sustainable transportation system through infrastructure investments. According to Pettersson et al (2017), this collaborative work is necessary in order to provide charge infrastructure solutions for the nation. However, despite progress in expanding charging infrastructure, challenges still arise throughout the planning process that require coordination between many stakeholders.

1.1 Problem Analysis

With increasing urgency around reducing carbon emissions and tackling climate change globally, transitioning towards sustainable transportation has become essential. Planning for a reliable infrastructure network for charging these types of vehicles presents numerous challenges that need attention.

Planning for optimal location of charging stations is complex with various factors such as trucking routes, access to electrical networks, and land use coming into play. Lam, Yiu-Wing Leung,and Xiaowen Chu (2014) highlights how vital it is to plan before facilitating any electrification transformation by carefully considering location, ensuring they are optimal. In order to plan for these new locations, data regarding traffic and route planning would be beneficial. However, few companies share such data due to the information being considered sensitive business information (Swahn, Wallinder and Strömberg, 2019).

There is a lack of standardisation when it comes to electric truck charging methods and suppliers might hinder the effectiveness and user friendliness of the charging network. Diverse cost protocols and suppliers must work together seamlessly - this is where standards play a crucial role (Altaleb and Rajnai 2020).

The Swedish power grid operators can operate on three different levels of hierarchy and operate different parts of the power grid network (Nordling, 2016). However, the application process associated with connecting to the power grid network can take months and applications to the wrong hierarchical level can lead to a major additional increase in lead times (Svenska Kraftnät, 2023). Communication between different levels of power grid operators and from the power grid operators to external stakeholders is scarce and many stakeholders, such as logistics service providers, testifies about lack of guidelines for applying (Tenggren et al., 2016). The new Fit for 55 proposal and AFIR directives pressures rapid development of the green transition within the transport sector (Kågeson et al., 2022), however the administration of the charge infrastructure development remains in a slow procedural framework (Tenggren et al., 2016; Svenska Kraftnät, 2023).

Many stakeholders are involved in the sustainable transition of the transport sector (Nordling, 2016) and each project, originating from the demand of a logistics company or otherwise, affects the power grid network (IVA, 2020). Every project is contributing to the development of the power grid network and every project is affected by the rules and traditions connected to the power grid development. The projects that expand upon and reinforce the power grid network resemble a typical mega project structure (Flyvbjerg, 2014) and could therefore suffer the same challenges as a typical mega project would.

Rules and traditions regarding administration of the power grid network development (Tenggren et al., 2016), as well as norms associated with sharing of data (Swahn, Wallinder and Strömberg, 2019), have an impact on the sustainable transition of the transport sector. Institutional theory suggests that the rules, norms and traditions shape the stakeholder interactions (Willmott, 2010). In order to reduce the challenges associated with the institutional aspect of planning charge infrastructure an understanding of these paradigms is necessary (Staffan Furusten, 2013).

1.2 Purpose

To facilitate the sustainable transition for different charge infrastructure stakeholders that come together in developing electric trucks charging stations across Sweden, this thesis will provide a deeper understanding on how to plan for heavy vehicle charge infrastructure. By recognising obstacles connected to planning new charge infrastructure, and identifying the institutional paradigms, norms and traditions that influence interactions between different actors, it is hoped that future planning of heavy vehicle charge infrastructure can be improved.

Purpose:
The purpose of this report is to identify the main challenges of planning new charge infrastructure for heavy vehicles
and
to understand what actions could be taken to overcome the main challenges of planning new charge infrastructure for heavy vehicles.

1.3 Research Questions

In order to fulfil the purpose of the report, the research group will answer the following **research question**:

- How is the planning of new heavy vehicle charge infrastructure in Sweden affected by the current institutional paradigms?

By researching the following sub-research questions:

1. What are the main challenges in planning charge infrastructure for heavy vehicles in Sweden?
2. What institutional paradigm shift could have the greatest effect on reducing the impact of the challenges?

2. Frame of reference

2.1 Interaction between different levels of organisation

Theoretical views and frameworks from a variety of disciplines may be used to analyse the planning process for the placement of large electric truck charging stations from the perspective of various Swedish stakeholders. Below is an illustration of the theoretical framework Institutional theory applied within this report.

2.1.1 Institutional theory as a framework

2.1.1.1 Importance of choosing one framework

The need for having one theoretical framework when examining interviews and analysing the situation contains several critical points.

Firstly, with a focused direction provided by such a framework, researchers gain more clarity in identifying and addressing their research question comprehensively. Secondly, this approach promotes coherence across various data sources throughout the planning process under scrutiny, ensuring that all pertinent information is used correctly while avoiding fragmented analyses (Huijg et al., 2014).

The utilisation of a singular theoretical framework is instrumental in facilitating comparisons with the existing research. By leveraging on established knowledge, we can make significant contributions towards enhancing the theoretical comprehension of electric truck charging infrastructure planning and development, which is vital due to its complexity and dynamic nature.

Nonetheless, it's crucial to acknowledge that theories are not infallible, and each has its advantages and disadvantages (Green, 2014). In some circumstances, an individual theoretical perspective may fall short in providing a comprehensive analysis of the planning process; hence multiple perspectives may be required. In evaluating the theoretical framework for our research on electric truck charging infrastructure, it is crucial to critically analyse its appropriateness and adaptability.

Incorporating supplementary theoretical perspectives becomes necessary if they help us answer our research question effectively (Green, 2014). Fundamentally, it is imperative to identify the most suitable theoretical framework that helps us comprehend the development and deployment of electric vehicle charging infrastructure better (Huijg et al., 2014).

2.1.1.2 Institutional theory as a way to understand planning

Institutional theory is a valuable tool for analysing the planning of electric truck charging infrastructure in Sweden due to its capacity to provide a robust analytical framework that acknowledges the intricate interplay among formal rules and regulations, informal norms and beliefs, and historical legacies that shape planning processes. Given this perspective, institutional theory offers insight into identifying actors, interests, and power dynamics that influence decision-making in specific institutional contexts. Institutional theory provides insight into the multifaceted nature of electric truck charging infrastructure planning (Zilber, 2011).

National and local regulations exert significant influence over the development of this type of infrastructure, with some policies acting as catalysts for its growth while others may impose barriers to installation through restrictions on location. Nevertheless, institutional norms and beliefs should not be overlooked when analysing the planning process. A range of norms and beliefs can emerge from the perspectives, values, and experiences of different stakeholders engaged in transportation planning (Staffan Furusten, 2013), including fleet operators, power grid operators, and truck manufacturers. Institutional theory offers a way to examine these informal institutional norms and beliefs by identifying potential interests as well as power dynamics. Furthermore, institutional theory recognizes that institutions possess a dynamic nature that evolves over time. The emergence of electric truck charging infrastructure has heightened the relevance of institutional theory due to the field's rapid evolution. Through the application of institutional theory, we can identify how institutions adapt to new policies, technologies, and market forces which is highly relevant in the context of sustainable transitions.

However, institutional theory is limited in its focus on macro-level factors that drive institutional arrangements such as formal rules and historical legacies. Although undoubtedly important, these factors may not fully capture the aspects of local-level planning processes in making decisions related to charging infrastructure. Moreover, institutional theory has its limitations, particularly its

descriptive nature. It can explain why things are the way they are but may not provide sufficient guidance on how to change them (Wang, Tseng and Yen, 2014). While it can identify institutional barriers and challenges hindering electric truck charging infrastructure development, it may not offer a clear roadmap for surmounting such barriers effectively. Hence, the limitations in terms of its macro-level focus and descriptive approach. By recognizing these weaknesses, planners could understand better the obstacles they encounter and come up with suitable solutions (Willmott, 2014).

2.1.2 Institutional theory

According to institutional theory, both formal and informal rules, norms, and values influence organisations and institutions. The framework could look at how institutional elements including institutional logics, practices, and cultures affect how electric truck charging infrastructure is planned and put in place at various levels of government in Sweden. This may entail looking at the various institutional logics that shape the institutions and organisations involved in the planning and development of charging infrastructure (such as transportation agencies, energy companies, and local governments), as well as how these logics impact the planning and implementation process. The framework may also look at how institutional elements like policy networks, policy feedback, and policy learning affect the policy environment (Rainer Lepsius, 2018).

