Meta-Governance in Integral Planning for Rail- and Energy Infrastructure

A comparative case study of ProRail, Infrabel, and Trafikverket

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Preface and acknowledgements

Life sometimes takes an unexpected turn for the best. After obtaining my Bachelor's degree in civil engineering, I would have never imagined that applying for a Master's in Spatial Planning at Utrecht University would turn out to be the academic adventure of a lifetime. Does that sound somewhat exaggerated? Well, think again after reading this thesis! During the Master's program, the lectures on Urban Governance in Spatial Planning sparked my passion for complex governance issues. Combined with a background in civil engineering and a coincidental, fun afternoon at ProRail, the foundation for a Master's thesis on meta-governance in integrating rail- and energy infrastructure was laid.

I want to take this opportunity to express my gratitude to Dr. Patrick Witte for all his time, knowledge of governance, the fun, and his ability to reassure or challenge me at the right times. I also want to thank Freek Schermers from ProRail for his critical, yet relaxed and supportive look at my thesis, and Thomas Kortekaas for making ProRail feel like home during my internship.

I am deeply convinced that humanity's purpose of cultivating the Earth is expressed in an endless variety of ways. I found my way in Spatial Planning, and this thesis can be considered one tiny part of humanity shaping the world that it was given to steward.

Abstract

Rail infrastructure operators are increasingly often involved in sector-transcending challenges regarding the energy transition. Due to net congestion, rail infrastructure operators face problems in expanding their own infrastructure. At the same time, both in society and literature, rail infrastructure operators are viewed as possible solution to these challenges, in opening their energy grids for broader use.

The integration of rail- and energy infrastructure, illustrates a shift from sectoral to integral planning. This shift often lacks the required shift in governance for making integral planning successful. One main failure in integral planning is the lack of coordination. Within governance theory, meta-governance can potentially provide this coordination. Therefore, this thesis explores how meta-governance can address governance failures in integral planning for integrating rail- and energy infrastructure, focusing on the role of the rail infrastructure operator. The main question this thesis answers is:

> "*How do rail infrastructure operators value the contribution of meta-governance in integral planning for integrating energy and rail infrastructure, in their positioning among other stakeholders in the integral planning process?"*

To answer this question, three cases from rail infrastructure operators in Belgium, Sweden, and the Netherlands are explored in an inductive research. Through semi-structured interviews, this thesis explores potential collaborations in the infrastructure and governance of rail- and energy infrastructure. It also identifies the main challenges rail infrastructure operators face regarding the rail energy system.

This research concludes that integrating rail- and energy infrastructure might be beneficial on local scale, but the impact on 'wicked problems' in the energy transition is limited. Furthermore, it draws conclusions on the conditions needed for meta-governance to be beneficial to integrating rail- and energy infrastructure. This thesis concludes with five main conclusions to answer the main question:

1. The impact of integrating energy- and rail infrastructure should not be overestimated, but it can provide solutions on local scale.
2. Integrating policies for *using* energy- and rail infrastructure could provide solutions, rather than purely looking at physically integrating infrastructure.
3. Meta-governance is beneficial in integrating energy- and rail infrastructure, when:
    a. The meta-governor is clearly coordinating the process
    b. It clarifies the role of rail infrastructure operators as executive agencies with an advisory role towards the meta-governor
    c. The meta-governor transcends sectoral boundaries and traditional hierarchies
    d. The meta-governor is trusted by the rail sector, while remaining independent.
4. The scale and complexity of the meta-governance structures and institutions should be proportional to the limited benefits of integrating rail- and energy infrastructure.
5. While integral planning processes still lack coordination by meta-governance, rail infrastructure operators should adopt a more active advisory role towards their responsible ministries, and address governance failures within integrating energy- and rail infrastructure planning.

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1. Introduction

In recent decades, the planning issues that spatial planners face have become increasingly complex. Due to rapid globalization, planning issues are less often bound to a specific place, but rather part of a larger complex network of actors (Paasi & Zimmerbauer, 2016; Vigar, 2009). Various planning issues, from increased carbon emissions and global warming, to scarcity of resources and the need for accelerating the energy transition, require cooperation across multiple sectors to find solutions (Kidd, 2007). However, sectoral borders often do not reflect the complex nature of the intertwined mechanisms that form society. Therefore, a conventional sectoral approach to planning often turns out to be insufficient to deal with these increasingly more complex, sector-transcending planning issues (Kidd, 2007).

One of these sector-transcending planning issues is the desire to accelerate the transition towards fully renewable energy sources (Warbroek et al., 2023). In the energy transition, the aim is to ensure the Earth's capacity to both generate energy and store emissions from energy consumption, is not exceeded (Kabeyi & Olanrewaju, 2022). In generating energy, the focus shifted from finite, often fossil energy sources towards renewable sources such as wind-, solar- and hydropower. Simultaneously, the energy transition increases the use of electric power not solely for the purpose of generating renewable energy, but also because using electric power decreases the levels of harmful emissions (Shue, 2017). As a result, it becomes both politically and economically increasingly appealing to shift towards renewably generated electric power as a main power supply for society (Newell, 2021). However, this shift to electric power poses challenges of its own. First, generating and transporting renewable energy requires more space (Wolsink, 2018). In densely populated areas, this proves to be a major bottleneck in enhancing the energy transition. Second, the energy grid is not suitable for transporting the skyrocketing supply and demand of electric power, leading to net congestion in densely populated areas at peak moments in energy supply or demand. Therefore, Dutch energy grid operators do not connect everyone to the energy net that demands transport capacity. Instead, people asking for a connection to the energy grid are placed on a rapidly growing waiting list (Netbeheer Nederland, 2024). As a result, the construction of new housing is delayed, the energy transition gets stuck and people start looking for alternatives to the energy grids.

One sector affected by the energy transition is the rail sector. Rail infrastructure operators are intensively involved in the energy transition, both in facing challenges and consequences, as well as in being considered to be part of solutions more often (Brenna et al, 2020; Kuznetsov et al, 2024). A challenge for rail infrastructure operators is the decreasing availability of energy transport capacity. With higher voltages on the catenary, trains can potentially accelerate faster, making it possible to have more trains in a certain timeframe (ProRail, 2022). Furthermore, to decrease CO_2 emissions from fossil fuel-powered trains, rail infrastructure operators look to electrify rail lines that currently have no catenary (Merchan et al, 2020). Railway operators pursue these developments, to create a more efficient railway system. However, these developments require additional power. With the shift towards more electric power in multiple sectors, not only the generating capacity but mainly the transport capacity of electric power proves to be insufficient. This results in delays or even cancellations of innovation and projects in the rail sector.

On the other hand, rail infrastructure operators are increasingly often considered to be a solution to the problem of net congestion. Rail infrastructure operators use a large electric power grid that feeds the catenary for power supply to trains. Railway infrastructure is used more intensively in and between densely populated areas. This means that the railway infrastructure, including the electric power grid, has a bigger capacity in the areas with the largest power demand (González-Gil, 2014). As a result, different parties or individuals look at the rail infrastructure operator as a solution for the congestion on the energy grid, by using the railway electric energy grid to transport energy, assigned for parties beyond the rail sector (Spoorpro, 2024; Energie in het OV, 2024). This leads to a call to action for the rail infrastructure operator (and parties from other sectors) to become more active in planning for a more integrated approach to using electric power grids. However, traditionally, the main focus of rail infrastructure operators is to ensure a robust network for trains to operate as efficiently as possible. This raises the question of how rail infrastructure operators should position themselves in integral planning processes regarding energy grid usage, especially when it is unclear how this affects their core business of providing rail infrastructure for trains.

Problem description

The issue is that parties from the rail and energy sector are increasingly often expected to abandon a sectoral approach to planning and participate in integral planning processes, while governance failures in integral planning are neglected (Arts et al, 2016). A part of this 'integral' planning process, is the question of whether the rail infrastructure energy grid can be used in a broader national energy grid system (Verbrugge et al., 2021; Kaleybar et al., 2022; Kaleybar et al., 2023). However, this would change the rail infrastructure operator's role from railway operator to energy grid operator. The problem with this 'integral' planning process, is that the rail infrastructure operator risks getting involved in energy-related issues, at the cost of its capacity to function as a railway operator. In other words, the shift from a sectorial approach to a more integral approach to planning for integrated energy grids, comes with the risk for railway operators to favor 'integral' planning needs over their own sectoral needs (Wesolowska et al., 2021). This shows that planning for integrating public and rail energy grids, often lacks coordination from an objective party, that ensures sectoral needs are met. Subsequently, it shows that conventional governance approaches to planning are less suitable for dealing with the complexity of integral planning processes (Arts et al., 2016). Since the integration of rail- and energy infrastructure can be part of solutions to the wicked problems that the energy transition faces, new forms of governance to guide this process are needed. Besides coordination problems in the actual integration of rail- and energy infrastructure, separated responsibilities between local, regional, and national government bodies create challenges for such an integral planning process. This lack of coordination, both between stakeholders in the integral planning process and between different layers of government, calls for an overarching form of 'governance of governance', guiding these processes.

In addition to the previously mentioned problems, the European rail sector is scattered and often lacks cooperation in governance and operations. However, the energy transition poses challenges for rail infrastructure operators throughout Europe. Although this thesis' main focus is not on European collaboration, it is helpful to acknowledge that these problems call for a Europe-broad perspective on governance in integrating rail- and energy infrastructure.

Goal & research questions

Since the main issue is the lack of coordination between stakeholders, this thesis explores meta-governance as a possible solution to governance failures in integral planning in the rail- and energy sector. In meta-governance, an objective party, the meta-governor, guides and coordinates the integral planning process. In theory, meta-governance seems suitable for addressing governance failures in integral planning. This thesis aims to explore under what conditions meta-governance can indeed address these failures in practice. This thesis takes an actor-oriented approach and explores how stakeholders involved in integrating energy and rail infrastructure feel the need for meta-governance and how they position themselves in relation to other stakeholders in the presence or absence of a meta-governor. Therefore, the main question this thesis aims to answer is:

How do rail infrastructure operators value the contribution of meta-governance in integral planning for integrating energy- and rail infrastructure, in their positioning among other stakeholders in the integral planning process?

This main question is broken down into the following sub questions:

1. *What is the infrastructural and governance context for integrating energy- and rail infrastructure?*
    a. *What rail energy infrastructure and governance structures are in place?*
    b. *How have the main challenges rail infrastructure operators face regarding energy developed over the past decade?*
2. *How do rail infrastructure operators collaborate with other stakeholders in integrating energy- and rail infrastructure?*
3. *Under what conditions do rail infrastructure operators see advantages of introducing meta-governance in planning processes for integrating energy- and rail infrastructure?*

To answer these questions, this thesis conducts a comparative case study between the national rail infrastructure operators in the Netherlands, Belgium and Sweden. In their different, yet comparable governance contexts, qualitative research explores how the rail infrastructure operators value or express the need for meta-governance in integrating energy and rail infrastructure. By comparing three different rail infrastructure operators, this thesis aims to give insights to answers to the previously stated research questions from multiple perspectives.

Relevance

The societal relevance of this research, lies in its contribution to planning processes in the energy transition, with both short-term and long-term effects. Due to governance failures in integral planning, sector-transcending solutions to address net congestion and accelerate the energy transition are at risk (Gerner, 2023; Risanger & Mays, 2024). By introducing meta-governance as a solution, this thesis provides a direction for governance in integrating energy- and rail infrastructure. This integration of energy- and rail infrastructure can be part of a solution to net congestion. Currently, net congestion is a main issue that affects various sectors, from housing to mobility. Therefore, by addressing governance failures in integral planning and exploring the role meta-governance can play, this thesis contributes to accelerating solutions to a major societal problem. Furthermore, governance failures in integral planning are undoubtedly present in planning issues among other sectors than energy and rail. Exploring conditions in which meta-governance can be part of a solution to governance failures, could be useful in other planning issues.

The academic relevance of this thesis is twofold. First, challenges in integrating energy- and rail infrastructure are somewhat discussed in the current literature. However, authors tend to immediately address technological issues, while the underlying governance failures in integral planning are often neglected (Çiçek et al., 2022; Kaleybar et al., 2023; Kaleybar et al., 2024). This thesis' academic contribution lies in further exploring governance failures in integral planning. Second, the relationship between meta-governance and integral spatial planning is little mentioned in the literature. Zonneveld & Spaans (2014) mention the governance concept once in relation to territorial planning for large-scale infrastructure projects, and Vigar (2009) mentions meta-governance in the context of integral planning, but does not explore this relation further. This thesis contributes to debates on governance in spatial planning, by explicitly exploring the relation between meta-governance and integral planning.

Reading guide

Since integrating energy- and rail infrastructure is a specific topic, this thesis starts with a context chapter that explains both the infrastructural and governance context of current energy- and rail infrastructure planning. Following this, the theoretical framework explores the concept of integral planning, and how meta-governance could potentially be beneficial in addressing governance failures in integral planning. Thereafter, a methodology section outlines the goals and methods for a case study of three rail infrastructure operators in Belgium, Sweden, and the Netherlands. The following chapter describes the results of this qualitative research, followed by a conclusions section that relates the findings from the case study to the theoretical framework. Finally, this thesis has a discussion section that discusses the academic and societal contributions of this thesis and points out directions for further research.

2. Context of rail energy infrastructure and governance

In the past decades, the problems that societies face have increased in scale and complexity (Lönngren & Van Poeck, 2021). One characteristic of this increased complexity, is that multiple sectors and various actors are involved in solving problems. A wicked problem that is caused by multiple sectors, while affecting those sectors as well, is the need for an energy transition. In pursuit of a more sustainable society, policymakers look for energy sources that do not exceed the Earth's generation capacity when generated, and do not exceed the Earth's limits for absorbing harmful emissions when energy is used (Kabeyi & Olanrewaju, 2022). Electric power proves to be one of the most common commodities for sustainable energy, since it can be both renewable when generated, as well as free from emissions when used. In the past decades, the generation of wind-, solar- and hydropower has increased massively (Brown, 2015). As a result, the portion of non-renewable energy sources in the total energy consumption, is decreasing. Besides effects on energy generation, the shift towards more electric power usage also results in less harmful emissions during energy consumption (Kabeyi & Olanrewaju, 2022).

2.1. Net congestion and renewable energy challenges in rail sector

Although the increased supply and demand of electricity as a power source has its benefits, the energy sector fails to keep up with the rapidly growing volumes of electric power that is generated, transported, and used (Schermeyer et al., 2018). First, the facilities and infrastructure for the generation of renewable energy require more space than conventional, non-renewable energy sources (Wolsink, 2018). In densely populated areas like the Netherlands, this proves to be a major challenge. Besides issues regarding energy generation, a major problem is the lack of transport capacity in the public energy grids. During peak hours in energy consumption and production, the energy demand exceeds the capacity of the energy grid to transport energy, leading to net congestion. As a result, new projects in various sectors, from construction to charging electric vehicles, are placed on waiting lists for a connection to the public energy grid (Milchram et al., 2018). Increasingly often, net congestion on the public energy grid is the main bottleneck for major societal developments. Expanding the public energy grid faces main challenges of its own. First, energy grid operators in densely populated areas like the Netherlands face problems with the scarcity of space. Second, there is a lack of available workforce on the labor market to fulfill all positions needed to complete projects (Fragkos & Paroussos, 2018). This increases the duration of expansion projects and ultimately results in higher costs, due to scarcity on the labor market. Finally, even if the public energy grid operators succeed in expanding the energy grid, chances are the expansions still cannot keep up with the even faster growing need for transport capacity.