Institutional theory offers insights into the various factors that shape the development and implementation of electric truck charging infrastructure in Sweden. Formal institutional forces, such as regulations, policies, and laws enforced by the Swedish government play a significant role in driving planning decisions related to renewable energy sources, climate change mitigation strategies and transport policy (Spiller, 2008).

The establishment of formal rules can have a significant impact on the installation, operation, and maintenance of electric truck charging stations. These rules may prescribe incentives or mandates for compliance, and thereby affect infrastructure development. In addition to these formal requirements, the role of social norms, cultural values, and stakeholder beliefs cannot be overlooked in shaping planning decisions for electric truck charging infrastructure (Staffan Furusten, 2013).

In Sweden, societal emphasis on sustainability and environmental protection is strong and underscores the importance of innovative solutions such as electric truck charging. Stakeholders play a significant role in determining the feasibility and acceptance of electric truck charging infrastructure. The adoption or resistance towards planning decisions is largely based on stakeholders' perceptions of societal norms and expectations (Willmott, 2010).

Planning decisions and the public acceptance of renewable energy can be influenced by informal norms and beliefs, including societal attitudes towards this source of energy as well as perceptions about its potential impacts. The public acceptance of renewable energy can be influenced by informal norms and beliefs, including societal attitudes towards this source of energy as well as perceptions about its potential impacts (Staffan Furusten, 2013). When planning renewable energy infrastructure in particular, policies from governing bodies and incentives can have a great impact on location selection and design choices (Willmott, 2010).

The institutional theory considers the power dynamics among stakeholder groups that influence these decisions. In this regard, certain stakeholders may have more power and influence as compared to others, leading to varying impacts on the overall planning process (Spiller, 2008). Additionally, power dynamics between stakeholders such as utility companies, developers of renewable energy sources, and local communities also play a role in shaping planning outcomes (Willmott, 2010).

The consideration of stakeholders' interests and power dynamics is crucial in illuminating planning decisions and outcomes. The theory of institutionalism proposes that historical circumstances and path dependencies should also be taken into account when designing electric truck charging infrastructure (Spiller, 2008).

Thus, Sweden's existing transportation systems, technological capabilities, and regulatory frameworks can significantly affect the selection of charging options during the planning process. Swedish electric truck charging infrastructure planning process can be well understood with institutional theory that offers a comprehensive framework. It considers formal and informal rules, social norms, power dynamics as well as historical legacies in assessing the planning decisions and overall outcomes (Willmott, 2010).

Therefore, incorporating the institutional theory aspect can help planners and policymakers effectively navigate the complexities of developing a sustainable and effective electric truck charging infrastructure.

2.1.3 Institutional theory and the Nordic context

The Swedish grid development strategy is grounded in the adoption of sustainable energy development policies to lessen carbon emissions due to global and regional environmental pressures. Sweden has set an outstanding target for renewable energy production, striving to achieve 100% renewable electricity generation by the year 2040 (Sataøen et al., 2015).

A comparative analysis of Norway and Sweden's grid development regimes reveals that the policies and practices are greatly influenced by power dynamics among stakeholders such as government agencies, traditional energy industries, and environmental groups. By using the institutional framework for examining grid development regimes from a societal perspective and analysing the influence of power dynamics between stakeholders policymakers and other involved parties can better understand the broader societal factors that shape energy policies and practices, as well as create effective strategies to achieve sustainable energy development (Sataøen et al., 2015).

Similarly in transportation infrastructure planning, formal regulations related to funding and operating public transportation may influence location and design decision-making processes (Spiller, 2008). Furthermore, informal beliefs tied to cultural attitudes around public transportation may sway how people feel about it. The planning process and outcomes of sustainable urban infrastructure are affected by power dynamics among stakeholders, which can include government agencies, transit agencies, and local communities (Staffan Furusten, 2013).

Regulations related to zoning, building codes and urban planning have the potential to influence decisions regarding the inclusion of sustainable features in urban infrastructure (Sorsa, 2008). Similarly, informal values and norms revolving around sustainability, environmental protection and livability can also shape planning decisions while impacting public acceptance. Understanding how different institutional factors shape infrastructure development is vital for effective planning as it enables planners and policymakers to make better-informed decisions (Willems et al., 2018).

Institutional theory offers a comprehensive framework which analyses formal and informal rules, norms, beliefs, power dynamics, and historical legacies that influence the planning process of infrastructures in addition to providing an understanding of these complexities and challenges associated with infrastructure planning (Willmott, 2010).

2.1.4 Key institutional aspects for this study

From figure 1 we can comprehend that there are many stakeholders involved in developing charging infrastructure - from power grid operators to transportation companies - all governed by formal and informal institutions shaping their interactions through rules and relationships. This is known as an institutional arrangement (Willmott, 2010). Norms also play an important role: they represent shared beliefs about what's expected from behaviours within certain contexts; while practices are the routine behaviours that say what's acceptable. Understanding these helps anticipate any potential barriers or conflicts when introducing new infrastructure (Staffan Furusten, 2013).

Different institutional pressures impact stakeholders involved in the planning process. Coercive forces come from regulatory bodies that require certain behaviour; normative from industry standards that inform certain practices; mimetic from those who imitate successful strategies; and social expectations at large. An analysis of stakeholders revealed that power dynamics play an influential role in the planning process (Rainer Lepsius, 2018).

Figure 1 (key institutional aspects)

Power refers to actors' ability to affect outcomes and mould their surroundings within institutions. These power imbalances can directly affect resource allocation and decision-making for charging infrastructure development, impacting how benefits and costs are distributed. Careful examination of these dynamics helps identify conflicts of interest while facilitating collaboration and negotiation among all parties (Spiller, 2008).

2.2 Power grid mega project

The Swedish investments in power grid infrastructure 2016 was 13,4 billion SEK with a total replacement value of infrastructure being 400 billion SEK (Nordling, 2016). It is also estimated that 668 billion SEK will be invested into the power grid between the years of 2021 and 2045 out of which 53% will be in the form of re-investments (Krönert and Bergerlind, 2022).

The development of the power grid network is crucial for many industries, including the transport sector (Krönert and Bergerlind, 2022). Considering the long lead times connected with power grid construction and the amount of money the investments will cost, one could regard the development of the Swedish power grid as a mega project. A mega project is typically defined by the cost of the project reaching over approximately 10 billion SEK (1 billion USD) but the scale of the project, the complexity and the timeframe is normally at an amplified level in comparison to a traditional project. Whereas mega projects usually are of individual nature, such as the construction of the channel tunnel between the United Kingdom and France, there is often a multi-level dimension where many project managers and stakeholders are involved in separate parts of the project in different levels of hierarchy (Flyvbjerg, 2014) similar to the structure of the Swedish power grid operators and users (Arbetsgruppen Transportsystem IVA, 2019).

If the development of the power grid network is to be considered a mega project, statistics show that the monetary costs of the investments are likely underestimated, the benefits of the investments overestimated and that there is a very high potential in delays (Flyvbjerg, 2014). However, there are recent studies that show that adopting a platform-type strategy to a mega project, instead of the traditional bespoke strategy, can benefit the outcome greatly by the adaptive and absorptive nature of the strategy. Namely, by re-evaluating the road-map to the goal of the project with new knowledge, data and information as well as establishing the new knowledge as

rules for operation, rather than committing and potentially over committing to a pre-established plan, projects are more likely reach the set goal within the time-frame and minimise delays and budget cost overruns (Ansar and Flyvbjerg, 2022).

The sustainable transition is a structural transformation with particular characteristic features to that of a mega project. New innovation and research show that to increase the chance of positive societal outcomes in these types of projects there is a necessity to recognise the impact of the project in terms of long term large scale economic investments, the social and economical importance of the project and finally the importance of adaptation and acting on new information during the lifespan of the project with strategies such as or similar to the platform development strategy (Ansar, 2022).

2.3 Swedish power grid

In order for the electronic truck recharge infrastructure development to follow demand there is great need for consensus among stakeholders regarding how the investment and planning process needs to proceed. In spite of the national strategy put in place in 2018 (Trafikanalys, 2021), there is no clear direction for how to expand the Swedish recharge stations and the current driving force behind expansion is split between municipalities, private companies, private individuals and energy businesses. The need for planning of future electric network spikes and other infrastructure challenges such as local, regional and national electric network capacity demand forecasting is of high priority in order for the transition into electric vehicles to happen (Arbetsgruppen Transportsystem IVA, 2019).