One sector affected by the energy transition and its consequences is the rail sector. Rail infrastructure operators are affected by the energy transition in goals to use renewable energy and cut down emissions, as well as in facing challenges due to net congestion on the public energy grid (ProRail, 2022). For various reasons, rail infrastructure operators have an increasing demand for electric energy. This paragraph discusses four main contributors to the increased demand for electric energy. First, in the shift towards renewable energy sources to power trains and infrastructure, rail infrastructure operators look for possibilities to electrify tracks that are currently unelectrified and operated by fossil fuel-powered trains (Merchan et al., 2020). This logically increases the demand for energy in the electrified area. Second, certain aspects of rail infrastructure still rely on fossil fuel to work properly. To prevent railroad switches from freezing during winter, the rails in the switch are heated using gas. The shift to renewable energy sources and cutting down emissions, means that these pieces of infrastructure are electrified, requiring more capacity from the energy grid. Third, the demand for emission-free construction projects increases rapidly (Lingegård et al., 2021). This means that construction sites, machinery, vehicles, and tools are more often electricity-powered. These vehicles and tools need to be charged, demanding capacity from the energy grid. Fourth, net congestion affects the rail infrastructure operator's ability to facilitate a growth in train traffic on the current tracks. To summarize, due to the rail sector's high energy demand during peak hours on the public energy grid, the rail infrastructure operator is part of the cause of net congestion, as well as a party that is affected by the consequences of net congestion. This provides an incentive for rail infrastructure operators to critically reflect on their role in energy issues.

Since the energy sector has a hard time expanding the energy grid, and the rail sector has an energy grid that faces challenges of its own, integrating both the physical energy grids and policy regarding the use of the grids in the energy- and rail sector, could potentially be part of solutions for various problems regarding energy. This section first outlines the basic principles of the working of rail energy infrastructure, followed by four issues regarding the energy transition in which parties desire collaboration or already collaborate in various European countries.

2.2. Rail energy infrastructure

Rail infrastructure operators have two main purposes for using energy: fixed installations like the infrastructure itself or train detection, and traction energy supply. Traction energy supply refers to the form of energy (traction energy) that trains use from the catenary to power their engines. The model in *Figure 1* shows the basic working of a rail energy system, with a distribution net for traction energy, connected to a public grid. All lines are power cables. The trains use traction energy from the catenary (1,5 kV DC, black line). This traction energy grid is connected to the regional public energy grid. AC energy from the regional public energy grid (grey lines) is transported via cables from the rail infrastructure operator (yellow lines) to a substation (SS). In these substations, energy is converted to be used on the 1,5 kV DC catenary. Besides the catenary, the substations also supply power to a 3 kV energy grid (red line), from which all safety measures in the infrastructure (railroad crossings, signs, relay systems and train detection) are powered. Besides the main grids for connection to the public grid (yellow), traction energy (black), and the 3 kV grid (red), there are connections to the regional public grid (grey lines), used for example for lighting within the substations or bridges that require power to operate.

In the light of exploring integrating the energy system with parties beyond rail, certain characteristics of the rail energy system are important. First, once power is converted into the 1,5 DC system, it can not go back to the regional grid. This makes the grid less suitable for rail infrastructure operators to connect their own electricity generation systems like solar parks or wind turbines, since all energy needs to be used within the system. Second, as *Figure 1* shows, the traction energy system is ultimately powered by the regional public energy grid. Parties that ask the rail infrastructure operator for transport capacity on the operator's AC net (yellow lines), are practically asking for a connection on the regional public grid, but bypassing waiting lists by having the connection behind the connection of the rail infrastructure operator. Third, the 3 kV system (red) is of high importance for the safety of the rail system, making it less appealing for integration with other systems.

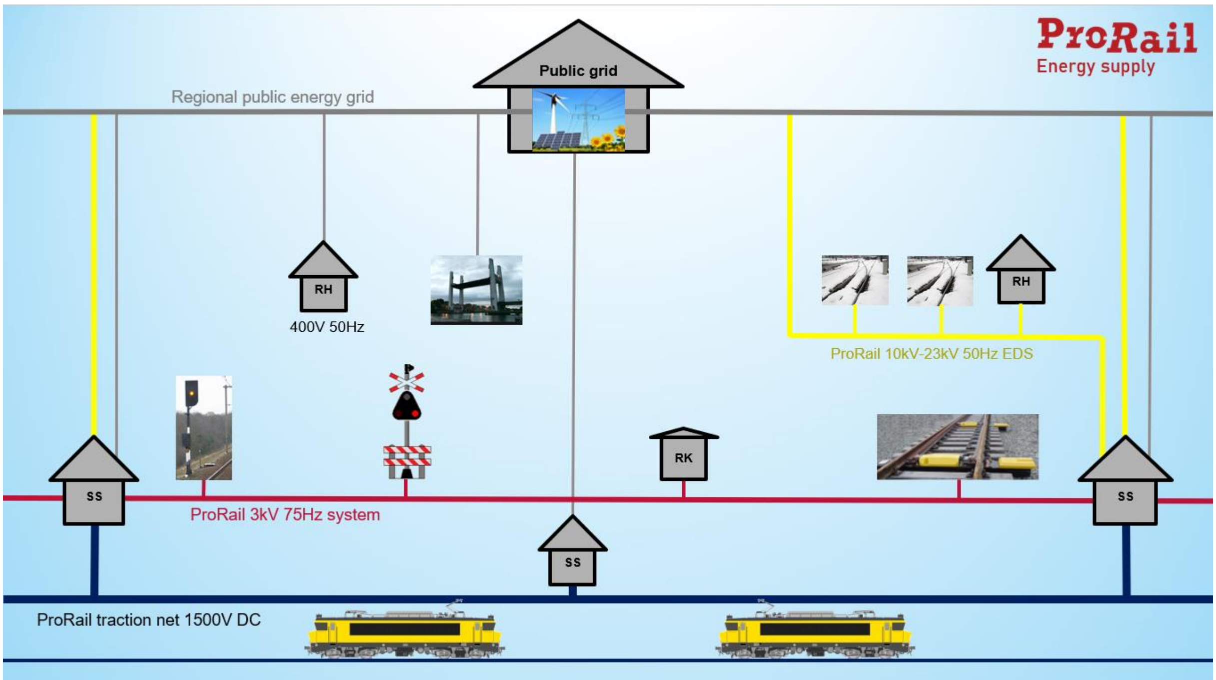

Figure 1 Example traction energy supply system (ProRail, 2022)

Besides the physical infrastructure, the use of a traction energy system is of a special nature, due to the high variation of peaks in energy demand. During rush hour, the rail system requires high amounts of energy. Other examples of reasons for peaks are when all trains simultaneously start heating at the start of the day in winter, or when multiple trains simultaneousely need to accelerate after a disturbance in the system. To cope with these peaks, the rail energy infrastructure has the capacity to provide energy to trains in most peaks. Therefore, parties beyond the rail sector are looking for applications of the rail energy system's capacity inbetween peaks.

2.3. Literature on integrating rail- and energy infrastructure

Integration of rail and energy infrastructure is a relatively new topic in literature. Researches into the topic mainly focus on the integration of renewable energy sources in rail infrastructure. Kuznetsov et al. (2024) review technologies that enable rail infrastructure operators to use more renewable energy sources for both traction- and non-traction energy usage. The integration of renewable energy sources in the rail sector makes the already low-carbon rail transportation even more sustainable and can potentially reduce the financial cost of rail transport (Kuznetsov et al., 2024). In a recent article, published in March 2024, Kaleybar et al. (2024) discuss smart energy grids in rail infrastructure. Increasingly often, experts seek innovative solutions to increase energy efficiency in the rail sector. The authors mention that "one promising strategy involves integrating renewable energy sources, energy storage systems, and electric vehicle charging stations into current electric railway systems" (Kaleybar et al., 2024). As is the case with most of these recent articles on integrating rail and energy infrastructure, Kaleybar et al. dive straight into the technological needs and opportunities of such integration. In this case, by introducing the concept of a smart energy grid into rail infrastructure. Other authors also discuss the integration of rail infrastructure with charging infrastructure for electric vehicles and renewable energy sources (Çiçek et al., 2022). Çiçek et al. (2022) also mention the use of existing unused energy infrastructure capacity from the rail infrastructure. After introducing the concept of integrating these systems, Çiçek et al. (2022) also immediately dive into the specifics of the technology needed for integration of these infrastructures. Even though this thesis will shift its focus more towards the governance regarding the integration of energy and rail infrastructure, articles like Kaleybar et al. (2024), show that the rail and energy sector share information and concepts.

2.4. Opportunities for integrating rail- and energy infrastructure

As previously mentioned, various parties outside the rail sector, increasingly often ask for a connection to the rail energy grid to bypass the waiting list on the regional public energy grid due to net congestion (Khayyam et al., 2015). Although the rail energy infrastructure is not directly built for such applications, there are multiple ways in which the public and rail energy grids could potentially strengthen each other. This thesis identifies four fields for integrating rail and public energy grids: Generating energy, transporting capacity, charging, and sharing space. First, both energy grid operators and rail infrastructure operators look for opportunities to increase the portion of renewable energy in the total produced and consumed energy. In the rail sector, constructions like stations and noise barriers are provided with solar panels. Since the rail sector is a major energy consumer, rail infrastructure operators see increasingly often opportunities in investing in renewable energy generation projects like wind-, hydro- or solar power. These investments can further accelerate the shift towards renewable energy sources. Second, rail energy infrastructure has transport capacity for energy during hours that the rail system does not need all capacity. However, some European rail energy grids, like the outlined Dutch grid, are not sufficient to transport large amounts of energy. These grids lack sufficient overcapacity and opening them up poses risks for necessary railway signaling. However, some rail energy system, like in Germany, have an extra layer of grid between the public energy grid and the traction energy grid. In Germany, this 110 kV grid is already used by parties outside the rail sector to transport wind energy from North to South and solar energy from South to North. By doing so, the rail energy grid helps the public grid operator in providing a relief on the public grid by sharing transport capacity. Third, the broad range of peaks in energy demand in the rail sector, can potentially provide capacity for charging infrastructure. A major downside of using the rail energy infrastructure for purposes beyond the rail sector, is the uncertainty of continuous capacity due to changing peaks in demand. However, when combining the rail energy infrastructure with charging infrastructure, this downside is surmountable. In Belgium, the rail infrastructure operator conducted pilots to research how other modes of transportation, mainly electric busses, could be charged between peaks in the energy demand of trains, with loading stations connected to the rail energy system. If the rail system needs extra capacity, it can shut down power to loading stations for a few minutes, until trains have accelerated. A short shutdown of power in loading stations has nearly no negative impact on the users. In this manner, integrating the rail and public energy systems can provide more capacity to meet the rapidly increasing demand for loading infrastructure for electric vehicles. However, this only accounts for minor peaks. Since the rail system is dependent on the public energy grid, new charging infrastructure is (indirectly) still contributing to net congestion on the public grid. Fourth, rail infrastructure operators often own large plots of land around rail yards and lines. Especially in contexts where space is a scarce resource, the rail infrastructure operator can rent out plots of land to public energy grid operators for expanding their grid or generation capacity. A benefit of integrating these grids in the same area, is that it requires partially overlapping safety zones. Another opportunity in line with the previous one, is sharing the strips of land designated for cables. However, the downside of sharing this space is that the rail infrastructure operator becomes less flexible to further expand the railway infrastructure in the future, when the public energy grid operator already occupies the space.

2.5. Risks of integrating rail- and energy infrastructure

The previous literature review shows that in recent years, there has been increasing attention for the integration of renewable energy sources and electric vehicle charging infrastructure in rail infrastructure systems. Literature shows that technological developments provide opportunities for this integration. However, there is little attention in current literature for the required governance structures to ensure that integration of energy and rail infrastructure is successful. Besides literature showing a shift to more integration, paragraph 2.3 on opportunities for integrating rail- and energy infrastructure show a shift in society, to planning for a more integrated rail- and energy system. However, paragraph 2.2. on rail energy infrastructure clearly showed the specific nature of a traction energy system. Although it is technically possible to integrate other energy systems with this train energy system, it is poorly researched how this affects the role of rail infrastructure operators, and this topic lack attention in practice. Additionally, paragraph 2.1 on challenges regarding net congestion and renewable energy, show an incentive for rail infrastructure operators to engage in these integral plans for rail- and energy infrastructure. To summarize; both in theory (Çiçek, et al., 2022; Kaleybar et al., 2024; Kuznetsov et al., 2024) and in practice (various stakeholders and the rail infrastructure operator themselves), parties drive the shift to more integral plans for rail- and energy infrastructure, while lacking reflection on potential process failures and required shifts in governance. Since the topic of integrating rail- and energy infrastructure can potentially contribute to solutions to wicked problems, this thesis will first construct the crucial theoretical framework on integral planning and its potential governance failures, to mitigate major risks involved with neglecting the process aspects of these integral plans.

3. Theoretical Framework

As mentioned in the final paragraph of the context chapter, it is crucial that the object of integrating rail- and energy infrastructure is accompanied by supporting process and governance structures. Therefore, this thesis constructs a theoretical framework, starting at the concept of integral planning. In constructing the framework, this thesis identifies various failures in integral planning that are relevant to the integration of rail- and energy infrastructure. With coordination problems at the core of governance failures in integral planning, this theoretical framework explores governance modes in infrastructure planning, and arrives at multi-level meta-governance as possible direction for governance modes in integral planning issues regarding rail- and energy infrastructure. This results in a conceptual framework, in showing how governance failures in integral planning and characteristics of meta-governance are complementary. This forms the basis for further empirical research on how rail infrastructure operators potentially value the role of meta-governance in integrating rail- and energy infrastructure.

3.1. Integral planning

To obtain a better understanding of integral planning, this section discusses sectorial planning and failures in sectorial planning that resulted in the need for more integrated approaches to planning. Within sectorial planning, the planner aims to gain a deep understanding of each sector involved in a planning process, rather than immediately aiming for a holistic view (Delmastro et al., 2016). This leads to specific expertise and a clear understanding of the needs of each sector (Cardoso & Hoffmann, 2019). In this way, policies can be tailored to fit these needs in each sector and resources can be allocated according to these needs (Cardoso & Breda-Vázquez, 2007). In theory, this does not mean that each sector aims to profit as much as possible at the cost of other sectors, but rather seeks the optimal solution for *all* individual sectors. As a result, sectors become more efficient and open to social justice, due to tailored regulations rather than general ones (Cardoso & Breda-Vázquez, 2007). The specific expert knowledge from each sector often results in sectors being more easily able to develop a long-term strategy for their sector (Salman et al., 2019). Critiques on sectorial planning from various authors concern the artificiality of sector borders, since society is a complex system of multi-sector developments (Papa & Boelens, 2015).

Critiques on sectoral planning not being sufficient in addressing complex, interrelated planning issues, gave rise to theorists supporting comprehensive planning (Berke & Conroy, 2000; Kelly, 2012). Although there are critiques regarding the limits of comprehensive planning, other theories such as integral planning and holistic planning are still popular in both planning theory and planning practice. However, although the terms differ, comprehensive, holistic and integral planning are used for a variety of planning processes and their differences are often poorly defined. Therefore, this thesis chooses to shortly discuss how the three theories are presented in literature, before further exploring integral planning.