In order to receive permission for new power grid installations and improvements, there are permit processes that need to happen. The time before a permit process is complete is highly unpredictable and often stretches over long periods of time. For smaller additions to the power grid the planning process is typically shorter and quicker whereas bigger and more conventional power plant planning is typically very slow (Nordling, 2016). This creates difficulties in regards to long term planning for the power grid capacity planning because smaller projects like small solar cell parks have a much shorter lifespan than power grid infrastructure. With a planning deviation in terms of short term demand and long term capacity, the network infrastructure planning becomes more

challenging. In addition, the increase in different types of network demands such as home owners producing solar electricity, as well as infrastructure parks for charging vehicles with temporary electricity demand spikes similar to that of a small city (Conzade, 2022), calls for a more efficient, more thorough and swifter planning and execution process on all levels of state (Nordling, 2016).

2.3.1 Power grid organisation

Sweden's power grid organisation includes the transmission system operator (TSO) of Svensk Elkraft, regional system operators and local system operators, both being defined as distribution system operators (DSOs). Svensk Elkraft has the monopoly and final responsibility of the functionality of the national high power electric transmission network. The regional system operators consist mainly of three organisations called Vattenfall, Eon and Ellevio whereas the local distributors are 170 energy companies out of which 129 are controlled by the municipalities. The TSO operates the main power lines transporting great amounts of electricity at very low loss rate across long distances, whereas the DSOs further distribute the energy regionally and finally on a local level (Nordling, 2016).

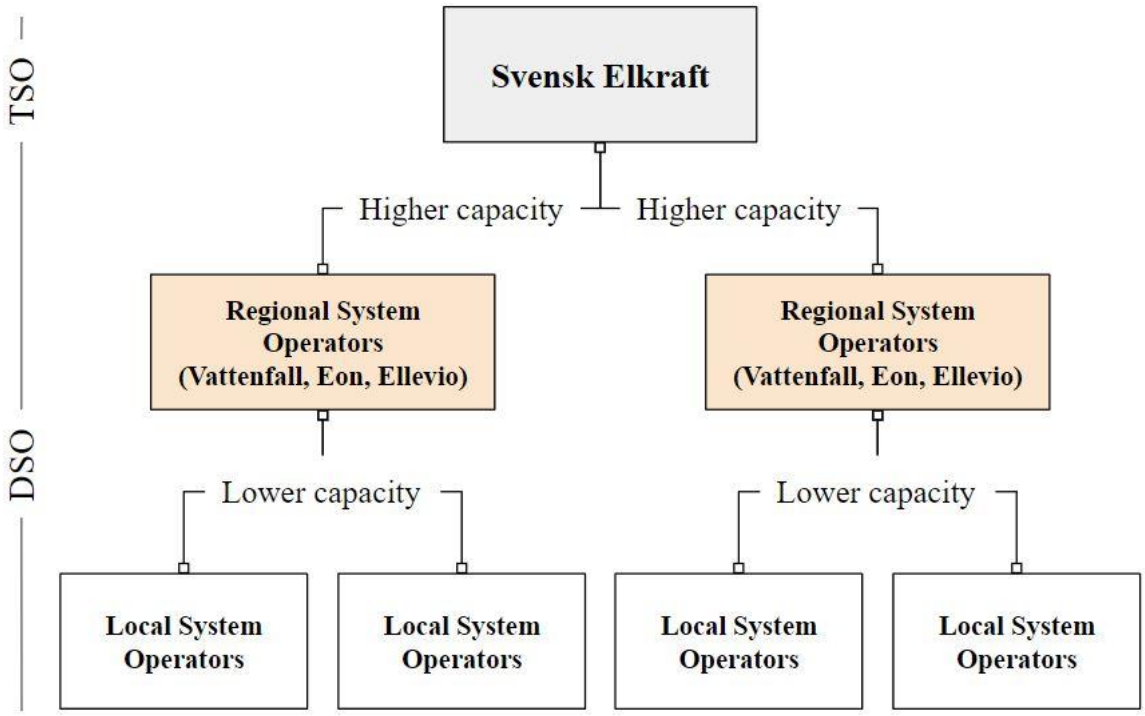

Figure 2: Network operator hierarchy based on Nordling (2016)

2.3.2 Power grid capacity

Most new charge stations for electric vehicles are expected to be constructed in close proximity to highly developed power grid infrastructure in and around cities (Lindgren, 2021). However, fast charger parks in connection to highways with capacity for 20 heavy vehicles and 10 cars would resemble a momentaneous impact on the power grid of 20 megawatts (20 000 kilowatts), like that of a city with 20 000 inhabitants. Such a demand for electricity could require additional investments in the high voltage transmission systems, and in the least additional investigations during feasibility screenings. In Stockholm, the average installation time for a direct current fast charger is seven months (Conzade, 2022). The new EU directive AFIR regarding new charge installations along the Trans-European Transport Network (TEN-T) specify a 3500 kwh capacity every 60 km along the main roads and every 1600 kwh every 100 km along connecting roads (European Commission, 2021).

Figure 3 (European Commission, 2023): Map of TEN-T road network in northern Europe.

These directives does not specify how countries such as Sweden with a low population density (i.e 57 per square kilometre in the Götaland area and 52 per square kilometre in the Svealand area, the two most densely populated regions in Sweden, compared to 130 and 227 in Denmark and Germany), and instances of more than 100 km in between villages with less than 500 people should act regarding new constructions on the national high capacity transmission network required to supply the regulated charge station density (Kågeson et al., 2022). These directives provide a baseline on investments for charge infrastructure, however, power grid operators have little knowledge on charging behaviour of trucks making demand-based planning of charge infrastructure difficult (Conzade, 2022).

2.3.3 Planning of logistics charge stations

Guidelines and directives regarding planning of charge infrastructure are in place on a multinational level (Kågeson et al., 2022), however, the large volumes of charge stations and the request for haste in the sustainable energy transition does not match the long term perspective of the transmission grid development (Tenggren et al., 2016). As of 2019, a total of 2.6 terawatt hours (TWh) was used within the transport sector. In 2045 there is an estimated demand of 25 TWh, out of which 15-20 TWh is generated by road vehicles alone (Arbetsgruppen Transportsystem IVA, 2019). Constructing new power grid infrastructure is normally very costly, and is typically funded by state finances (IVA, 2020). Nonetheless, the technical lifespan of power grid investments are estimated to be approximately 40 years whereas the lifespan of the smaller investments such as charge stations are considerably shorter (Nordling, 2016).

The level of ambition of the Swedish government's power grid investments is unclear and in spite of national goals being in place there are few binding targets on volumes passed by the government (Tenggren et al., 2016). Recent investigations on a strategy to increase the flexibility within the Svenska Kraftnät organisation has concluded that the applications for connecting to either the local grid network, regional grid network or the transmission network are often delayed due to actors applying to connect on the wrong network level. In addition to that, lack of communication between the network operators results in delays and rejections of applications. It is estimated that the administration of many applications could have been resolved by correcting the application to the actual demand of the applicant. An applicant applying to connect to the wrong level of power

grid network for their project could be forwarded to the correct power grid operator instead of rejected or delayed (Svenska Kraftnät, 2023). The lack of communication is also causing confusion about how the application procedure should be administered generating many mistakes and even longer application processes, with data showing that the problem resides not in the application process itself but rather in the lack of guidelines and legal precedents (Tenggren et al., 2016). The Swedish municipalities have a monopoly on detail planning of the new infrastructure developments and can delay new investments if they are not aligned with local plans. Investments of a bigger scale can be delayed in several municipalities simultaneously unless preparatory negotiations are conducted in advance of the final government application (Sataøen, Hogne Lerøy et al., 2015) which further escalates the need for clear communication channels.