3.2.1. Comprehensive planning

In comprehensive planning, the planner not only considers a certain limited area or sector as object of planning, but rather seeks policy integration and coordination among stakeholders (Bjärstig et al., 2018). A comprehensive approach to planning views the world as a complex system of interrelated activities, and theorists often describe a comprehensive approach as ‘integrated’ and ‘holistic’. Since comprehensive planning aims to take all relevant elements to a planning issue into account (Branch, 2018), those advocating for comprehensive planning regard it to safeguard public interest and to be suited to achieve long-term goals. However, others challenge the ideals of comprehensive planning. Abukhater (2009) gives an overview of some main critiques on comprehensive planning. First, critics say that there will never be sufficient access to information and resources to fully comprehend complex relations between actors. Furthermore, Lindblom (2018) states that human beings will never be intellectually capable of fully comprehending a single planning aspect, let alone a complete planning issue. As a result, comprehensive planning tends to oversimplify reality and lacks the capacity to reach optimal solutions and easily overlooks alternative solutions (Lindblom, 2018). Abukhater (2009) summarizes Lindblom's critique as follows: "Planning comprehensively seems beyond human cognitive ability and institutional, technical and organizational capacity".

3.2.2. Holistic planning

Within holistic planning, planners view the object of planning through all perspectives that are deemed relevant to the problem. The holistic approach often involves modeling the effects of certain planning decisions on an area, using a variety of indicators that cross different sectors (Mattoni et al., 2019). In this approach, holistic planning is process-oriented and is concerned with taking all relevant perspectives into account (Stoltz, 2014). Another approach to holistic planning is that it is not only holistic in its process, but rather holistic in the sense that it is concerned with both the planning process and the planning objects that result from the process (Carmona & Sieh, 2008). Carmona & Sieh (2008) argue that holistic planning acknowledges the complexity of planning as a discipline, by viewing both the product- and the service-based sides of planning (Carmona & Sieh, 2008). However, even if holistic planning succeeds to take both the planning process and outcomes into account through broad models, the methods used and interpretation of results still leaves room for failure in obtaining a fully holistic process and outcome. Besides holistic planning being both product- and service-based, it is also characterized by the variety of methods it uses (Carmona & Sieh, 2008).

3.2.3. Integral planning

Within spatial planning, there is an ever increasing consensus on the need for integrated planning (Kidd, 2007). In her article, Kidd (2007) argues that this integration involves both the spatial organization of society, as well as the integration of policy. She quotes Schön (2005), who concluded that "a territorially more integrated approach (to spatial development) is necessary to achieve the goals of structural innovation and sustainable economic growth" (Schön, 2005; Kidd, 2007). Schön states that, besides the object-oriented integration of policy and plans, there is an increasing need for coordination and cooperation between stakeholders (Schön, 2005).

Nadin et al. (2021) describes how spatial planning, there is a shift to more integration of sectoral policies in spatial planning. Specifically on themes regarding sustainable development, theorists increasingly often mention the rise of integrating landscape planning, water management, green space development, and sustainable infrastructure in spatial policies, defining spatial planning increasingly often as integral planning (Hersperger et al., 2020; Monteiro et al., 2020; Ronchi et al., 2020). However, all these integrations of different sectors into spatial planning require a certain coordination to be successful.

Kidd (2007) and Schön (2005), as well as more recent authors (Hersperger et al., 2020; Monteiro et al., 2020; Ronchi et al., 2020) all describe integral planning as spatial planning in which both the object of planning (policies and plans) as well as the process of planning (cooperation and coordination among stakeholders) become more interconnected. Although the terms comprehensive, holistic, and integral planning show different nuances, they are all concerned with obtaining a complete view of the planning problem or process at hand (a comprehensive, holistic view), in order to integrate planning objects or processes (integral planning). Therefore, this thesis deemed it necessary to discuss these three, to highlight each relevant aspect of integral planning, as a framework to break down the often vaguely defined notion of 'integral planning'. In the object of integrating energy- and rail infrastructure, these three refinements of 'integral planning' are all necessary to keep in mind. First, integrating energy- and rail infrastructure requires knowledge of two highly complicated systems. A comprehensive approach, in which policy-makers seek to thoroughly understand the systems and market mechanisms in energy- and rail infrastructure, is crucial for achieving goals in integrating infrastructure. Second, energy- and rail infrastructure development is concerned with long-term planning for large areas. Therefore, integrating these infrastructures requires knowledge of indicators that cross different sectoral and spatial boundaries. With a holistic approach to planning, this is embedded in the various methods used to obtain a holistic perspective. Third, integral planning focuses mainly on the integration of both the object of planning, as well as the planning processes. When changing the nature of energy- or rail infrastructure due to integration, it is important that policy changes with it, to prevent discrepancies between infrastructure planning and policy. Although all perspectives of comprehensive, holistic, and integral planning thus contribute to understanding what is needed in planning for integration of energy- and rail infrastructure, this thesis further uses the term 'integral planning', meaning the combination of the three perspectives as described in this paragraph.

3.2. Governance failures in integral planning

The shift from sectoral to integral planning, requires to be accompanied by a shift in governance structures in order to be successful. Nuissl & Heinrichs (2011) effectively define governance as "how actors balance their interests, coordinate activities and share information". Governance not only looks at a planning process, but also incorporates the planning *context* in planning. Following Nuissl & Heinrichs (2011), this thesis considers it crucial to analyze planning issues through an analytic governance lens. Therefore, the following section outlines different types of governance on different scales that coordinate planning processes regarding (rail and energy) infrastructure. By discussing these modes of governance, this thesis aims to further specify conditions and characteristics of governance that contribute either to the success or failure of integrating rail and energy infrastructure.

Decentralization and increased complexity cause coordination problems

Traditionally, governance is concerned with the often hierarchical relations between the state and the market. In hierarchical infrastructure planning, a local, regional or national government initiates a project and coordinates collaboration with market parties to execute the plan. However, this hierarchical form of government has changed over the past decades. Swyngedouw (2005) introduces civil society as a third realm beside state and market. In collaboration between the state, market and civil society, governance is needed to guide planning processes. Critics say that traditional hierarchical governance structures are not suitable to deal with the complexity of current issues and adapt to the rapidly changing context of planning issues. Jessop (1998) mentions heterarchical governance as opposite of traditional hierarchic governance structures. In heterarchical governance, economic and political entities exchange autonomy for influence. Jessop (1998) comes up with three forms of heterarchical governance that increase in scale: selective interpersonal networking, complex inter-organizational relations and co-evolution of institutional orders. With these forms, Jessop's analysis of heterarchical governance comes close to newer ideas of multi-level governance. In selective interpersonal networking, the governance rationality is dialogic and often on a local level (Jessop, 2002). Complex inter-organizational relations are at least on a regional scale and emphasize the synergy of resources. This emphasis of resource synergy and the integration of different organizations from different sectors, is where Jessop's rationale for heterarchical governance relates to this thesis' topic of integrating rail and energy infrastructure. Jessop's third form of governance, co-evolution of institutional orders, have societal objectives and take place on a national scale. With Jessop's second form of heterarchical governance in complex inter-organizational issues, heterarchy introduces the flexibility to adapt to failure. Four leading types of failure that are put forward are:

- Oversimplification
- Coordination problems
- Governability issues
- Absence of government

Especially coordination problems are a main concern in complex intra-organizational collaborations between rail and energy infrastructure. Not only does integrating rail- and energy infrastructure face challenges with transcending sectoral and spatial boundaries, it also transcends traditional hierarchical modes of governance. When regional energy- and rail infrastructure operators from different scales become more integrated in nature, the multiple levels of government that are responsible for the parties need to be coordinated as well. Attention for this multi-level governance is needed in successfully integrating rail- and energy infrastructure (Hooghe & Marks, 2010). Although heterarchical governance comes with more flexibility then hierarchical governance, the complexity of the planning object (integrating rail and energy infrastructure) and the various scales that affect the planning process, limits the success of heterarchical governance in guiding planning processes. A theoretical finding regarding the coordination of integrating rail and energy infrastructure, lies in Jessop's (1998) main argument that in order to adapt to governance failure, a governance structure needs to have the ability to switch coordination modes over time.

Why is lack of coordination a problem in integrating rail- and energy infrastructure?

Although integral planning is often not properly defined, it is concerned with collaboration between stakeholders and cross-sectoral policy-making. However, due to governance failures in integral planning, this coordination is not always sufficient for the planning issues planners face. This leads to three main problems. First, the absence of coordination between stakeholders, leaves collaborations vulnerable to parties pursuing their own agendas, rather than seeking 'integral' solutions that provide the best outcomes for the entire system of stakeholders. In this case, it is questionable whether a process is truly integral, or rather favors the most powerful stakeholder, covered under the vague term 'integral' (Rahman, 2015). In this manner, the term 'integral' is mainly used to create strategic ambiguity, so policy-makers do not have to take responsibility for the process. Second, the lack of coordination in policy integration poses risks that certain policy-domains are neglected. Third, without clear coordination, it is unclear who decides which stakeholders are involved in decision-making. Once again, this poses the risk of marginalized groups and less powerful stakeholders to be overlooked (Liu, 2018). The very start of determining who is part of the stakeholder field, directly steers towards a certain outcome.

Failure of networked governance as decentralized governance solution

Networked governance as solution

Since heterarchical governance still faces challenges in coordination when planning issues become more complex in scale and nature, another approach to failures in hierarchical governance is letting go of the state as important actor and put an emphasis on relations between market and civil society. Rhodes (2007) for example hints at a decentralized approach to governance. In this networked governance, the idea is that an increased autonomy for local networks improves the effectiveness of planning processes. This decentralized approach increases the efficiency of planning, because each planning issue can be addressed by a tailored-fit group of stakeholders. Market mechanisms become part of public services, leading to differentiated policy in which governance structures become more diverse and complex (Rhodes, 2007).

Limits of networked governance as solution in integral planning

In the past decades, Western countries have made this shift towards more decentralized services and more autonomy for parties in market and civil society. However, some major problems transcend the capability of local networks to solve them. Once again, the effectiveness of the governance structure is related to the complexity and scale of the planning issue. With sector-transcending initiatives and problems in integrating rail and energy infrastructure, networked governance proves to be limited. Although decentralized networked governance has been the main mode of governance in Western countries over the past two decades, increasing complexity calls for more coordination in solving planning issues.

Need for governance of governance

Evers & De Vries (2013) oppose the notion that hierarchy and joint-decision-making form a dichotomy. They argue for re-introducing hierarchy and government in governance, and propose that hierarchy and joint decision-making can co-exist. In this line of thought, a hierarchical power can oversee and guide governance processes, while leaving room for autonomy for local networks to a certain extend. Jessop (1997) calls this the organization of self-organization, and introduces meta-governance as the state's role to provide ground rules, ensure compatibility and contribute to collective intelligence (Jessop, 1997).

Since the planning object of integrating rail and energy infrastructure happens on different scales, it is a too complex planning issue to address without a form of coordination in networked governance. On the other hand, Western societies have already shifted towards a decentralized approach to governance and hierarchical governance structures fail in their inability to adapt to rapidly changing context of planning issues. Therefore, this thesis further explores the concept of meta-governance as possible approach to governance in integrating rail and energy infrastructure.

3.3. (Multi-level) Meta-governance

In debates regarding the role of governance in society, authors are often concerned with relations between state, market and civil society (Wang et al., 2018; Jessop, 1998; Rhodes, 2007). Traditionally, these relations entailed the state being on the top of the hierarchy, and planning top-down for how the market and civil society should look like (Jessop, 1998). In this hierarchal structure, the objects of planning were often spatially confined problems and sectoral challenges. However, the nature of these objects of planning have changed over time. Due to globalization and increased complexity in societal challenges, the traditional hierarchal relation between state and market and civil society, started to change (Cole, 2003). This thesis does not participate in debates regarding the definitions of government and governance and whether a shift from government to governance has taken place or not. However, this thesis acknowledges the changing nature of relations between the state and the market and civil society (Selle et al., 2018).

Two main approaches to this changing nature of relations between state, market and civil society, are Jessop's meta-governance approach (Jessop, 1998), and Rhodes' self-organization approach (Rhodes, 2007). Rhodes suggests that the market and civil society have the capability to self-organize in a form of networked governance. However, this approach to governance adds to the lack of coordination that this thesis previously established to be a main failure in integral planning. Jessop (2002), on the other hand, explores a meta-governance approach to the changing nature of relations between state, market and civil society. In a political economy approach, the state becomes 'just' another party among parties from the market and civil society. Jessop argues that this eventually undermines the role of the state. Without the state as entity on top of the hierarchy, governance is inevitable subjected to coordination problems. Therefore, Jessop (2002) argues for an entity outside of the state, market and civil society to act as a coordinating meta-governor.

After Jessop's (2002) argument for meta-governance as solution to coordination failures, different authors from a variety of sectors have written about this concept of meta-governance. Gjaltema et al. (2020) analyzes 79 papers on meta-governance, using a rather simple framework of who-, what-, why-, and how-questions to explore points of consensus, debate or neglect among theorists who write on the topic of meta-governance. Both the context chapter and theoretical framework of this thesis show that in integrating rail- and energy infrastructure, there is need for coordination. However, it is often unclear who is responsible for integral plans regarding rail- and energy infrastructure. Subsequently, it remains unclear under what conditions a coordinating entity would be beneficial in these plans. Therefore, before discussing the potential of meta-governance in integrating rail- and energy infrastructure, the 'who' of meta-governance needs to be further explored. At the same time, the context chapter concludes that there is a shared understanding in both theory and practice, that integrating rail- and energy infrastructure can contribute to solutions for challenges in the energy transition. It also becomes clear that integrating these infrastructures poses specific challenges in the changing role of rail infrastructure operators. Another risk mentioned in the theoretical framework, is that the object of planning (the 'what'), is purposely kept vague, so nobody has to take responsibility for the strategic ambiguous process. Therefore, before discussing the potential of meta-governance in these integral plans, it is needed to explore the 'what' of meta-governance, and see what elements relate to the 'what' of integrating rail- and energy infrastructure. The main problems in integrating rail- and energy infrastructure, are the ambiguous nature of the planning object ('what'), and the lack of coordination and vision on who can fulfill a coordinating role (who). Therefore, the following section adopts this analysis (Gjaltema et al., 2020) and aims to take the 'who' and 'what' of meta-governance one step further, in adding aspects and constructing the relation with integral planning processes regarding integrating rail and public energy infrastructure.

3.3.1. Who?

Jessop (1997) considers a meta-governor to be the state, involved in setting the rules in which governance takes place. However, Jessop (2002) also argues that the state is too much involved in governance processes, and therefore cannot be the coordinating entity a meta-governor should be. One of Gjaltema et al.'s (2020) main conclusions on the 'who' of meta-governance, is that meta-governors are often not clearly defined. However, certain characteristics of meta-governors can be derived. First, Jessop (1997) describes that meta-governance is needed to address coordination problems in governance. This means that a meta-governor needs to have a certain coordination capacity. This is reflected in Gjaltema et al.'s analysis, that concludes that meta-governors are often public entities, rather than private parties. Further, in most cases it is not possible to define one single party as meta-governor, but meta-governance is rather in the hands of multiple meta-governors working together (Wang et al., 2024). However, this leads to a failing mechanism in meta-governance: "In meta-governance cases, the roles of the multiple meta-governors can easily become blurred and it is very well possible for them not to work towards the same goals" (Gjaltema et al., 2020). This quote reflects the relocation of the problem. There are coordination problems in the governance between state, market and civil society. As a solution, meta-governance is introduced, but it remains vague who is exactly the meta-governor. This results in multiple meta-governors, that lack coordination themselves, which results in the same situation as before: a group of parties that lack coordination. In a recent paper on multi-level meta-governance in four cities in India, the researchers use Gjaltema et al. (2020) as analyzing framework (Marsden et al., 2024). In this paper, the authors describe the implementation of multi-level meta-governance in existing governance structures, in which there is "a scaling up of the municipality to a metropolitan region, by transferring the power of rural and urban local bodies to state government-level specialized governance instruments" (Marsden et al., 2024). Subsequently, there is not a single meta-governor in the Indian case, but rather a network of local networks, that are becoming more formalized. Therefore, in the Indian case, there is no clear single meta-governor, but rather a package of governance instruments that enable existing local networks to scale up and act as meta-governing bodies. This is a clear example of multi-level meta-governance, in which multiple meta-governors are coordinated by meta-governors on different levels (Marsden et al., 2024; Wang et al., 2024; Thuesen, 2013)

Besides often being public and often sharing the role with other parties, meta-governors are ideally independent towards the planning process and actor relations they coordinate. Although the state is often considered to be the most suitable meta-governor, the state is involved in the governance between state, market and civil society, making it an entity with an interest in the process that is coordinated (Jessop, 1998).

In conclusion, it is often unclear who the meta-governor is in cases of meta-governance. However, a meta-governor often:

- is a public entity (although not by definition);
- is capable of coordinating others;
- influences other stakeholders;
- ideally is independent, not pursuing its own agenda;
- is not bound to one specific scale of governance / transcends governance scales

In literature, meta-governance is often viewed as some concept of governance or a vague mode of governance. This thesis suggests that meta-governance is nothing without a clear meta-governor. Instead of focusing on the governance context and implications for modes of governance, this thesis starts exploring meta-governance with the meta-governing entity: the meta-governor.

3.3.2. What?

The 'what' of meta-governance is concerned with what is exactly governed. Gjaltema et al. (2020) reveals that in most cases, it is hard to define what is actually governed in meta-governance. This is also the case in integrating energy- and rail infrastructure. At first sight, the 'what' that needs to be governed seems the integration of physical rail- and energy infrastructure. Current literature on this integral planning process, complies to this by being concerned with the technological challenges of integrating infrastructure (Çiçek et al., 2022; Kaleybar et al., 2023; Kaleybar et al., 2024). However, the main challenges for integrating multi-sectoral objects, are often more concerned with governance failures than technological challenges. Therefore, properly defining the 'what' of meta-governance is a necessary condition for meta-governance to be beneficial in addressing governance failures. Generally, meta-governance is often concerned with governing actors and processes, rather than institutions and objects. In meta-governance, the meta-governor often governs a network with actors from public entities, market parties and civil society (Klijn & Edelenbos, 2007). This governing of networks of actors often takes place at the local or regional level, rather than the national or international level.

Besides governing actors, meta-governance is in some instances concerned with governing different modes of governance. In these instances, meta-governance is more concerned with the institutional organization of networks and systems and aims to coordinate different forms of governance (Rayner, 2015; Wang et al., 2024). This strongly relates to multi-level governance, in which meta-governance increasingly often is mentioned as possible mode of governance to overcome coordination failures. In integrating energy- and rail infrastructure, there are different modes of governance. On the one hand, most infrastructure operators are owned by the state, resulting in hierarchical governance. However, resulting from privatization, rail- and energy infrastructure operators often became private companies, with the state as main stock owner. This leaves infrastructure operators with complex governance structures, in which the line between hierarchy and heterarchy is often blurred. In a recent paper, Xing & Xing (2023) show how meta-governance can be beneficial in coordination of "trade-offs between collective and selective benefits". The interesting part, is that this happens on a local level in collaboration between different parties. This shows how meta-governance can guide existing governance structures in integral planning.

3.4. Conceptual framework

The previous two chapters looked at the context and governance related to integrating rail- and energy infrastructure. Together, these chapters show that failures in integrating rail- and energy infrastructure, are partially complementary to strengths of meta-governance. The shift towards integral planning is supported by theory on complexity and decentralization, and at the same time illustrated by the position of rail infrastructure operators in challenges regarding the energy transition. Theoretical governance failures of integral planning, namely the lack of coordination and clarity on the object of planning, are illustrated by the context of rail infrastructure operators, lacking coordination for collaborations between the rail- and energy sector. Figure 2 conceptualizes the main causes, problems, and relations as found in the previous two chapters:

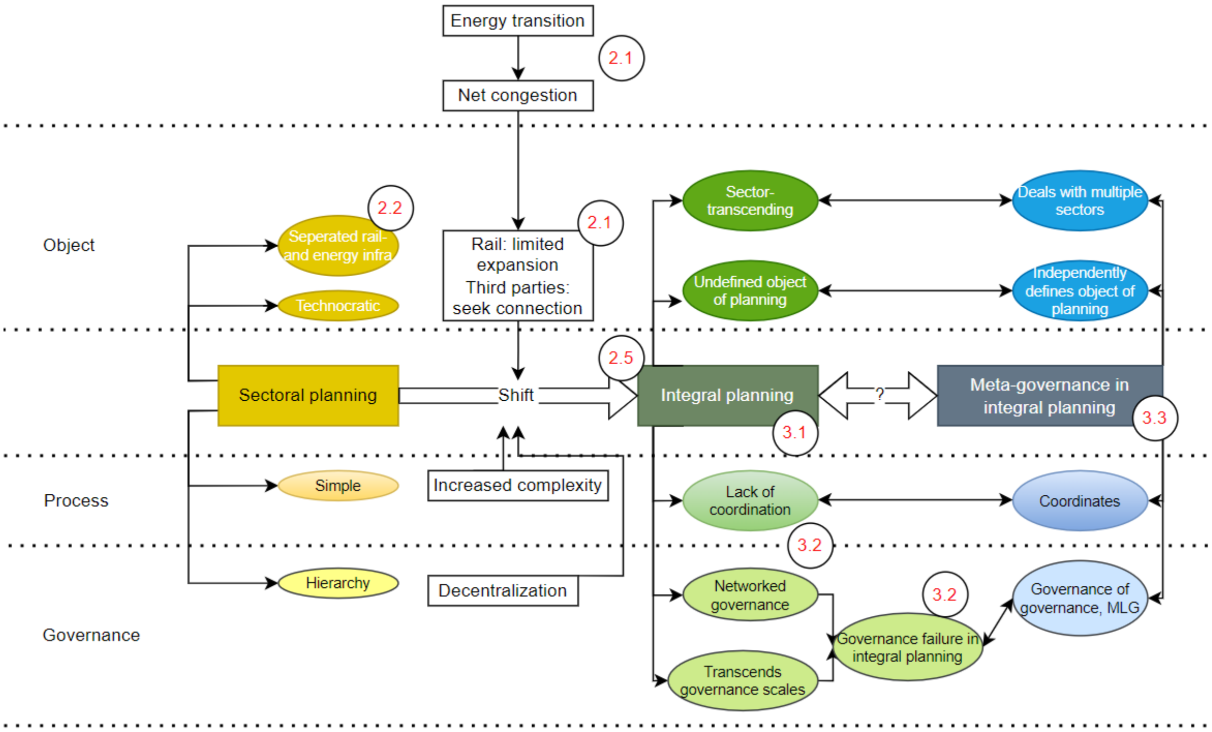

Figure 2 Conceptual Framework

It shows how both the object of integrating rail- and energy infrastructure and the processes related to this, face difficulties due to governance failures. These findings call for further research into how stakeholders involved in this integral planning process, view the contribution of a potential meta-governor to the governance of planning. Therefore, this thesis continues with an empirical research to explore how meta-governance can complement integral planning in the eyes of rail infrastructure operators involved in integrating rail- and energy infrastructure.

4. Methodology

This methodology section first discusses the break-down of the main research question into four subquestions. Following this, the research methods to answer these questions are discussed. Subsequently, the subquestions are operationalized into various subjects that from a structure for gathering results in a qualitative research. Following this, there is a section on how the results are processed and how conclusions will be drawn. Finally, the case selection for the study is conducted.

4.1. Research design

This thesis conducts a case study to three different rail infrastructure operators, to answer the following main research question:

> *How do rail infrastructure operators value the contribution of meta-governance in integral planning for integrating energy and rail infrastructure, in their positioning among other stakeholders in the integral planning process?*

To answer this question, it is broken down into three main subjects. First, the object of integrating energy- and rail infrastructure is further explored. Both the object and the processes of planning, the physical infrastructure and governance context are discussed. This study aims to reveal developments in the main challenges infrastructure operators face. A thorough understanding of the challenges is needed to reveal the areas of infrastructure planning where collaboration and meta-governance can be beneficial. Second, current and desired collaborations between the rail infrastructure operator and different stakeholders in integral planning processes for energy- and rail infrastructure are researched. Finally, this study explores when rail infrastructure operators feel a need for meta-governance, and under what conditions meta-governance could be beneficial to integrating energy- and rail infrastructure. This is summarized in the following subquestions:

1. *What is the infrastructural and governance context for integrating energy- and rail infrastructure?*
    a. *What rail energy infrastructure and governance structures are in place?*
    b. *How have the main challenges rail infrastructure operators face regarding energy developed over the past decade?*
2. *How do rail infrastructure operators collaborate with other stakeholders in integrating energy- and rail infrastructure?*
3. *Under what conditions do rail infrastructure operators see advantages of introducing meta-governance in planning processes for integrating energy- and rail infrastructure?*

Qualitative research with inductive approach

The research first aims to better understand the infrastructural and governance context of integrating rail- and energy infrastructure. For understanding context, a qualitative research is more suited than quantitative research. Furthermore, the theoretical framework shows that governance regarding integration of rail- and energy infrastructure is a complex matter. To further explore this complexity, a qualitative research provides room for unexpected results to surface. Although the conceptual framework provides some direction for questions, the approach to the qualitative research will be inductive, since there is no clear hypothesis to be researched. The research openly searches new insights into challenges for the rail sector and the rail infrastructure operator's valuation of integration of infrastructures and the potential benefits of meta-governance.

4.2. Research methods

This study used multiple methods to gather results. Besides desk research, this study conducted expert interviews and stakeholder interviews to gain insights in rail infrastructure operators.

4.2.1. Expert interviews

To obtain a broader sense of the governance context in the infrastructural planning in the countries in which the researched companies are based, expert interviews will be conducted. Since the researcher is already familiar with the governance context of the Netherlands, and expert interview was conducted with a professor specialized in the governance of the infrastructural planning in Belgium. For Sweden, one of the stakeholders could provide these insights into the governance structures, making an additional expert interview unnecessary. The expert interview further explored how this integration is already affecting governance structures. Furthermore, the expert interview identified governance failures in integrating rail- and energy infrastructure that not only illustrated findings from the theoretical framework, but also added to this in providing new insights into the less mentioned parties, such as a regulator, involved in integral infrastructure planning. The expert interviews, combined with desk research, are mainly connected to subquestion 1: *What is the current infrastructural and governance context for integrating energy- and rail infrastructure?*

4.2.2. Stakeholder interviews

To explore how rail infrastructure operators view their positions in the stakeholder field of integral planning processes, stakeholder interviews with three employees at these companies are conducted. In the selection of participants, the aim is to include at least one employee involved in strategy and one employee involved in the energy grid operation or innovation. The first part of the interviews explore what challenges rail infrastructure operators face and how they value opportunities and challenges. The inductive approach to the interviews led to new challenges surfacing during the interviews. This topic is logically mainly connected to subquestion 1b: *How have the main challenges rail infrastructure operators face regarding energy develop over the past decade?* Second, during the interviews, collaborations between the rail infrastructure operators and different stakeholders are explored. The theoretical framework suggests that collaboration in integral planning processes faces governance failures. The interviews broadened the understanding of how rail infrastructure operators position themselves among other stakeholders, and how they cope with governance difficulties in these collaborations. This led to conversations on the conditions that are needed for a solutions such as meta-governance to be beneficial in addressing these failures. Therefore, this subject is connected to subquestion 3: *How do rail infrastructure operators collaborate with other stakeholders in integrating energy- and rail infrastructure?* The subject also lays a foundation for the third subject to be discussed: the perception of coordination or the lack of coordination by rail infrastructure operators. The theoretical framework suggests that the changing nature of planning problems, both in scale and integrality, leads to coordination problems. The stakeholder interviews seek to unravel how rail infrastructure operators deal with this and how this affects their role in planning processes. This third subject relates mainly to subquestion 4: *Under what conditions do rail infrastructure operators see advantages of introducing meta-governance in planning processes for integrating energy- and rail infrastructure?*

4.2.3. Desk research

In desk research, the contexts of the three cases are explored to gain a broader understanding of the comparability of the cases and to prepare for the interviews. The main documents used in this research are described in paragraph *4.4. Data collection*.

4.2.4. Processing of results

Although the theoretical framework provides some direction for questions regarding challenges rail infrastructure operators face, collaborations they seek and conditions for meta-governance to be beneficial, the interviews are explorative in nature. This means that the researcher does not seek specific answers, but rather aims to uncover what is happening in the planning practice of integrating energy- and rail infrastructure. Therefore, the interviews will follow the three main topics as discussed in the paragraph on 'stakeholder interviews'. Subsequently, an open coding method will be used to structure results. The open coding method is used to realign responses with the structure of the four subquestions. Therefore, the coded results will be used to draw conclusions for each subquestion, leading to an answer on the main question. Paragraph 4.4 provides an overview of the data gathered.

4.3. Case selection

For determining which national railway infrastructure operators to study, a longlist is made based on comparability, after which a shortlist is made based on feasibility. Cause for this thesis were signals from the Dutch rail infrastructure operator, that planning processes regarding integrating energy- and rail infrastructure faced major governance challenges. Since the Netherlands is a densely built country, with the busiest used railway system, this thesis chooses to take the Dutch rail infrastructure operator ProRail as starting point, as first case included in the study. Subsequently, the main criterium for the longlist, is a certain overlap in governance context between the cases. First, within railway infrastructure planning in the Netherlands, regulations from the European Union become increasingly prominent (ProRail, 2023). Therefore, this thesis limits the possible cases to railway operators within the European Union. Second, ProRail is the main Dutch railway infrastructure operator and is the only main railway infrastructure operator on the Dutch public railway net. This thesis seeks cases that share this characteristic of being the only main company in maintaining the main public railway infrastructure. This resulted in a list of 17 companies in the European Union that are the main railway infrastructure operator in their country.

The following step is the selection of a short list, based on feasibility. ProRail already collaborates with various colleagues in Europe on different subjects, while lacking contacts with other railway infrastructure operators. Due to the very limited time frame in which this research is conducted, the researcher chooses to make a short list of countries that are already related to ProRail. After informal exploratory conversations with employees at ProRail, this results in a list of 5 companies.