Commercial actors are driving the development of the Swedish power grid generating a two-way uncertainty both in terms of long term planning of the transmission grid monopoly from the side of the government but also in regards to how the geographical and technological investments will continue due to the shifting interests of the private sector (Tenggren et al., 2016). However, the data regarding logistics flows is often considered sensitive information for private logistics companies (Swahn, Wallinder and Strömberg, 2019). Considering that data-sharing of logistics flows and improved inter-organisational stakeholder communication are essential for enabling efficient strategies for planning of new charge infrastructure (IVA, 2020; Svenska Kraftnät, 2023; Swahn, Wallinder and Strömberg, 2019; Kågeson et al., 2022), providing practical solutions for these issues is a key element for the success of the strategies. Whereas some individual organisations strive to develop and adapt strategies for infrastructure investment flexibility (Svenska Kraftnät, 2023) there is a possibility that a more clear national strategy is necessary to increase the efficiency of the infrastructure development on a large scale, rather than within individual organisations.

2.3.4 National goods transportations strategy

A national goods transportation strategy for Sweden was developed in 2018 (Arbetsgruppen Transportsystem IVA, 2019). The section regarding charge infrastructure development for heavy road vehicles, the transport mode contributing to 90% of the total volume of goods transported domestically in 2016, states that there is a need for a demand analysis to be conducted in the future

(Regeringskansliet, 2018). The analysis estimates that energy availability for truck charge infrastructure will not be a problem, and that the power capacity is relatively easy to scale in parallel with demand of capacity. It is estimated that most of the infrastructure demand will be depot charge stations in locations with good accessibility to the grid network, and that local and regional infrastructure availability might be unavailable initially (Lindgren, 2021). Although there are mentions of depot charging (Trafikanalys, 2021), there are no mentions of how to strategically address the issue of fast charge infrastructure along main roads.

If the electronic truck recharge infrastructure development is to follow demand there is great need for consensus among stakeholders regarding how the investment and planning process needs to proceed. Currently, there is no clear national strategy for how to expand the Swedish recharge stations and the current driving force behind expansion is split between municipalities, private companies, private individuals and energy businesses. The need for planning of future electric network spikes and other infrastructure challenges such as local, regional and national electric network capacity demand forecasting is of high priority in order for the transition into electric vehicles to happen (Arbetsgruppen Transportsystem IVA, 2019).

In July 2021 the European commission proposed a climate package called Fit For 55 that included several proposals for future regulation of fossil fuel usage (Gannedal and Wadmark, 2023). Included in this proposal is the AFIR directive that aims to improve charge infrastructure availability for trucks and cars along main road networks (European Commission, 2021). The goal with AFIR is to enable legislation on the electrification of the road transport within the EU, and the goal with Fit For 55 proposal is to create legislative precedence on the green transition for the EU including within the transport sector (Store and Pausch-Homblé, 2023). These proposals create challenges for the heavy charge infrastructure development (Kågeson et al., 2022), but also increase the legal pressure on the EU national governments, including the government of Sweden, to politically encourage the national charge infrastructure and power grid developments.

3. Methodology

By researching the challenges connected to developing and planning the infrastructure necessary for the logistics sector to meet the very urgent need of green technology adaptation with a focus on Sweden, the research group is navigating a field of limited previous research. Whereas there are many reports connected to technological development, emissions calculations and economical potential of the implementation of electrified road vehicle fleets, there are sparse amounts of literature addressing and aggregating challenges regarding the multi-stakeholder planning processes within the aspect of the electrical grid infrastructure and charge stations development efforts.

3.1 Research Design

This **exploratory** study aims to create a deeper understanding of the challenges that are connected to the planning of new charge infrastructure for heavy road vehicles and how to approach said challenges. In order to create this understanding, a qualitative research method will be employed. When conducting qualitative interviews the research group will have the opportunity to receive concrete examples of challenges, but also the individual perspective of the challenge as well as reflections as to why the challenge exists and what could be done to reduce the impact of said challenge. The research group can ask follow-up questions and have the interviewee reflect upon the topic with personal experiences and views which in turn creates a nuanced depiction of a complex topic (Yin, 2010). With a combination of the aspects of several stakeholders, the research group hopes to achieve a deeper level of understanding of challenges connected to the topic.

By gathering information from previous research in planning of charge infrastructure in areas connected to logistics, the research group will create a suitable interview guide and conduct interviews with relevant individuals in different stakeholder organisations. The research group will then analyse the results from the interviews with a frame of reference consisting of reports and directives as well as an institutionalist aspect on the Swedish charge infrastructure development. With the insight from the interviews, the research group hopes to identify gaps and similarities between the existing material and the aspects of the interviewees and contribute with new ideas to

progress within the field of challenges within planning of heavy vehicle charging infrastructure as is associated with the exploratory approach (Bell et al., 2019).

3.2 Case study

Considering the urgency connected with the topic of electrification and the limited research available in the specific area of this report, the exploratory **case study** format is particularly suitable (Collis and Hussey, 2013). The research group conducted a case study investigating relevant stakeholders within the planning of charge infrastructure for heavy vehicles. The research team aims to understand the challenges connected to planning the relevant infrastructure within the natural context of the phenomenon. The organisation of the power grid administrators is a setting of which the contemporary problem of electric vehicle transition is highly relevant, and a research topic where the writers of the report aspires to provide new insights in line with case study methodology (Collis and Hussey, 2013).

In order to reach a deeper level of understanding, the research format of case study is beneficial (Flyvbjerg, 2006). Whereas some researchers regard results of case studies non-generalisable (Bell et al., 2019) there is also the opinion that it is the nature of the case-study that determines if the result is applicable in a general perspective or not (Flyvbjerg, 2006). In this report, the case study is directed on a specific target group directly involved in planning of charge infrastructure for heavy vehicles. In terms of generalisability, the research group hopes to identify challenges and potential solutions that results in beneficial information for many different stakeholders attached to the planning of aforementioned infrastructure. Whereas the breadth of the research is not sufficient to confirm that the results from the research benefits the entire target group, one could argue that if the challenges and solutions presented in the report are highly relevant for the participating stakeholders then it is very likely that the same information is relevant for many stakeholders in said target group (Flyvbjerg, 2006).

3.3 Data collection

In order to create a deeper understanding of the challenges for Swedish power grid stakeholders, **interviews** with relevant actors were conducted to generate primary data. These interviews were

semi-structured, enabling the research group to achieve additional exploration of the subject with the use of follow up questions without diverting from the core topic (Bell, Bryman and Harley, 2019). The potential interviewees have been identified and contacted based on participating in reports and projects such as the IVA (2020) report *Resurseffektiv transport och mobilitet i Sverige* and Ättekulla truck charge infrastructure project in Helsingborg (Skoglund and Lundblad, 2021). Recommendations did also occur, where the researchers got the contact information to a potential interview object through the recommendation of an interviewee or person of initial contact. Thus the gathering of respondents followed a purposive sampling process where the research group contacted stakeholders deemed relevant to the research topic (Bell, Bryman and Harley, 2019).

In order to generate an interview guide, a framework of secondary data, in the form of previous research and reports as well as other relevant information from news articles and documents, will be established through a literature review. The peer-reviewed academic articles are accessed mainly through the University of Gothenburg library database through the library search engine Supersök. The information gathered for the frame of reference that are not peer-reviewed academic articles are reports and analytics ordered or conducted by governmental organisations and research institutes.

3.3.1 Ethical considerations

In order to respect the integrity of the interview objects (Brennen, 2012) the research group has anonymised the interviewees entirely. Since this report aimed to research individual experiences and aspects, the decision to anonymise was made in order to make the interviewees feel that there would be no direct association between the personal answers and the respective organisations.

3.3.2 Interviews

In order to generate a deeper understanding of the challenges involved in the planning of new charge infrastructure the research group contacted interview objects with roles in organisations relevant for planning of charge- and power grid infrastructure. Due to the complexity of the research topic and limited advance information regarding interviewee roles, some people contacted might have been less relevant for the research project. The purposive sampling method might result in this type of problem due to the subjective nature in which the interviewees are selected (Bell,

Bryman and Harley, 2019). However, we only received two declinations due to anticipated lack of relevant contribution where the contacted interviewees judged themselves insufficiently experienced or knowledgable in the subject.

Initially the research group intended to receive many different perspectives on the planning process for heavy charge vehicles from different stakeholders. Nonetheless, due to the response rate the scope shifted into mainly the perspectives from regional and local power grid operators.