The last step in the case selection is a quick scan on the feasibility and comparability of the companies on the short list. The summary of this quick scan is added in appendix A. Outcome of this scan is that this thesis will conduct a case study to Infrabel (Belgium), Trafikverket (Sweden), and ProRail (The Netherlands).

4.4. Data collection

This section describes the data and sources used in this study.

Desk research

Tables 1-4 show the policy documents that were used during the desk research.

General desk research

Table 1 List of documents desk research (general)

Document	Title	Reference
Energy TSI	Technical Specification for Interoperability Energy	(EU, 2014)
Richtlijn tot instelling van één Europese spoorwegruimte	Richtlijn tot instelling van één Europese spoorwegruimte	(EU, 2012)
EU Railway regulations	Third Railway Package of 2007	(EU, 2007)

Case Belgium (Infrabel)

Table 2 List of documents desk research (Infrabel)

Document	Title	Reference
Net declaration	Netverklaring 2025	(Infrabel, 2023)
Brochure energieafname	Your Power – Tractie-energie 2022	(Infrabel, 2022)
Elektriciteitswet	Elektriciteitswet 29 april 1999	(Federale Overheidsdienst Jusittie, 1999)

Case Sweden (Trafikverket)

Table 3 List of documents desk research (Trafikverket)

Document	Title	Reference
Net declaration	Network Statement 2025	(Trafikverket, 2024)
The Railway Market Act (2022:365)	Järnvägsmarknadslag (2022:365)	(Sveriges Riksdag, 2022)
The Electricity Act (1197:857)	Ellag (1997:857)	(Sveriges Riksdag, 1997)
The Swedish Transport Agency's regulations for access to railway infrastructure and services (TSFS 2022:32)	Transportstyrelsens föreskrifter om tillträde till järnvägsinfrastruktur och tjänster (TSFS 2022:32)	(Transport Styrelsen, 2022)

Case The Netherlands (ProRail)

Table 4 List of documents desk research (ProRail)

Document	Title	Reference
Rail concession	Beheerconcessie 2015-2025	(Ministerie van Infrastructuur en Milieu, 2014)
Net declaration	Netverklaring 2024	(ProRail, 2024)
GDS Exception	Besluit ontheffing Railinfratrust elektriciteit	(Autoriteit Consument & Markt, 2014)
National rail law	Spoorwegwet	(wetten.overheid, 2019)
Statuten ProRail	Statuten van ProRail B.V.	(ProRail, 2019)
Ppt energy vision	Energievisie	(ProRail, 2022)

Interviews

Table 5 shows the interviews that were conducted during this case study. The topic lists and coding books are added in appendices C and D.

Table 5 List of conducted interviews

Respondent	Function	Company	Interview date
Respondent 1	Energy Management	Infrabel	16-04-2024
Respondent 2	Expert Competence Center Electrification – Energy Transition	TUC RAIL	17-04-2024
Respondent 3	Guest Professor Transport Economics	University of Gent	29-04-2024
Respondent 4	Strategy Expert	Infrabel	29-04-2024
Respondent 5	Power System Specialist	Trafikverket	30-04-2024
Respondent 6	Power System Engineer Project Manager Power Supply High Speed Rail	Trafikverket	06-05-2024
Respondent 7	Program Manager Sustainability Spatial Planning	ProRail	02-05-2024
Respondent 8	System Specialist Energy Supply	ProRail	07-05-2024
Respondent 9	System Specialist Energy Systems	ProRail	07-05-2024
Respondent 10	Corporate strategist	ProRail	28-05-2024

Limits of findings

This thesis needed to be finished in a timeframe of five months. This limited the number of interviews the researcher could conduct. Therefore, a main limitation of the results is the fact that nearly all respondents are from the rail sector. Although the goal of this thesis is to explore the role of the rail infrastructure operator, interviews with policy-makers and other stakeholders could clarify this role further.

Another limitation is the inevitable bias of the researcher. This thesis was written during an internship at ProRail, which provided valuable connections. However, this also meant that the researcher became especially familiar with one of the three cases.

5. Results

This results chapter outlines the results from both desk research and the conducted empirical research. For each case, the current working of the rail and energy infrastructure is shortly discussed, followed by the current governance context. These are both partly results from desk research and partly from expert- or stakeholder interviews. Finally, this chapter discusses general results regarding conditions for meta-governance to successfully guide the integration of rail- and energy infrastructure, as well as limits to the integration of rail- and energy infrastructure and the role of meta-governance in integral planning.

5.1. Belgium

5.1.1. Infrastructure

In Belgium, the main rail infrastructure operator is Infrabel. Infrabel controls two main traction energy systems that feed the catenary from which trains can get their energy (Infrabel, 2022). One energy grid runs on 3 kV DC power for most of the Belgian railways. The other grids are the 25 kV AC power traction grid between Dinant-Bertrix-Athus, primarily for cargo transport, and the 25 kV AC power traction grid for the high speed railway. The traction energy grids have a total of 85 connections to the public energy grid from which energy goes into the rail traction system. Figure 3 shows a simplified basic model of the connection between the rail and public energy grids. Here, the green lines show the public energy grids. Yellow lines show the substations ("tractie-onderstation") that convert energy from the public grid to the desired (3 kV DC) power that can be used in the traction energy grid to feed the catenary. 60 of the 85 substations for the traction energy grid are connected to the high voltage public energy grid, the transmission grid operated by Elia. The other 25 substations are connected to medium voltage energy grids, the distribution grids operated by various regional energy grid operators. As figure 3 shows, generated energy goes into the public energy grid (via the blue arrows), and there is no direct connection between the generation of electric power ("Productie") and the traction energy system that Infrabel uses. Therefore, rail energy supply is directly or indirectly connected to and dependent on the public grids. This means that changes to use of rail energy grids, affect the public energy grids. The lack of transport capacity on the public grids is not solved by using the rail energy grid as an alternative, since this would still indirectly entail a connection to the public grid via the rail energy grid.

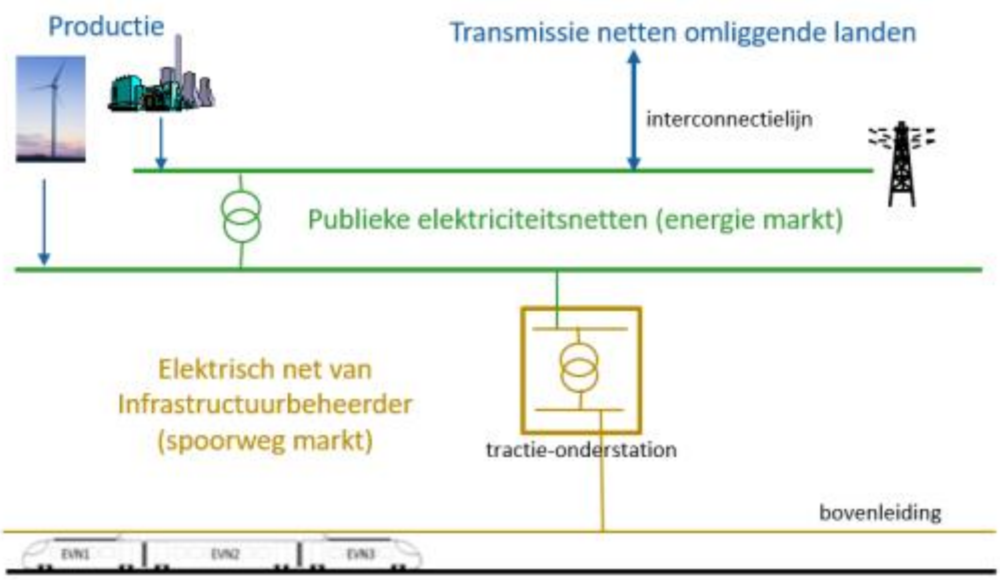

Figure 3 Model connections between public and traction energy grids (Infrabel, 2022)

5.1.2. Energy

On a national scale, Elia is the energy grid operator for energy transport via the high-voltage transmission net. For the lower distribution energy grids, each of Belgium's districts (Flanders, Wallonia, and Brussels) has its own distribution grid operator. This is Fluvius in Flanders, Ores in Wallonia, and Sibelga in Brussels (Infrabel, 2022). Besides these main energy grid operators, there are various smaller energy grid operators. In line with findings in the theoretical framework (3.2), the increased complexity of planning issues due to the multiple scales on which stakeholders operate, need a form of multi-level governance and scale-transcending guidance (Hooghe & Marks, 2010).

The end-users in the rail energy system, the train operator companies, have to use Infrabel's catenary and traction transport and distribution infrastructure when operating on the Belgian railway. However, it is not mandatory for end-users to choose Infrabel as energy supplier. Under the federal electricity law (FOD, 1999), end-users of rail infrastructures are free to choose any energy supplier. In practice, train companies have never chosen for an energy supplier other than Infrabel. However, respondents 1 and 4 from Infrabel both point out that this law of free choice of energy supplier withholds Infrabel from investing in long-term energy generation projects. The respondent emphasizes that multiple offshore wind parks are built in the coming years. Parties that invest in such projects, often have a 20 year contract getting energy from the wind park. However, Infrabel cannot make any contracts to resell the energy to train operators for longer than 2 years, since the electricity law prohibits this. Therefore, an investment in energy supply for 20 years, without the certainty of a similar long-term contract with train operators for reselling, poses a too great risk, leading to no long-term investments in long-term energy supply from Infrabel's side. Respondents highlight that this law is important and is unlikely to change in the near future. This illustrates what the theoretical framework describes as the limits of networked governance, where free market mechanisms are not suitable for long-term planning issues beyond local scale. It shows a need for some form of hierarchy or coordination, to overcome failures of short-term interests of market parties (Evers & De Vries, 2013).

Respondent 1 also argues that Infrabel should have more collaboration with other parties for buying energy: *"NMBS has a very predictable profile of energy-demand. Buying energy in collaboration with parties with different peaks, could provide opportunities for more appealing buying profiles on the market".* On this moment, such collaboration with other parties does not exist yet. Respondent 3, an expert on economics and the rail sector, mentions that the *"rail sector is quite closed and traditional".* This culture might complicate such collaborations.

5.1.3. Current governance and stakeholders

For engineering consultancy, Infrabel mainly relies on TUC Rail. Although TUC Rail is a private company, respondent 2 emphasizes that Infrabel and TUC Rail are interwoven in their business. As an example, respondent 2 mentions that Infrabel needs to give an official research request for TUC Rail to execute. However, TUC Rail is highly involved in setting up the formal request from Infrabel. In some instances, TUC Rail has an innovative idea and seeks to steer Infrabel towards their goals.

Respondent 2 also highlights that this relation between TUC Rail and Infrabel can sometimes cause friction. Employees at Infrabel feel undermined in their position of when TUC Rail proposes too many innovative ideas. At the same time, employees at TUC Rail feel undervalued in their innovative ideas and face resistance from a rather traditional rail sector. This fits in the picture of the rail sector as quite traditional, as mentioned by the expert respondent 3.

Rail infrastructure operator as energy grid operator

Respondent 4, an energy strategist at Infrabel, reflects on the relation between Infrabel and public energy grid operators. On a national level, Infrabel has connections to Elia's energy grid and a good relation. However, on lower scales, energy grid operators often view Infrabel as nothing more than a customer. Respondent 4 says that these regional or local energy grid operators are often unaware of Infrabel's role as energy grid operator.

Besides the unclarity of Infrabel's role as energy grid operator to certain public energy grid operators, respondent 4 mentions a problem in the governance of integrating rail and energy infrastructure. In Belgium, the national government is responsible for Infrabel. This means that regional ministers are not responsible for Infrabel and therefore less concerned about their plans. However, these regional ministers are responsible for the regional energy grid operators. Respondent 4 explains how Infrabel tried to offer their capacity as an energy grid operator to help with grid capacity, but that regional ministers blocked these efforts. In these cases, Infrabel was considered competition for regional energy grid operators, rather than a helping stakeholder. Since the regional ministers are not responsible for the national Infrabel, the risk of competition for regional energy grid operators outweighed possible opportunities. This illustrates a clear failure in multi-level governance.

> *"We do not feel any pressure to do anything to help the public energy grids. It is rather the opposite: we fear that if we were to do anything on the grid, regional governments will block us, because we would become competition in the eyes of regional ministers. They are not responsible for us, so they are not interested in us as well"*

Respondent 4 describes the relation between Infrabel and the state as good. The respondent mentions that "*specific on energy, they are super supportive. (...) They are a real partner. Even with specific legal questions, they support us with advise".* However, the regional governments in Belgium are less supportive and view the rail energy infrastructure as a threat, rather than an opportunity. This emphasizes this thesis' notion in the introduction, that research of the governance aspects of integrating rail- and energy infrastructure is at least as relevant as research of the technical aspects.

Lack of market regulation

In integrating rail- and energy infrastructure, the regulatory bodies from both the rail market and the energy market are involved. In the perception of respondent 4, the "*railway regulator is not active at all. They are only concerned with the cost of train paths and infrastructure, but totally neglect energy".*

Respondent 4 mentions large-scale project developers as another party with which Infrabel would like to collaborate. However, this faces legal challenges: *"Since we're not private, we cannot bilaterally close a contract with a renewable energy developer. We have to launch a public tender. If there are not enough candidates, we cannot do it. So we would like to collaborate more with that type of actor, the developer, but that is hard due to regulation".* The respondent points out that certain regulations could change over time, but that would take time and has the risk of being only a theoretical solution with little effects on the planning practice.

5.1.4. Main challenges for integrating rail- and energy infrastructure

Cooperating in purchasing energy

The Belgian respondents point out various main challenges for integrating rail- and energy infrastructure. Respondent 1 mainly focuses on the processes of buying energy. There are less and less parties willing to supply energy to the rail system, and respondent 1 sees the need for more collaboration. *"Larger volumes and a more fixed profile, makes the energy demand more predictable and therefore more easy to agree on financial hatches."* The respondent sees collaboration with parties within the public sector in collectively buying energy as a possible solution. However, respondent 1 directly points out that this is complicated: *"A problem with this is the structure of the Belgian state. There is a Flemish energy cooperation that does this collective buy-in for the public sector in Flanders, whereas we would like to* *see this for the entire country".* For now, there is no contact between Infrabel and the Flemish energy cooperation yet, as Infrabel is not part of this cooperation of the public sector. Infrabel purchases its own energy, lacking cooperation with other parties. Respondent 1 points out that a first step is to provide more detailed insight in Infrabel's energy demand. Following, Infrabel needs to reach out to the Federal Government and the Regulator, to ensure that there is no breach of the rail- or energy market in the collaboration. Only after the needed legal changes, contact with the Flemish energy cooperation for broader, nation-wide collective energy purchase could be discussed.

Core business vs innovation
Respondent 2 points out the renewal and expansion of rail infrastructure as main problem, even in the light of integrating rail- and energy infrastructure. The respondent *"wants to talk about the core-business: ensuring trains can drive".* The focus in this 'core business' has changed over the past decades, from being focused on expansion to more emphasis on 'only' renewal of rail infrastructure.

The respondent also strongly believes in the need for an energy transition and leads different initiatives to convince people of this challenge and the effects on railway infrastructure. "*I strongly believe in it, it is the only way. (…) We can help the transition in the field of mobility, other parties need to do things beyond the scope of mobility."* However, the main priority remains the core business of ensuring trains can drive: *"We all know, the energy transition is necessary. I started initiatives to convince people at TUC Rail and Infrabel that we can do a whole lot more with our energy grid than just powering trains. But the main task, the core task remains: letting trains drive and increase the capacity for more trains to drive".*

The apparent dichotomy between pursuing the core business of facilitating rail infrastructure and accelerating the energy transition, is visible throughout Infrabel's organization. *"The CEO of Infrabel is positive towards initiatives to help the energy transition, but certain groups within the company show skepticism and resistance".* Respondent 2 observes two main reasons for this resistance. First, people believe the energy transition is not part of the core business of Infrabel. Second, the relation between TUC Rail and Infrabel knows some tension. Colleagues at Infrabel sometimes wonder "*what are those guys at TUC Rail doing? They work for us and should just do what we ask. We (Infrabel) will determine whether the energy transition is interesting or not"*.

When the main priority would be ensured, the respondent points out that international collaboration is needed to accelerate the energy transition in the rail sector. Within the taskforce of European Rail Infrastructure Managers (EIM), the respondent actively seeks partners in the energy transition. However, *"although there are partners that could help, we need a whole coordination on a European level and more standardization".* This illustrates the theoretical finding that increased complexity of planning issues exceeding local scales, need guidance to find solutions (see 3.2).

5.1.5. Meta-governance in integrating rail- and energy infrastructure
Respondent 2 points out five main developments in Infrabel to accelerate the energy transition. Within these developments, Infrabel seeks collaborations with parties within the mobility sector. There is some need for coordination, since the respondent strongly believes that collaborations should only be to the extent of the public mobility sector. Respondent 2 points out the need for the law to change and make these collaborations possible.

Respondents 3 and 4 emphasize the need for coordination and regulation of the rail- and energy market, to support efforts to integrate rail- and energy infrastructure development. The multiple governance levels in Belgium, with one national government and relatively autonomous governments in the three districts, cause governance failures in integrating rail- and energy infrastructure. Flanders is the only district with an active, independent regulator on regional scale. Since this market regulations is concerned with the relation between two layers of government, respondents 3 and 4 mention that the independent regulator from Flanders could scale up to a national level and partly take on this role. Respondent 4 points out that coordination is needed, to ensure there are no inconsistencies between different layers of government in their support for collaboration. The party responsible for the rail sector (the national government) is on a different level than the parties responsible for the energy grid operators (regional government). This separation of responsibilities complicates collaborations and the respondent calls for coordination.

Respondent 3 highlights that the market should not be dominated by the state nor by private parties. *"With dominant private players, there is a risk of unfairly high profits. With the state as dominant party, losses are often piling up, resulting in poor service. I think a regulator should steer the market".* In sections on integrating rail- and energy, the respondent often comes to the conclusion that an independent regulator is needed as a guide to ensure fair processes. Multiple stakeholders and literature point out that whoever is coordinating the complex multiple levels involved in planning processes for rail- and energy infrastructure, should be independent and transcend traditional layers of responsibility.

5.2. Sweden

5.2.1. Infrastructure

In Sweden, the rail infrastructure operator Trafikverket operates one of Sweden's largest energy grids. Trafikverket manages 10.000 kilometers of catenary for electrified rail lines. This system is fed by a 11 or 22 kV system of traction energy lines. To feed this catenary system, Trafikverket also operates a 132 kV high voltage transmission energy grid. This grid is used to transport energy over large distances in the country with minor energy losses. Energy is supplied to the system via either own generation or the public grid, and via substation converted to the desired power. Besides internal power supply, Sweden imports traction energy from Norway at the border. Specific the 132 kV high voltage transmission grid could potentially provide additional transport capacity for transporting energy over large distances.

5.2.2. Energy

In Sweden, there are different energy grid operators. The main high voltage (400 kV and 220 kV) transmission grid is owned by the state and operated by Svenska Kraftnät. Below this transmission grid, there are various distribution grids with lower voltages (<130 kV). This market of distribution grids is privatized, with different energy suppliers using the distribution grids in a market, supervised by the regulating Energy Markets Inspectorate. Nord Pool is the market on which energy is traded. Trafikverket has a contract for the energy-supply for the rail power system from Nord Pool. The rail power grid is considered an 'internal, industrial power grid', owned by Trafikverket. This status entails that Trafikverket is not allowed to open its grid for different energy suppliers or to sell energy to make a profit. Trafikverket is only allowed to 'pass the costs along' (Trafikverket, 2015). These characteristics of the energy grid, makes that Trafikverket "*does not have to follow all the legislation an energy company or grid owner has to follow".* This, combined with their position as largest single energy user, makes the prices of Trafikverket very competitive, ensuring operators do not need to choose their own supplier (Respondent 6). Although this is beneficial within the rail sector, these characteristics of the special status of the closed rail energy grid complicates collaborations beyond the rail sector, since this potentially harms the beneficial position of Trafikverket in the Swedish energy market.

5.2.3. Current governance and stakeholders

Integrating expertise between different modalities

In Sweden, the rail infrastructure operator is part of the broader Swedish Transport Administration, Trafikverket. Trafikverket is responsible for the infrastructural planning for road, rail, shipping and aviation. Respondent 5, an power supply specialist at Trafikverket, explains that a power specialist at

Trafikverket is not necessary a specialist in one of these four domains, but rather an expert that shares expertise for all modalities. Besides Trafikverket, SL, IBAB, GS and certain industries are other rail infrastructure operators on a either a more local scale, or for a specific railway. Respondent 5 does not see a clear potential for collaboration between the rail energy infrastructure and other parties in integrating the physical use of the infrastructure. However, the respondent points out that within Trafikverket, the different sectors (road, rail, shipping, and aviation) help each other in sharing expertise: "*they all operate separately. But now when they're trying to make the ferries electrical, they come to us with questions regarding charging for example".*

Rail infrastructure operators as executing agency

Respondent 6 reflects on the relation between the political and technological aspects of rail infrastructure planning, and favors the integrated form of the ministry and rail operator at Trafikverket over governance structures in other European countries: *"In other countries, it can happen that you have to do something that is technically nonsense, but they just have to fulfill it. I really prefer it like we have it. It's just targets which are not technical, and then it is up to us how we fulfill it."* This means that, although Trafikverket also houses the ministry of infrastructure, it stands relatively free from the political aspects of infrastructural planning. "*The politicians don't care at all about hów we increase our punctuality".* Respondent 6 mentions that this has been the case in Sweden for decades. "*The responsible minister (political, red.) does not call our general director (Trafikverket, red.) and tell him what to do. That's called 'minister-steering' and I don't know if that is officially not allowed, but it's at least a tradition that you don't do that".*

5.2.4. Main challenges for integrating rail- and energy infrastructure

Respondents 5 and 6 explain how executing maintenance faces different challenges for Trafikverket. A first challenge is the large amount of maintenance that is needed in the coming years. Respondent 6 points out that there has been "*a lack of maintenance for so many years, so the system is aging."* Respondent 6 continues: "*We have funding to reinvest in it, but we don't have any capacity on the tracks at all because there is so much traffic. It is hard for us to get access to the tracks in order to do maintenance"*. In 2016, an internal study at Trafikverket showed that passenger traffic will increase with 50% until 2040 and the cargo volume transported via rail will increase with 35% (Trafikverket, 2016). Although this growth is accompanied by state funding, one bottleneck is the ability to temporarily close tracks to renew the infrastructure.

Respondent 5 adds that it is hard to find the right contractors and operators to carry out the maintenance. The respondent describes how these contractors were once fully state-owned, but have become increasingly privatized. This gives contractors more freedom in choosing the jobs they want to carry out and those they do not. Respondent 5 describes how rail maintenance is not appealing to contractors for various reasons: *"They (the contractors) can work with whoever they want. We have very few operators and they don't have the time or capability to work with us. (…) We also have a weakness in our unclear and hard to follow requirements and rail system. So it's very hard for new entrepreneurs to come in"*. There is a shortage in contractors, and the complexity of regulations and the rail system makes it harder for new contractors to start, worsening the shortage. Besides, respondent 5 explains that Trafikverket cannot just pay more to make it more appealing for contractors to work for Trafikverket, since it is fully government-funded and they do not want to overpay. This illustrates the notion from paragraph 3.2 in the theoretical framework, describing that the privatization of the rail market leads to failures in addressing current issues on national scale.

Lack of long-term planning

A challenge that surfaces as a result of the privatization of maintenance, is that all maintenance and building projects are fixed in 6-year contracts. Respondent 5 explains how this stands in the way of long-

term investments and infrastructural planning: *"They are buying a maintenance contract for 6 years, but then it's constant fighting over these 6 years that they don't do what is in the contract. It is frustrating, and in these contracts it are just small fixes, but we cannot do anything for 10 years for example, since we made the contract for 6 years."* Subsequently, "*these contracts are only focused on doing it the cheapest way possible, but that is not always the most beneficial. Sometimes you have to pay more to make it efficient in the long-run."* Respondent 5 sees a responsibility for Trafikverket to take more control, although this faces legal challenges: *"It would be better if Trafikverket should actually maintain these contracts in-house the best way possible, in more innovative ways. I feel it is better if we take more control there, but Trafikverket is not allowed to own too much or have too much in contract. But as it is working now, it frustrates people from both sides."*
Respondents 5 and 6 both point out that privatization and contracts with the market, resulted in a lack of long-term infrastructure planning. Since integrating rail- and energy infrastructure requires collaborations that span over the duration of these contracts, this privatized market stands in the way of integrating infrastructure from different sectors.

Rail energy grid for third parties
In Sweden, there is a lot of hydropower generation in the North, that needs to be transported towards the more densely populated areas in the South. Respondent 6 explains how Trafikverket has looked into their possible role in using the rail energy infrastructure to transport volumes of energy for purposes beyond the rail sector. However, this faces a few challenges. First, under current laws, "*Trafikverket is not allowed to transmit any other energy than for our own needs. On the other hand, we are not obliged nor allowed to connect anyone else to our network. But we don't need any concession for our network either. So we are allowed to build power lines, even if they run not exactly parallel with the railway."* This means that changing the law so the rail energy infrastructure could be used more broadly, also affects benefits of current legal structures for Trafikverket. Respondent 6 points out that technically and legally it is possible to use the 132 kV high voltage energy grid to transmit energy from North to South, as long as Trafikverket does not use is to resell energy for profit. Trafikverket can pass the costs along and transmit. However, although the 132 kV system runs over long distances from North to Stockholm, *"the system is designed to transmit power over 500 or 300 kilometers at maximum, because the capacity is quite low. So it is designed in order to lower the amount of converter stations, not to transmit power over long distances."* The respondents point out that even if there are possibilities for a broader use of the rail energy grid, it is not designed for those purposes, and the actual contribution to capacity problems is marginal.

5.2.5. Meta-governance in integrating rail- and energy infrastructure
Respondent 6 tells how in Sweden *"there was a role named 'sector-coordinator'. That means that someone was responsible for the sector, but that role does not exist anymore. So there is no real coordinator".* The respondent explains that *"there is no one responsible for the system as a whole".* As a result, politicians make plans and targets, but these change often and the targets are specific, rather than supporting an integral plan for an efficient railway system in the entire country. Respondent 6 points out that the market can always choose for itself to cooperate and make more integral plans, but "*there is no coordination to make it mandatory or anything. We lack this kind of function."* The respondent uses the scattered ticket-infrastructure in Sweden as an example of how the lack of coordination results in less efficient use of the rail system.

Respondent 5 points in the same direction regarding coordination, and paints the picture of politicians that are deciding what the main policy directions for the rail- and energy sector are. Furthermore, when discussing coordination in integration of infrastructure, respondent 5 points out that *"we are so used to put a lot of trust in the market, but right now, I feel like doubting that more and more".* The respondent challenges the idea that the privatization gives the market the freedom to come with solutions to large problems. The respondent sees the lack of long-term infrastructural planning (including possible integration) as a result of market failure. *"If we are in control and take these steps, we can develop our grid over time. Now, nobody will invest for anything outside their contract for over 6 years."* Respondent 5 sees the need for Trafikverket to coordinate their own targets and infrastructural planning more, rather than a greater task for the political government.

5.3. Netherlands

5.3.1. Infrastructure

Rail traction energy supply dependent on public energy grid

In the Netherlands, ProRail is the main rail infrastructure operator. ProRail operates different energy grids. The main energy grid that powers the catenary on electrified rail lines, is a 1,5 kV DC traction grid, illustrated in figure 4. ProRail has connections to the public energy grid (grey lines), and via substations (yellow lines to substation) the power from the public grid is converted to the 3 kV distribution grid (red lines). Signs and train detection systems are connected to this grid. Power is also converted to 1,5 kV DC power, to feed the traction energy grid (black lines) that supplies trains with power via the catenary. Besides the energy grid for safety systems and traction energy, ProRail has some regular connections to the public energy grid (grey lines) to power certain infrastructures as bridges and to power systems within the substations.

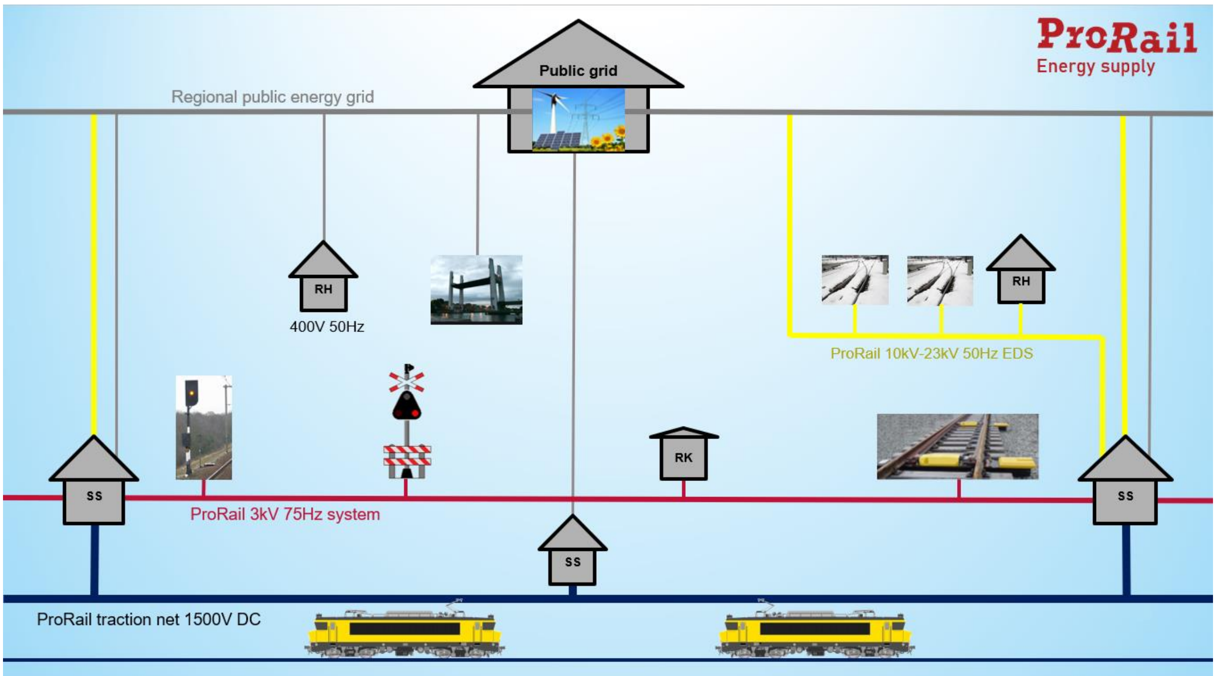

Figure 4 Current ProRail energy supply system (ProRail, 2022)

ProRail aims to use 100% renewable energy sources to power its operations in 2030, and explores possibilities for own power generation. However, connecting renewable power sources to the 3 kV grid (red lines) is not desirable for two main reasons. First, the grid is not built to transport these large volumes of energy over its 3 kV system. Second, the 3 kV grid powers all train safety systems. A broader use of this net is complex, since ProRail will not take any risk with these vital system. Therefore, the study resulted in a preference for the system as shown in figure 5. In this system, there is one 10-23 kV energy grid that is connected to various energy sources, either to privately owned renewable sources or via substations to the public energy grid. Both the rail safety systems, energy demanding infrastructure and the traction energy grid are connected to this system.