In spite of receiving responses and even in some cases booked interview sessions with several contacts, some of the contacts either cancelled or simply stopped responding. The research group found that the best way to make contact with the potential interview objects was to call the person directly or colleagues of the intended interview object and send reminders via mail. Some contacts received through recommendations did cancel or simply not attend the interview, however, the group found that recommendations was the most successful way of receiving interviews.

The initial interview served as a pilot interview and the interview object was informed that we would appreciate feedback after and during the interview regarding structure and content. By having the pilot interview the research group could test and make sure that the questions asked was pertinent and answerable for the intended stakeholders (Bell, Bryman and Harley, 2019). After the pilot interview, the interview guide remained similar to its original form but some questions were slightly adapted to be more relevant to the specific role of the interviewee during the interview sessions, without diverting from the topic of the question.

All of the interviews except for one were conducted with online meetings with webcams turned on. This allowed for a flexible scheduling where participants could join from respective offices without being located in the same area of Gothenburg or in some cases in different cities. By having webcams turned on the authers and the participants had the benefit of being able to use body language to communicate more freely, in order to avoid misunderstandings (Yin, 2010). The last interview with a researcher from a research institute consisted of written questions and answers via mail with a follow up session over phone, still obtaining the benefits from a semi-structured interview by getting to ask follow up questions after the initial written responses.

Category	Requests	Type of contact	Responses	Interviews
Local power grid operator	9	Mail, LinkedIn, Phone, Recommendation	6	5
Regional power grid operator	12	Mail, LinkedIn, Phone, Recommendation	4	3
Transmission grid operator	7	Mail, Phone	1	0
Research Institute	8	Mail, LinkedIn, Phone	1	1
Manufacturer	5	Mail, Phone, Recommendation	2	1
Transport	5	Mail, LinkedIn	1	0
Regional government	6	Mail, Phone	0	0
Local government	3	Mail, Phone	2	0
Total:	***55***		***17***	***10***
Rate of total:			***30.9%***	***18.2%***

Table 1: List of requests and conducted interviews

3.4 Data analysis

In order to structure and analyse the data gathered through interviews, the authors have adopted a thematic analysis method. This method is widely used in analysis of qualitative data and enables the researcher to process the vast amounts of data that qualitative methods often generate. One way to identify relevant themes is to reflect on the key categories connected to the research questions (Bell, Bryman and Harley, 2019). In this report, the key categories that are the focus of the interview guide have been derived from the frame of reference. For example, the question "*How would a client share necessary data/information with you? Could you use that data outside the project?"* is a result of the information Swahn, Waillinder and Strömberg (2019) provides regarding logistics companies treating data as a business secret as well as other reports, presented in chapter 2.3.3, viewing data sharing as essential in order to plan charge stations for electrified

vehicle fleets (IVA, 2020; Svenska Kraftnät, 2023; Swahn, Wallinder and Strömberg, 2019; Kågeson et al., 2022).

The themes have then been identified by the research group assessing the most commonly raised topics in the answers from the interviewees. In order to ensure the presence of institutional theory aspect in the analysis, an additional guide (Appendix B) was created and used by the research group when evaluating both the interview guide and the answers. The content of Appendix B are the key categories of the institutional theory chapter 2.1. With this approach, the risk of conflating the interview guide with the topic of institutional theory, which is not a specific topic of expertise for any of our interviewees, was evaded without losing the potential of analysing the answers from the interviewees through the lens of institutional theory.

3.5 Research Quality

The research quality of this thesis is measured by its adherence to the principles of validity and reliability - key factors that ensure a trustworthy and credible study.

In qualitative research, reliability refers to the consistency of findings despite different circumstances (Roberts & Priest, 2006). This thesis covers external and internal reliabilities.

The former assesses the replicability of research under different conditions which can be challenging when employing semi-structured interviews (LeCompte and Goetz, 1982). However, utilising standardised interview guides and highlighting relevant questions enhance external reliability in this thesis. The study's sample size may be a limitation as it is relatively small. This fact might restrict the generalizability of the findings despite efforts to include participants from various industries. It is important to note that the findings may not fully encompass the perspectives and experiences of all stakeholders involved in planning charge infrastructure for heavy vehicles in Sweden. The latter dimension evaluates observer (Interviewers) agreement regarding their observations (Bryman & Bell, 2011). In order to maintain internal reliability and avoid any biases, both researchers actively participated in every interview while also listening to recordings several times over. This helped them gain a comprehensive understanding of their data while promoting continuous discussions that eventually led them towards reaching a consensus on their analysis

results.. However qualitative data interpretation is subjective and subject to bias from both researchers and participants. Thus introducing a degree of uncertainty and potential for misinterpretation.

Implementing structured data analysis techniques including use of a singular framework to analyse the finding to secure reliability further. Lastly, members checked the research findings eliciting feedback from participants to determine accurate reflections.

In addition, they employed an objective approach through thematic methods that further increased internal reliability and credibility.

Maxwell (2013) defined validity as the degree of accuracy or dependability presented within any given study's account, conclusion, interpretation or explanation. In terms of this research project, it is necessary to address both internal and external validity. Internal validity considers how well observations align with generated theory or results (Bryman & Bell, 2011), which was guaranteed by employing star-marked questions in the interview guide that allowed for consistent treatment of samples as groups rather than focusing solely on individual components.

By aligning data with the developed theory, this thesis reinforces the consistency between research conclusions and observations. To minimise bias in transcription and analysis processes while ensuring comprehensive accuracy in interview representations, both authors were involved.

As such, internal validity is enhanced considerably. Generalisability across diverse social settings is determined by external validity (Bryman & Bell., 2011). Qualitative research methods may be limited by small sample sizes that reduce generalizability (LeCompte & Goetz.,1982). However, by incorporating interviewees from various stakeholder groups into our study's design we have attempted to address these limitations partially thereby strengthening potential generalizability of findings to some extent. Additionally, our investigation aims to explore reasons behind observed gaps between claimed sustainability potentials and actual implementation/planning with reference to cases as a group rather than individually examined ones allowing us to identify similarities as well as frequency which further strengthens generalisation.

It is important to note that the findings may not fully encompass the perspectives and experiences of all stakeholders involved in planning charge infrastructure for heavy vehicles in Sweden.

Moreover it is worth mentioning that the research has focused specifically on Sweden's challenges in planning charge infrastructure for heavy vehicles. Therefore caution should be exercised when attempting to apply the findings directly to other regions or countries that have different regulatory frameworks, infrastructure conditions, and stakeholder dynamics.

This thesis showcases a meticulous method of ensuring research quality by taking into account both reliability and validity. The techniques utilised - standardised interview guides, continued conversations, thematic analysis, and shared involvement in data analysis by both researchers - all contribute to upholding the reliability and validity of the study. These endeavours advance the credibility and trustworthiness of the results, enabling purposeful interpretations and potential application in the process of planning for charging infrastructure for heavy vehicles in Sweden. However, the interpretation and application of research data inevitably come with limitations that give us an insightful framework for comprehending each study's boundaries or potential constraints.

To upscale future studies effectively, wider sample sizes should be incorporated alongside targeted qualitative analysis that explores additional perspectives across several contexts. It is essential to note that although institutional paradigm shifts could improve planning processes they may not comprehensively cover all possible shifts or alternative perspectives, furthermore limited by study timeframe with emerging and future institutional arrangements potentially missed. Lastly, while qualitative data provides rich insights into challenges and potential improvements, quantifying extent/magnitude identified challenges and impact potential paradigm shifts on the planning process will prove challenging as quantitative data is absent, with time constraints further limiting depth and analytical exploration of long term effects. The rapidly changing nature of this area underscores the need for consistent monitoring and evaluation.

4. Empirical findings

"We do not have a way of knowing what innovations we want to push. When we try to improve our technology, we have no way of knowing if it will work with directives that could appear in the future. We would like if the technologies [charge stations and electric trucks] *could evolve in parallel to each other… to be able to know what type of technologies other companies have, what direction they are pushing, so we could innovate together."* - Manufacturer interviewee

4.1 Planning

The planning process for projects connected to the energy sector has looked the same for the last decades but the current surge in demand for energy both in terms of power and capacity has vastly increased the need for speed in the planning process. Capacity restrictions is one of the main challenges faced by the power grid operators in Sweden according to some interviewees. Some interviewees remarked that to identify future energy production capacities, market research and prognostics are crucial. Data is also playing a vital role in prognostics when it comes to determining future energy demand, which is another critical aspect mentioned by several interviewees during the discussions. Currently the number of trucks are not a problem for the power grid, but according to some interviewees there are uncertainties connected to when the bigger part of the heavy vehicles will appear on the roads.

Until recently the planning aspect of new developments affecting the power grid was reserved for a certain number of actors whereas projects today are of industries demanding electricity as a main source of power instead of using fossil fuel based sources for machines and on premise transports. According to several interviewees there is not only an increase in demand on capacity and power from established industries. When the heavy vehicle fleet is to be using electricity as a primary source of power there are many changes affecting the power grid happening at once which all need to be taken into consideration which, the interviewees mean, increases the importance of having dialogue between project owners and grid owners early in the planning process.

Almost all interviewees agree that power grid applicants do not always know of the complexity involved in projects regarding power grid applications. Today there is discussion happening before the actual application for the projects. It is emphasised by some interviewees that it is of great

importance to initiate the dialogue at an early stage in order to avoid complications during the permit process.

Several local power grid operators state that the technological lifespan is considered mainly for the economic value of the structures, but also with regards to when the stations need to be replaced. There was no one that took the power grid infrastructure into consideration in regards to technological lifespan for the charge infrastructure.

Many interviewees think that one of the most important changes with great potential to improve the planning process is to have a dialogue with the power grid operators at a very early stage. In order to manage the recent increase in capacity demands from projects it is a determining factor of success. That way the project owners can reduce potential delays and the network companies can plan the construction and development at a better rate. One local power grid operator put emphasis on that the process before a new power line is constructed could last around ten years, and most companies do not want to add that to their project estimated at only a couple of years.

4.2 Location and capacity

Some interviewed actors mention that there are forecasts of future capacity demand being calculated based off of planned projects. There is an agreement that the way heavy charge infrastructure development occurs today is not easily calculated, due to lack of earlier project data to draw from. In the meantime in regards to charge stations for trucks, it is difficult to know when the trucks that require the charge stations will be on the roads as well as difficult to know where the peaks of capacity will be. There is a consensus amongst the interviewees on that data availability regarding routes and traffic which would assist geographically assessing the optimal locations for the charge stations is scarce. Some interviewees also mention that it is difficult to know. Since the peak capacity is affected by how many trucks need charging simultaneously, many actors bring up the difficulty to estimate the necessary capacity for locations with multiple chargers in order to meet the fast charge demand. If there would be methods to reduce the peak capacity by spreading out the charging over a longer period of time, that is when not all trucks load at once but rather at different times of day, there is less demand on the power grid. If not, then there would probably be situations where fast charge is not possible to the same extent if there are more stations

than capacity for fast charging. A problem that could arise in that scenario according to some interviewees, is that each truck would charge at a lower rate than optimal due to the finite capacity at the charging site. Several interviewees bring up that the requirements for commercial vehicles are different from those used for private travel in regard to when the vehicle has to be charged. A commercial vehicle needs to charge when the truck would naturally stop and not cause additional stops or delays for the trucks because it needs charging. The major challenge will be to know where the charge stations are to be built in order to optimise the operation of the business.

Knowledge sharing regarding transport probably needs to change in the future according to the majority of the interviewees, since the companies owning the traffic data typically view it as a company asset that they do not want to share. However, building the infrastructure to match the transporter's routes and needs requires a level of route data transparency.

One interviewee brought up that there is a lack of capacity in the greater city areas of Sweden's bigger cities that already hinders infrastructure projects that rely on the power grid.

4.3 Power grid

There might also be difficulties in connecting to the local power grid considering the high capacity required by heavy vehicles in comparison to ordinary cars. Some actors mention that local power capacity might not be sufficient and that in turn raises questions regarding the regional grid capacity and the transmission grid capacity. If the local grid capacity is not sufficient and communication is required upstream with higher levels of grid operators the scale of the project immediately becomes more challenging and time consuming. One local power grid operator emphasised that how much more challenging it might become depends on the individual conditions but the most convenient situation is when local power grid capacity is sufficient. The understanding amongst several interviewees is that local capacity might initially be adequate but if additional charge stations for heavy vehicles are constructed in the area new evaluations are necessary with the potential of delaying the new additions due to lack of capacity.

4.4 Policies

Some interviewees recognise that electric truck charging projects can influence other infrastructural elements like traffic flow and emphasises the importance of careful consideration in planning. Moreover, one local power grid operator underscores the role that policies surrounding carbon footprint allocation play in enhancing the efficiency and sustainability of energy production. Many clients desire not only charge stations for sustainable truck fuel but also sustainably sourced electricity. For example, the carbon footprint of residential waste is allocated from the actual waste generators and unto the power grid operator. Many interviewees agree that there are no clear ways to give feedback on such policies that currently restrict the demand for otherwise sustainable energy sourcing and further infrastructure development. The consensus amongst some interviewees is that in the end, many clients requesting charge infrastructure want environmentally friendly transports and sustainably sourced energy.

According to several interviewees, fluctuations in policies and regulation is an obstacle in planning for new power grid infrastructure. If the political climate is unstable regarding energy directives projects can end up delayed or sometimes not even initiated. Many interviewees think that if governmental plans would stretch over several years instead of being changed depending on contemporary trends, the planning process would stabilise and more actors would be confident in both infrastructure investments and electric vehicle investments.

Several interviewees mention that municipalities and local governmental bodies are typically very strict regarding energy regulations and when a conflict of interest arises concerning the local plans either regarding money for development investments or land space priorities that can delay or sometimes cancel projects.

4.5 Communication

Collaboration among various sectors and stakeholders in the energy industry is essential for the efficient development of the power grid infrastructure. One local power grid operator interviewee in particular stressed that in order to achieve influence on the regional or transmission grid network there is a need to establish and communicate a clear picture of the demands of the future. The network owners possess knowledge of local projects and if the information on demand for capacity

is properly delivered upstream in a timely manner there is potential to calculate the future capacity on both local, regional and national power grid level. The majority of the interviewees agreed that transparency between the power grid owners is crucial for effective charge- and power grid infrastructure development.

Some interviewees agreed that the power grid operators can act as a platform for information gathering and distribution that enables the planning. For this information distribution process to work it is of great importance that project owners are contacting the power grid owners at a very early stage.

5. Analysis

5.1 Planning

Institutional theory provides the lens through which we can analyse the challenges encountered in the planning process of Sweden's electric truck charging infrastructure as revealed in the results of our interviews (Rainer Lepsius, 2018). Among these challenges is the need for speed due to high demand, a manifestation of institutional pressure for efficiency that is common in many institutional environments (Spiller, 2008). This is exemplified by power grid operators facing capacity restrictions, which are also indicative of institutional isomorphism whereby organisations converge on similar structures and practices (Staffan Furusten, 2013). The need to identify future energy production capacities through market research and prognostics is rooted in external pressures that drive organisations towards conformity with the expectations of stakeholders such as regulators, customers, and the public.

This need manifests itself in various ways, including the importance of data in prognostics and determining future energy demand reflecting an institutional pressure for rationality that demands objective decision making based on quantifiable criteria. The trend towards using electricity as a primary power source for heavy vehicles responds to another important external pressure- namely, institutional pressure for environmental sustainability (Spiller, 2008). Historically the main source of fuel for the transport sector has not originated at the power grid structure rather fossil fuel providers. The new trend is recognised by the interviewees and the future demand for electricity as a fuel for the transport sector is estimated to increase from 2.6 TWh to 15-20 TWh in the coming 20 years (Kågeson et al., 2022).

Institutions exert multiple and interrelated pressures on organisations in a given field, and this institutional complexity affects changes to the power grid (Rainer Lepsius, 2018). Early dialogue between project owners and grid owners becomes crucial due to the institutional pressure for conformity that drives organisations to align their practices with those of other actors in their environment. The interviewees predicted the need for effective early communication between stakeholders as one of the major hindrances and opportunities in terms of planning for charging infrastructure projects.