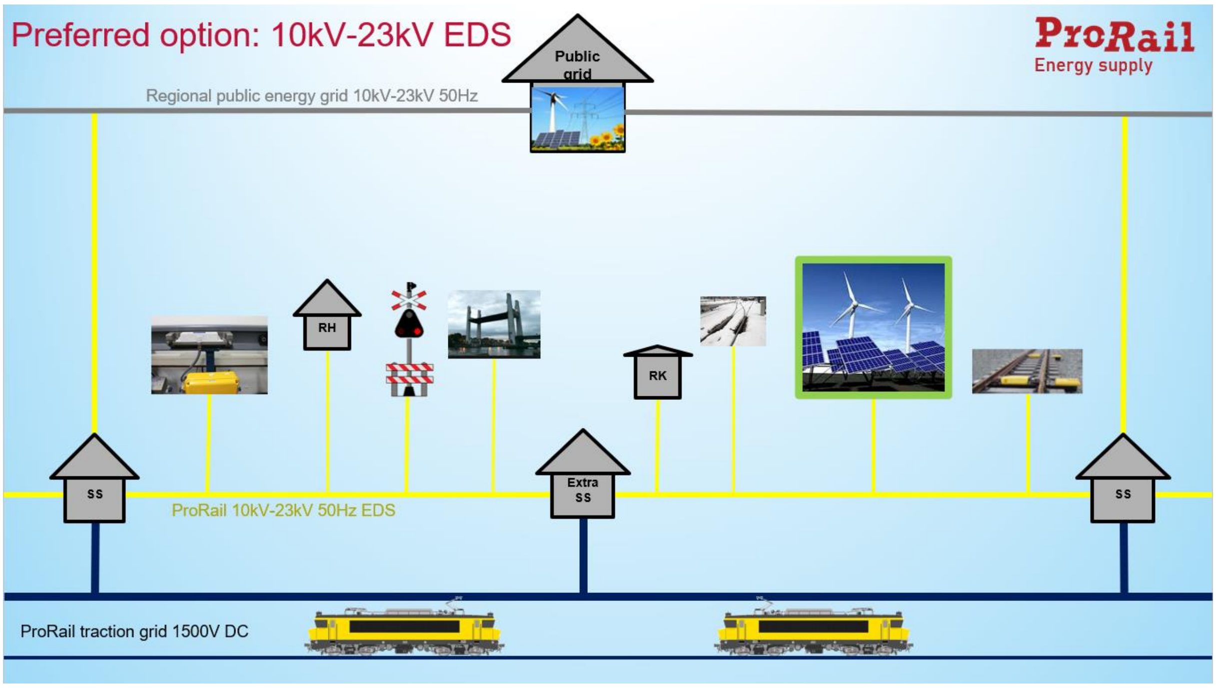

Figure 5 Potential new ProRail energy supply system EDS (ProRail, 2022)

5.3.2. Energy

For the purchase of energy, since 2008 ProRail is member of the VIVENS cooperations, in which various rail companies are collectively purchasing energy. The main members are ProRail as rail infrastructure operator, the national train operator NS, various regional train operators and contractors.

Various respondents mention connecting third parties to the ProRail power systems as both an opportunity, and (more often) a threat to rail infrastructure. All respondents are resolute that connecting large industries or residential areas to the rail energy system is not beneficial. Reason for this is that *“we do not have enough added value”* and *“lack the capacity to properly do something for industry”*. With connecting residential areas to the rail system, the governance of prioritizing rail over residential purposes becomes hard. Respondent 8 mentions that *“we can play a very small role. Maybe, in the shift to 3 kV, we can provide more flexibility and therefore help. But we are relatively small. (…) People who say that we can mean a lot for public energy grid operators are in a dream. Public energy grid operators do not focus on us, they focus on the larger converters.”* This shows a clear discrepancy between the stakeholders’ view on the broader use of the ProRail energy grid, and recent media coverages on the topic. The latter increasingly often view the rail sector as useful and substantial opportunity in solving problems regarding net congestion. This gap indicates that the risk of sectoral needs being overlooked in integral plans is present, and a form of guidance is needed to ensure a process in which the rail infrastructure operator feels understood. In addition, the limited contribution of the rail energy infrastructure, means that a too large (meta-)governance structure might be disproportional in regards to the goals it wants to achieve.

Core business

Respondent 7 also highlights that this form of collaboration on the rail energy grid, poses risks for the rail infrastructure itself: *“You have to ensure that your own systems are protected. Collaboration means that the system becomes fluctuating. When a train passes, power goes to the train, I don’t know if it would be appealing to a commercial party to connect charging infrastructure to ProRail’s systems.”*

5.3.3. Current governance and stakeholders

ProRail being a private company, while fully owned by the state, results in ambiguity on ProRail's relation with I&W. Respondent 7 points out that some say *"ProRail is an executive agency, so I&W needs to stand up for the interests of the rail sector"*, while others say *"it is up to ProRail. Others (including I&W) will not stand up for the interests of the rail sector".* Respondent 8 is clear on the role of ProRail in relation to I&W: "*We will always remain an executive agency. (…) I&W gives us the funding, both for function allocation and function maintenance. (…) I&W decides everything and we basically do not decide anything."* Respondent 10 points out that ProRail increasingly often functions as a relative independent advisor to I&W, while still acknowledging that the decision power lies with I&W: *"I believe it is a good development that we become that independent advisor to the Ministry".* Although results are not fully conclusive, all respondents from ProRail acknowledge the complexity of the relations between ProRail and I&W, but have a broad consensus on the fact that decision power is with the Ministry. Respondent 7 and 9 mention that ProRail needs to look after its own interests. Respondent 8 considers ProRail's role to execute decisions from I&W, with an emphasis on ProRail not being the decision-making party, and respondent 10 suggests that ProRail should invest in its active role as advisor to I&W, nuancing the view of ProRail 'just existing' for executing I&W policy.

5.3.4. Main challenges for integrating rail- and energy infrastructure

Spatial challenges

Respondent 7, active in the spatial planning department of ProRail, points out that scarcity of available space is one of ProRail's main challenges, also in expanding the energy system. *"When we want to expand our energy systems, for example by building extra substations, you have to fit that in spatially. (…) The main issue is to find available space that can be used without ecological difficulties".* The respondent highlights that renewable energy sources often consume more space than conventional sources. ProRail's plots of land are often available, yet hard to use for constructing solar parks, respondent 7 mentions, because of the ecological value present. "*Because there is no agricultural activity in those areas, and we do not maintain those areas regularly, these plots of land become safe-havens for various plant- and insect species."* As soon as ProRail initiates a project to let a party construct a solar park on these plots of land, a species is discovered and *"then you have to compensate 5 acres of land with ecological value. That is nearly impossible".*

Respondent 8 adds to this that the energy transition is *"mainly a spatial planning issue, not primarily a technical one. We could help with something different than only how many electrons we transport to each other".* One idea is to use the strips of land that are used for rail power cables, and allow energy grid operators to use these strips for their power cables as well. ProRail also already rents out a piece of land for a solar park. However, respondent 7 also points out that ProRail should be careful not to risk its own expansion plans for the future, by cooperating with energy grid operators too much. Respondent 7 adds to this that ProRail is reactive in its approach to these spatial challenges, and lacks the capacity to "*monitor what is happening policy-wise on a municipal or provincial level".*

Net congestion

Respondent 7 also points out that net congestion is one of ProRail's main challenges. *"Net congestion affects us negatively. If other parties are unable to expand, then we cannot expand our grid in those places as well. We submit requests for expanding our grid capacity, but these are rejected."* The respondent also doubts whether *"we have this problem on the radar properly",* and emphasizes the importance of more capacity for monitoring developments in spatial planning policy.

Respondent 8 shares a different perspective on net congestion, by pointing out that the whole problem of net congestion is actually beneficial for energy grid operators. "*People feel that moving to 3 kV is a* *problem for public grid operators, but I dispute that. It is actually a beneficial move for them, let me explain that. When looking at net congestion, which I purposely do not mention as a main challenge, that is a game that's very good for public grid operators. Those guys receive billions that they can invest."* After discussing this response with other stakeholders at ProRail, it becomes clear that this view is not shared widely within the organization and that ProRail seeks collaborations with public grid operators, starting with a shared understanding of net congestion as major challenge. However, such comments can also point to the need for guidance and coordination in solving sector-transcending issues like net congestion, to prevent stakeholders from feeling unequally affected by these issues, while others seem to benefit.

Backlog of maintenance
Besides net congestion and spatial challenges, respondent 10 points out that "*there is simply just a lot that needs to be done".* The respondent describes how the post-war rail infrastructure in the Netherlands faces major needs in maintenance, and that the core of this problem shifted from funding to availability of work force: *"First we thought that the funding would be a major problem, that we did not have enough money to do everything. However, that is shifting towards the ability to actually use the money. (…) We just need the mechanics, that is the bottleneck".* Respondent 10 emphasizes the need to "*look smart at what we do. (…) Maybe it is smart to accept a certain risk somewhere, so we can do other things elsewhere".* Although the respondent's vision on thinking 'smart' seems valid, it could potentially face governance problems due to the previously mentioned ambiguity surrounding ProRail's role in relation to the state. Since it is I&W that is responsible for the railways and officially determining what needs to be done, thinking 'smart' and taking risks gets complicated, because political entities are less willing to publicly take risks.

Lack of long-term planning
All respondents in some way pointed out that there is a lack of long-term vision plans for the rail sector. Respondent 8 describes how *"the problem is that we do not look forward enough. In discussing how to deal with issues in 2025, we see that we have to take some more risks. (…) That has everything to do with a lack of long-term planning. In planning for energy-supply, we are used to be just a little ahead of the new train schedules. But currently, that becomes more and more short-term. I think that is becoming a huge problem. (…) This way, it is impossible to steer at the last-minute, so you will get more risks. That is a real problem".* The respondent highlights that "*long-term planning can be postponed one or two years, but these processes are postponed to long right now."* This is in line with previous findings, in both the empirical study and literature, that the decentralization of power and privatization have decreased the rail infrastructure operator's ability to make long-term plans.

5.3.5. Meta-governance in integrating rail- and energy infrastructure

Respondents 9 and 10 argue for more collaboration with train operators to ensure more flexibility in the rail system. *"We can start the conversation with the train operators. Can you use less energy? Or hypothetically, if we see that tomorrow will be a cold and windy day, we have a problem with the energy supply, can a train operator change the train schedule from 6 trains to 4 trains per hour? Can we design a flexible system?"* Respondent 10 argues for a smarter use of current infrastructure, rather than endlessly expanding it. *"Can we collaborate and ask a train operator to accelerate a little slower, instead of changing our infrastructure? (…) We are already doing workshops with the NS. (…) In these workshops we ask: what can we do collectively, knowing that not everything is possible? That collaboration is constructive. I would like to have these conversations with other regional and cargo train operators as well."* Although these ideas for collaboration and smarter use of current infrastructure can potentially be part of solutions, the stakeholders do not reflect critically on the (governance) challenges that come with these smart solutions. As mentioned in the theoretical framework on integral planning (3.1), the shift from sectoral planning to integral planning poses a risk for certain sectoral needs to be overlooked. These smart solutions and collaboration with other parties, seem to illustrate this. In other words, although not mentioned by stakeholders, the desire for smart solutions in collaboration with other parties also entails a need for coordination and a shift in governance structures.

Respondent 7 points out that coordination for spatial plans regarding rail- and energy infrastructure is hardly doable on a regional or local level. *"On a national level, coordination might be possible, but any further is not".* At the same time, other respondents see problems in 'the state' coordinating energy- and rail infrastructure planning. Respondent 10 describes how *"the Ministry (I&W, red.) decides everything. That is their role, but that complicates things. I often see a lack of consistency at I&W, there is no broader big picture. You often hear that it is just a bunch of loose teams, talking about nice things, but it lacks overarching choices."* Respondent 10 still thinks that it is up to the state to coordinate efforts to integrate energy- and rail infrastructure planning. *"I think it is our job to pick up signals of what the main issues are, and communicate those to the ministry. It is still up to them to make the decisions."* Respondent 8 shares the same opinion, in which ProRail is an executive agency, and I&W should make the decisions on a coordinating level. Although stakeholders often mention a potential for the state to act as coordinating entity, it remains unclear how this coordination would function in practice. One objection would be that 'the state' is separated in different departments, where the Ministry of Economic Affairs and Climate Policy (EZK) is responsible for energy and I&W for the rail sector. Even if the state would coordinate integral plans between these sectors, there needs to be a coordinator that coordinates the different parts of the state. This is in line with Gjaltema et al.'s (2020) notion that a meta-governor can also govern multiple other modes of governance. However, stakeholders seem only limited aware of the complexity of 'the state as coordinator'.

5.4. General comparison

To obtain an overview of the topics discussed in the interviews, this paragraph compares the three cases, following the same structure as the results section of each individual case study. Table 6. provides an overview of the comparison, with a qualitative summary of each rail infrastructure operator's view on the five topics. An overview of the extent to which respondents mentioned certain topics is added in appendix B.

5.4.1. Infrastructure

Regarding the rail energy infrastructure, the results show that the Belgian and Dutch infrastructure are relatively similar, while the Swedish infrastructure is different. The major difference is the need for a higher voltage transmission grid in Sweden, due to the large distances that need to be covered. The Belgian and Dutch rail infrastructure is more dense than the Swedish infrastructure. Stakeholders also indicate, contrary to different interest parties, that the impact of sharing physical infrastructure with public energy grid operators has limited impact in all cases.

5.4.2. Energy

In the Netherlands, ProRail purchases its energy via VIVENS, a cooperation between different parties that collectively buy energy. Belgium lacks this kind of cooperation. Even more, in Belgium, the freedom of choice for energy supplier economically paralyzes Infrabel in investing in long-term renewable energy projects. Trafikverket is the energy supplier for Swedish train operators. Due to the special nature of the closed distribution grid, Trafikverket can supply energy for low prices.

5.4.3. Current governance and stakeholders

The relationship between the state and rail infrastructure operators is ambiguous in Belgium and the Netherlands. Especially in the Netherlands, it is unclear whether ProRail can function as private company and set out its own long-term agenda, or whether it is a form of executive agency for the Ministry of

Infrastructure and Water Management. This results in a lack of long-term planning. In Sweden, the executive side of Trafikverket clearly has the role of executing political decisions. This clear role is perceived as beneficial for rail infrastructure development by the respondents. However, relations between the rail infrastructure operator and market parties still lacks coordination. Belgium lacks a proper market regulator in both the energy- and rail sector. Belgian respondents mention the absence of this independent party in various context.