This is seen as essential in the early planning stages to increase predictability in energy demand forecast and in order to reduce potential delays and complications during the permit process (Svenska Kraftnät, 2023; Tenggren et al., 2016), which is a manifestation of the institutional pressure for efficiency. Institutional pressure for stability is evidenced in the stakeholder discourse concerning the accurate prediction of investment requirements and energy consumption amidst currency fluctuations and political uncertainty (Spiller, 2008). This same institutional pressure compels organisations to prioritise predictability and consistency as key components of their operational environment. In contrast, institutional pressure for rationality impels firms to make decisions based on objective and quantifiable factors such as reliable forecasting and technological lifespan to ensure long term economical sustainability (Staffan Furusten, 2013). Ultimately, analysing these pressures is crucial in planning electric truck charging infrastructure in Sweden as revealed by insights extracted from interviews. The comprehension and effective handling of these pressures have the potential to decrease probable impediments and secure favourable outcomes for the projects.

5.2 Location and capacity

In light of institutional analysis, it becomes evident that the recent surge in energy demand and capacity not only challenges the conventional norms, rules, and values of the energy sector but also, according to the empirical findings, indicates a necessity for change in the traditional planning process (Willmott, 2010). Although this system has served the fossil-fuel-based industries adequately for several decades, new sectors including the transport sector are transitioning into more electricity demanding operations. The resulting increase in capacity demand requires quick-paced planning methods. Interviewees mention the potential risks involved with a lack of capacity on a local level resulting in a potentially decade long establishment process. Consequently, this shift in requirements creates a fresh institutional setting where existing norms and regulations may no longer suffice (Zilber, 2011).

The significance of strategic location selection cannot be underestimated in today's institutional environment (Spiller, 2008). Several interviewees agree that the location of heavy charge infrastructure is not only important in terms of relevancy to routing and traffic but also in regards to general land use planning and investments priorities conflicts. In Sweden, electric grid operators

confront significant issues regarding their network's maximum capacity. The Swedish government predicts that initial transitioning into heavy charge infrastructure development will not be a challenge due to capacity availability (Trafikanalys, 2021). However, the interviewees bring up not only the capacity issue as a current problem in planning for charge infrastructure, but also the general surge of capacity demand from several sectors impacting the potential of building charge infrastructure at a local and regional level. This implies contradiction between the stakeholders in terms of understanding of the capacity problem. These challenges are especially noticeable in urban centres where energy consumption rates are at their peak but also outside city areas where the power grid infrastructure might not be developed sufficiently for heavy charge infrastructure development. There is a consensus amongst the interviewees that capacity deficits can substantially impede heavy charge infrastructure projects that place a heavy reliance on electrical grids; therefore, it is critical to factor in both construction sites' location and electricity limitations during early stages of planning.

An additional recommendation from the interviewees is to encourage dialogue between project implementers and electricity companies as early as possible since such coordination could minimise negative impacts associated with heightened handling of energy demand increases. Collaboration and communication between actors in the institutional environment are crucial to effective planning and implementation of energy projects (Zilber, 2011). This assertion is evident in the essential nature of dialogue between project owners and network companies which assists the former in limiting potential delays while aiding the latter with better construction and development planning.

Institutional theory further illuminates the difficulties encountered during capacity demand forecasting for energy projects, particularly where locations have multiple chargers(Rainer Lepsius, 2018). It is challenging to accurately estimate necessary capacity due to insufficient previous project data coupled with unpredictable heavy charge infrastructure development phases. When it comes to determining optimal locations for charge stations, data on routes and traffic is essential (IVA, 2020; Svenska Kraftnät, 2023; Swahn, Wallinder and Strömberg, 2019; Kågeson et al., 2022). However, the interviewees unanimously agreed that data sharing in this regard can be a challenge due to companies owning the said data viewing it as a business asset. This scenario raises questions not just around transparency but around institutional norms and values in the

energy sector too. Taking an institutional perspective highlights the need for recognizing extant industry rules, norms, and values even while adapting to newer industrial requirements (Zilber, 2011). Effective planning and implementation of energy projects require thorough consideration of location and strategic planning. The literature and empirical findings both suggest that collaborative efforts and clear communication among institutional actors are indispensable elements to achieve success in this process.

5.3 Power Grid

The issue of connecting heavy charge infrastructure to the local power grid highlights a crucial role of power grid regulations and emphasises potential challenges stemming from the lack of coordination among different actors from an institutional perspective. Inadequate local power capacity results in involvement from regional and transmission grid operators, making cooperation between local power grid operators, regional grid operators, and transmission grid operators essential. The framework in which these actors operate is critical for the success of such projects as there can be significant delays associated with evaluating and upgrading the grid infrastructure evident by the result of both the empirical study and frame of reference. To ensure the success of sustainable transportation infrastructure development, it is crucial to recognize the importance of location and planning in coordinating the efforts of power grid operators and infrastructure developers. The complexity involved in connecting heavy charge infrastructure to the power grid highlights institutional and regulatory challenges that must be overcome (Willmott, 2014). It is evident that actors need to collaborate seamlessly across different contexts and levels for this project's success.

5.4 Policies

Policies that govern carbon footprint allocation are crucial for the advancement of sustainable energy production and infrastructure. Interviews conducted with industry experts highlight the effect of these policies on demand for sustainable energy sourcing and subsequent infrastructure development. These experts recommend clear feedback mechanisms to influence policy changes as changing regulations can impede the planning process for new power grid infrastructure,

creating a challenging environment to navigate. Political instability with regards to energy directives often leads to project delays or cancellations.

Local municipalities and governing bodies tend to strictly enforce energy regulations and there may be conflicts of interest over land space priorities or investment in development processes that could further hinder progress (Sataøen, Hogne Lerøy et al., 2015). Concerns such as how electric truck charging projects might affect traffic flow should also be considered by policymakers during planning phases, to encourage efficient and sustainable infrastructure development.

5.5 Communication

To ensure successful development of power grid infrastructure, effective communication among different stakeholders in the energy industry is critical (Rainer Lepsius, 2018). Transparency is one key aspect that interviewees emphasised in fostering effective collaboration. It was noted that the power grid operators have a significant role to play in facilitating communication among various actors involved in the project. However, it was stressed that such communication should occur at an early stage of the project, and project owners should initiate this collaboration by contacting and planning with power grid operators (Spiller, 2008).

Besides enabling greater collaboration, having a clear understanding of future demand is necessary for effectively influencing regional or transmission grid networks (IVA, 2020). In order to ensure efficiency and sustainability of power grid infrastructure, timely communication of demand for capacity upstream to network owners is crucial according to several interviewees. This enables calculation of future capacity at local, regional, and national levels. Affecting energy regulations and priorities can be catalysed by municipalities and local governmental bodies in this regard.

Power grid infrastructure development often faces challenges due to conflicting interests among stakeholders that can delay or even cancel projects (Sataøen, Hogne Lerøy et al., 2015). Therefore, effective communication is pivotal in addressing these issues and accommodating everyone's concerns. Successful collaboration and efficient power grid infrastructure development demand transparency, early communication, and anticipation of future demand. It should also be noted that the institutional setting significantly influences project outcomes (Spiller, 2008). One of the stakeholders, who was from the manufacturing and transport sector, mentioned how early

communication or the lack of it; holds the technological innovation in terms of the projects they are working on to make charging technology for the electric trucks.

6. Discussion

6.1 Implications of how the current institutional paradigms affect the planning of infrastructure for heavy charge vehicles

The issue arising from the recent shift within several industries of demanding electricity as a main source of energy and its impact for the transport sector is somewhat neglected in the reports regarding the subject. The institutional pressure for change (Rainer Lepsius, 2018) exposes the issues with slowness in the application process (Tenggren et al., 2016) as well as lack of communication between stakeholders (Svenska Kraftnät, 2023) and the potential of conflicting interest in municipal detail planning (Sataøen, Hogne Lerøy et al., 2015). When interviewees mention the competition between actors in terms of capacity, land use and investments affecting the development of heavy vehicle charge infrastructure there is an indication that synchronisation of industries' demands could be necessary on a regional or national level in order to sufficiently meet the surge in demand for each sector, including the transport sector. Organisational rules, norms and values that encourages individuality and rigidity within the industries and the authorities that could affect the energy transition (Zilber, 2011), such as data sharing restraint and drawn out permit processes, needs to be reconsidered.

The permit system is acknowledged to have worked in a context that up until recently have been homogenous for several decades. However, traditional norms within the governmental organisations regarding slow (Tenggren et al., 2016) and complicated application processes (Svenska Kraftnät, 2023) are directly opposing the pressure for institutional efficiency and stability (Spiller, 2008) called upon from the interviewees, researchers (Tenggren et al., 2016; Kågeson et al., 2022), multinational regulations (European Commission, 2021) and even the energy infrastructure authorities themselves (Svenska Kraftnät, 2023).

If the transition into an electric powered transport sector is to be considered a mega project, the positive outcome of the project is highly dependent on the ability of the project organisation, in this case the power grid development stakeholders, to act on new conditions and information instead of relying on a pre-established norm of operation (Ansar and Flyvbjerg, 2022). The

relatively new societal movement into electric transition is a shift of setting where the current institutional norms may be insufficient (Zilber, 2011). By regarding the transition as a mega project on a national level there could develop a self-awareness necessary to re-evaluate not only the potentially hampering institutional traditions but also to improve the chances of succeeding in the project, delivering a more efficient transition with lower costs and higher societal benefits (Flyvbjerg, 2014). Indications from the research (Svenska Kraftnät, 2023; Tenggren et al., 2016; Staffan Furusten, 2013) as well as from the interviews indicates that a there is a desire to change into a more flexible and transparent institutional structure which the mega project platform-type strategy approach (Ansar and Flyvbjerg, 2022) could facilitate. The new AFIR directive (European Commission, 2021) that aims to regulate electrification of road transport by legislation creates a legal pressure for further institutional change and efficiency.

Institutional instability connected to regulation and policymaking is a concern raised by several local system operator interviewees. Not only in the institutional environment within which local stakeholders operates, such as DSO's and municipalities, but also on a national level. Uncertainties with municipal monopoly on detailed planning and land-use (Sataøen, Hogne Lerøy et al., 2015), confusion regarding the permit process itself (Svenska Kraftnät, 2023) as well as the lack of a clear national strategy (Tenggren et al., 2016) indicates a need for action. In spite of a national strategy being put in place 2018 (Arbetsgruppen Transportsystem IVA, 2019) there is an alarming optimism regarding the charge infrastructure development for heavy vehicles. A report regarding the specific subject conducted by Trafikanalys (2021) concluded that the current power grid network is sufficient for the charge demand in the initial phase of development, and that the power grid will not have trouble in meeting the demands of the industry in the later phases of development. The European Commision AFIR directive (European Commission, 2021) was not in place when the report was written and will probably have a great effect on the national long term development strategies and in turn the institutional stability.

7. Conclusion

How is the planning of new heavy vehicle charge infrastructure in Sweden affected by the current institutional paradigms?

The complexity of the transition into electrically powered heavy vehicles is reinforced by the shifting demand of many sectors. The development of new charge infrastructure for heavy vehicles is dependent on capacity in the power grid. Currently, the institutional norms within the logistics industry is limiting the data availability. Logistics service providers must reconsider the value of sharing data on routing and traffic. The lack of information and the short notice of coming projects makes forecasting capacity for new development and planning of optimal locations for truck charging stations very challenging. A new view on data sharing is something that would greatly benefit the forecasting and construction of new charge infrastructure for heavy vehicles. In addition, the institutional tradition regarding the permit process and processing times is rigid and complicated – the opposite of what is desired from the industry and authorities and required for an efficient transition. Involving power grid operators and sharing anticipated demand at a very early stage in the planning process would be highly beneficial in dealing with the challenge of making accurate forecasts, deciding optimal locations for new charge infrastructure for heavy vehicles and for a more flexible permit process.

The institutional instability originating from political fluctuation regarding directives and strategies for the power grid development has a major impact on the planning process of new charge infrastructure. Without the presence of stable, long term plans for developing the Swedish infrastructure, power grid operators and private actors such as transportation companies face uncertainties when planning coming projects. The challenges arising from this problem are difficult to overcome due to the unpredictable nature of political trends. However, the very recent AFIR directive could result in more institutional stability in the future.

The authors can conclude that the planning of new heavy vehicle charge infrastructure in Sweden is affected by the current institutional paradigms in many ways. New surges in demand, regulation and innovation have put the planning process to tests that indicates a need for institutional change.

7.1 Future research

The authors have by answering the research questions created a deeper understanding of the challenges connected to the future planning of charge infrastructure for heavy vehicles and the impact of the institutional norms. By using the institutional theory as a frame of reference the research provided understanding of the challenges in a context of norms, traditions, values and pressures which all affect said challenges. In turn, the report is heavily influenced by the institutional theory. Other frameworks could provide additional valuable aspects on the topic in future research. Additionally, the research group has mainly sufficed in gathering the views of local and regional power grid operators and future research could not only further investigate the challenges identified on a more detailed level but also proceed to understand them from the aspects of other stakeholders such as transporters and transmission grid operators. Conducting interviews is one way of studying the challenges, however, a deeper analysis of the AFIR directive and the national policies for heavy vehicle charge infrastructure development could also generate beneficial research.

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Appendix A - Interview Guide

- Have you been in a project that affected the power grid network in a more extensive way? (I.e single charge post vs. mall outside town)

- Do you consider technology lifespan when connecting new infrastructure to the power grid?

- How would a client share necessary data/information with you? Could you use that data outside the project? I.e forecasting/future planning

- Were you aware of any typical problems ahead of time that affected the planning process? How did it affect the process?

- If you could choose, what challenges do you consider the main challenges when planning for high capacity power grid infrastructure? (if you could mention two or three) In projects or otherwise (i.e forecasting).

- What changes to the planning process could benefit the building of new high capacity infrastructure in your opinion? *One or a couple of examples*

- How did regulation affect the work process (specify)? → Did you encounter any policies that influenced the planning process?

- Did you have any opportunity to give feedback to project stakeholders that could improve the planning process? I.e municipalities / policy makers.

- Companies have different ways of thinking and working. Have you encountered any industry norms amongst your clients that have affected the planning process?

- Have you been in a situation where the power dynamics of the different project stakeholders have had an effect on the planning? (Conflict of interest) I.e municipalities vs. client

- How do you think collaboration in the planning process would affect the development of high capacity charge infrastructure?

Appendix B - Institutional Analysis (Not used in interviews)

1) What are some factors, such as formal rules and regulations, informal norms, beliefs, and historical legacies, that influence the planning and development of electric truck charging infrastructure in Sweden?

2) How do policies and regulations impact the planning decisions related to the location, design, and operation of electric truck charging infrastructure in Sweden? Can you provide examples of specific policies or regulations that have influenced the development of electric truck charging infrastructure?

3) What are the industry norms and beliefs among stakeholders, such as truck manufacturers, logistics companies, and fleet operators, regarding the planning and development of electric truck charging infrastructure in Sweden? How do these informal norms and beliefs influence the decision-making process for charging infrastructure development?

4) How do power dynamics among stakeholders, such as government agencies, charging infrastructure providers, electric truck manufacturers, utility companies, and local communities, influence the planning and development of electric truck charging infrastructure in Sweden? Can you provide examples of specific power dynamics that have impacted the planning process or outcomes?

5) How do historical legacies, such as existing infrastructure, policies, and practices, impact the planning decisions for electric truck charging infrastructure in Sweden? Can you provide examples of how historical legacies have shaped the development trajectory of electric truck charging infrastructure in the country?

6) What are the challenges and barriers faced in the planning and development of electric truck charging infrastructure in Sweden, considering the institutional factors? How have these challenges been addressed or overcome in practice?

7) What strategies or approaches have been used to align the planning and development of electric truck charging infrastructure with the institutional context in Sweden?

8) What are the potential future developments or trends in the planning and development of such in Sweden, considering the evolving institutional context and market dynamics? What are the implications for the future planning and development?

9) How do you see the role of institutional theory in guiding the planning and development of electric truck charging infrastructure in Sweden? What are the key insights or lessons learned from applying institutional theory in this context?

10) What recommendations or suggestions do you have for policymakers, planners, and stakeholders involved in the, considering the factors and challenges associated with this process?