Respondents from all three cases see their role at least as advisory towards the political decision-makers.

5.4.4. Main challenges for integrating rail- and energy infrastructure

All rail infrastructure operators from the study face challenges regarding maintenance, due to the scarcity of workforce and the limited timeframes to do maintenance on the tracks. In the densely developed Netherlands and Belgium, a main challenge for achieving these goals is net congestion. Collaborations with public energy grid operators and third parties face challenges, due to the special nature of the closed distribution systems for the rail energy supply. In Sweden, collaboration in using transmission energy grids faces similar challenges regarding the special nature of the rail energy system. There is a shared understanding among rail infrastructure operators that mobility is a boundary for collaboration in using energy infrastructure.

In Belgium and the Netherlands, there are also challenges regarding separated responsibilities between different layers of government. In Belgium, this comes in the form of regional ministers viewing the nationally coordinated rail energy system as competition for regional energy grid operators. In the Netherlands, changing regional and local policies regarding spatial planning slows down developments in rail- and energy infrastructure. Additionally, the separation between EZK and I&W in responsibilities regarding energy and rail infrastructure complicates the potential role of the state as meta-governor. Stakeholders from Belgium seem actively reflecting on governance failures in their country, whereas stakeholders from the Netherlands are more abstract in sharing ideas on the state's responsibility.

At the core of major challenges, all three cases show governance and market failures due to privatization. In Sweden, this is seen in the lack of long-term planning and scarcity of contractors, due to the freedom for contractors to choose assignments.

5.4.5. Meta-governance in integrating rail- and energy infrastructure

Especially in the Netherlands and in Belgium, the results show a desire for more coordination between different layers of government. In all three cases, privatization led to deprivation of state-coordinated long-term infrastructure planning. All respondents shared a desire for at least partially reverse this privatization, to ensure that long-term infrastructure planning is coordinated. Multiple challenges, both in long-term planning and maintenance issues, are a result from the state being absent as coordinating party.

In all cases, respondents seek a form of guidance and coordination in issues that cannot be solved within the rail sector.

Table 6 Qualitative comparison cases per topic

Topic	*Specific issue*	Belgium	Sweden	The Netherlands
Infrastructure	Types of power grid	Traction energy grid, not designed for transporting large amounts of energy	Traction energy grid, and a high-voltage transmission grid. Broader use of this high-voltage transmission grid is not desirable.	Traction energy grid, not designed for transporting large amounts of energy
	Energy source	Dependent on public grid. Some pilots with own energy generation, but efforts remain on a small scale.	Dependent on public grid, own generation and a net inflow of traction energy from Norway.	Dependent on public grid. Ideas to renew the grid to allow for own energy sources to be connected. However, not feasible in short-term.
Energy	Freedom of choice energy supplier	Freedom of choice for supplier holds back long-term plans at Infrabel regarding energy.	Trafikverket can rely on train operators always choosing for Trafikverket as energy supplier. Due to the energy grid being a closed system, Trafikverket is competitive and the best choice for train operators.	ProRail purchases energy in cooperation.
	Relation with public grid operators	On national scale, good relations and support. On regional scale, Infrabel is viewed as either a customer or competition.	Not mentioned explicitly, but relation is functional and seems good.	Public grid operators make no exceptions for ProRail, due to the high pressure on them as a result from net congestion. Relations are formal and contract-based, and functional.
Current governance & stakeholders	Relation rail infrastructure operator and the state	Infrabel has a good relationship with the national government, that supports Infrabel's innovations. Relations with regional governments, that are important in Belgium, are less constructive, since they have no responsibility for Infrabel.	The political government only sets targets and goals for Trafikverket as rail infrastructure operator. Trafikverket has freedom in how to execute plans to achieve these goals. This is considered a constructive relation with clear boundaries.	Relations with the responsible ministry and ProRail are good, yet the exact role of ProRail remains unclear. The most desired role is that of an executive agency, with advisory role. Cooperation between different ministries is needed in integral planning, but proves to be complex.
	Collaboration with market parties	Belgium lacks a sufficient market-regulator. Furthermore, desired collaborations with large-scale project developers face legal challenges, due to Infrabel not being fully private.	The privatized market increasingly often lacks parties that are willing to do the maintenance for Trafikverket. Trafikverket cannot pay too much, yet is not attractive for market parties to collaborate with.	ProRail respondents do not mention major challenges in relations with market parties regarding standard operations. However, ProRail is trying to position itself within the broad stakeholderfield in sector-transcending issues.
Main challenges	Net congestion	Net congestion complicates the shift to renewable energy sources, but is not often mentioned as main challenge.	Although net congestion occurs in specific areas, it is not a main concern for Trafikverket.	Net congestion is viewed as a major problem and complicates various developments in the rail infrastructure. Other parties view the rail infrastructure as potential solution to net congestion, but ProRail sees only a limited role for itself.
	Lack of long-term planning	Freedom of energy supplier withholds Infrabel from making long-term infrastructural plans. Privatization plays a major role in this.	Due to privatization and frequent changes in the political landscape, long-term planning decreased within Trafikverket.	There is increasing attention for current problems with ad hoc solutions, resulting in less long-term planning.
Meta-governance	Need for coordination	Belgian respondents point out that market-regulation is needed. Furthermore, there needs to be more coordination between layers of government, to align national and regional interests.	Within Trafikverket, there is good coordination between the political entities and different modes of mobility. However, coordination is needed to overcome failures in the relation between public entities and market parties.	ProRail needs coordination, preferably from the state, to ensure its own (sectoral) needs are not compromised in integral planning efforts.
	Power distribution	On regional level, Infrabel faces challenges regarding ministers without any interest in Infrabel. Power needs to be distributed according to the responsibilities of government bodies and vice versa.	At Trafikverket, there is a clear power distribution. Political leaders take decisions on goals, Trafikverket decides how to achieve these goals.	ProRail's role is unclear, since it has characteristics of a government body, an executive agency and a private company. The most mentioned solution is to clearly define ProRail's role as executive agency with an advisory role to I&W.

6. Conclusion

The conclusion of this thesis aims to answer the main question:

> *How do rail infrastructure operators value the contribution of meta-governance in integral planning for integrating energy and rail infrastructure, in their positioning among other stakeholders in the integral planning process?*

To answer this question, this chapter adopts the results from the empirical research to answer the three formulated sub-questions (SQ). Subsequently, this thesis draws three main conclusions regarding the main research question and places these findings in the broader theoretical framework of meta-governance in integral planning for rail- and energy infrastructure.

SQ1: What is the infrastructural and governance context for integrating energy- and rail infrastructure?

SQ1a: What rail energy infrastructure and governance structures are in place?

The first conclusion regarding the context for integrating energy- and rail infrastructure, is that rail energy infrastructure is not designed to transport large volumes of energy. Especially in densely developed areas like Belgium and the Netherlands, rail energy infrastructure is mainly a distribution grid (ProRail, 2022). Usage of these grids faces both physical and legal challenges, while contributing little to help mitigate net congestion. Furthermore, the grids are dependent on the public energy grid for their power supply. Therefore, connecting third parties that are unable to connect to the public grid due to net congestion, only moves the problem to another grid, rather than solving it.

The governance of both rail and energy infrastructure operators is ambiguous in nature. Traditionally, ministries set out targets and long-term plans for infrastructure, and the operators function as executive agencies. However, due to privatization of the rail sector, these clear lines of responsibility have become blurred over the past decades, leaving rail infrastructure operators unsure of their role in the system. Rail infrastructure operators tend to become passive and reactive to plans from ministries, while these plans often are inconsistent or lack a long-term vision. There is some movement in strategy-teams in different rail infrastructure operators, towards a more active, advising role towards the responsible parties.

The governing entities responsible for energy- and rail infrastructure, are often separated and lack coordination in policy between the energy- and rail sector. Since there is often inconsistent policy within only a single governmental organization responsible for either energy or rail already, cooperative strategies for integrating energy- and rail infrastructure from governmental organizations seem hard to achieve in the near future.

SQ1b: How have the main challenges rail infrastructure operators face regarding energy developed over the past decade?

Rail infrastructure operators face three major challenges regarding energy infrastructure. First, resulting from privatization of the market, contractors have more autonomy in choosing which maintenance jobs to accept an which to reject. On top of that, the needed contractors for maintenance is increasing, while the number of specialist on rail infrastructure is decreasing. This poses challenges for rail infrastructure operators to maintain and renew the rail (energy) infrastructure.

Second, in densely developed areas, public energy grids face net congestion and rail infrastructure operators are unable to meet their increased demand. As a result, rail infrastructure operators cannot facilitate more voltage to the catenary or add more electrified tracks. This delays efforts to make train schedules more efficient.

Third, due to privatization, rail infrastructure operators make short-term contracts with executing parties. At the same time, there is ambiguity on who is responsible for long-term infrastructure planning. As a result, rail infrastructure operators face higher costs and less innovation power, due to the lack of long-term vision.

SQ2: How do rail infrastructure operators collaborate with other stakeholders in integrating energy- and rail infrastructure?

Various theorists and interest groups suggest that integrating parts of rail- and energy infrastructure is just the beginning of a whole integrated system, in which unused capacity in rail infrastructure solves net congestion and other problems on the public energy grids (Spoorpro, 2024; Energie in het OV, 2024; Çiçek et al., 2022; Kaleybar et al., 2023; Kaleybar et al., 2024). However, on a national or international level, collaboration to integrate the systems is not the solution to problems on the public energy grid. Rail energy infrastructure does not have the capacity to make a large impact on net congestion. Furthermore, collaboration in sharing infrastructure faces legal challenges. Although laws can be changed, integrating the systems on a national level changes the nature of the rail energy system as closed system for traction energy. It seems undesirable to do so. However, on a regional or local scale, collaborations between the energy- and rail sector can be beneficial. Rail infrastructure operators already look at possibilities to use the hours between energy peaks to allow charging infrastructure to connect to substations.

Collaboration between the energy- and rail sector to integrate policy for *using* current infrastructure, seems more achievable than physically integrating the infrastructure. In collaboration within the energy sector, or within the rail sector between the train and infrastructure operators, stakeholders can seek for ways to spread the peak-demands in energy more evenly.

In specific cases, especially in densely developed areas, energy- and rail infrastructure operators can collaborate in sharing scarce space. Rail infrastructure operators often own or maintain plots of land near railways that are not used intensively. These plots of land could potentially be used to place renewable energy sources or expansions for the public energy grid. However, this seems hard to scale up, since there is a fear among rail infrastructure operators these collaborations in land-use affect their ability to expand the rail infrastructure in the future.

SQ3: Under what conditions do rail infrastructure operators see advantages of introducing meta-governance in planning processes for integrating energy- and rail infrastructure?

There are a few conditions under which rail infrastructure operators see advantages of introducing meta-governance in planning processes for integrating energy- and rail infrastructure. First, under current conditions, there is a lack of coordination and consistent decision-making. One of the characteristics of a meta-governor, is its coordinating nature (Gjaltema et al., 2020). There are no clear signs that rail infrastructure operators aspire to be responsible for decision-making themselves. Although their role is now somewhat vague, rail infrastructure operators seem comfortable in their role as executive agency to a ‘higher’ decision-maker.

Second, directly following the previously mentioned desire for coordination, the rail sector desires to be taken seriously. There is often a fear that the people in charge are unaware of the complexity of rail systems. One condition for meta-governance to be beneficial in integrating energy- and rail infrastructure, is that the meta-governing entity is trusted by the rail infrastructure operators. This trust is often gained by showing deep knowledge of the infrastructural complexity of the rail system. A meta-governor in integrating energy- and rail infrastructure, needs to find the hard balance between independence on the one hand, while being trusted through having knowledge of the rail system on the other hand. A condition for meta-governance to be beneficial, is the ability of the meta-governor to take advise from the rail sector into account, while maintaining independent.

Third, a meta-governor needs to transcend both sectoral boundaries, as well as the multiple levels of governance (Marsden et al., 2024; Wang et al., 2024; Thuesen, 2013). Different layers of government that are responsible for different layers of policy in both energy- and rail infrastructure, create a complex playing field for coordination. Therefore, a condition for meta-governance to succeed, is the meta-governor not being tied to a specific layer of government, as long as different layers of government are responsible for parts of the energy- or rail sector.

Conclusions main question

Following the previously mentioned conclusions, this thesis answers the main question in five conclusions. First, although integrating energy- and rail infrastructure can be beneficial in certain challenges, the impact of the integration is often limited. A second conclusion is that this integration of rail- and energy infrastructure, does not per se mean a physical integration. Integrating policies for *using* energy- and rail infrastructure could provide solutions to shared problems, rather than purely looking at physically integrating infrastructure. Third, this thesis found conditions under which meta-governance can be beneficial to processes of integrating rail- and energy infrastructure. These conditions are that a meta-governor needs to fulfill a coordinating role, while rail infrastructure operators act as executive agencies with an advisory role towards the meta-governor. Furthermore, the meta-governor needs to transcend sectoral boundaries and traditional hierarchies to prevent failures in multi-level governance, and finally the meta-governor needs to be trusted by the rail sector, while remaining an independent party. Fourth, although meta-governance is beneficial to integrating rail- and energy infrastructure under certain conditions, the limited impact of this integration as mentioned in the first conclusion, affects the scale and complexity of meta-governance structures. The scale and complexity of meta-governance structures and institutions should be proportional to the limited benefits of integrating rail- and energy infrastructure. Finally, the reality of integral planning for the rail- and energy sector is that a 'perfect' mode of meta-governance as guidance does not exist and will not exist in the near future, if ever. Rail infrastructure operators should still position themselves in these processes that lack guidance. This thesis concludes that while integral planning processes still lack coordination by meta-governance, rail infrastructure operators should adopt a more active advisory role towards their responsible ministries, and address governance failures within integrating energy- and rail infrastructure planning.

7. Discussion

This discussion sections places the previously found conclusions back in the context of the theoretical framework and challenges in society that were found at the start of this thesis. It discusses contributions to debates in academia and society, and gives recommendations for further research.

Academic contribution

This thesis started it's theoretical framework with a critical view on the shift from sectoral to integral planning. As shown in the conceptual framework, this shift is not just a shift in planning theory, but is illustrated by a shift in planning objects and a shift in planning processes. This thesis contributes to literature on this shift, by clearly showing that a shift in planning objects and processes, needs to be accompanied by a shift in governance. In exploring governance failure in integral planning, this thesis found a relation between challenges in integral planning, and characteristics of meta-governance. As a result, this thesis connected concepts from spatial planning theory and governance theory, and illustrated its effectiveness in solving problems in planning practice. Further research could construct a broader framework beyond integral planning and meta-governance, in which governance failures in various planning approaches can be compared to characteristics of different modes of governance, to scan which modes of governance can potentially be beneficial to solutions for failures in planning.

Furthermore, Gjaltema et al. (2020) constructed a framework to make some sense of the scattered notion of meta-governance across domains in literature. This thesis is among a few recent studies (Xing & Xing, 2023; Wang et al., 2024), a start in adopting Gjaltema et al.'s framework in practice. It illustrates how a meta-governor indeed needs to exceed traditional sectoral boundaries and hierarchies. Furthermore, it expands Gjaltema et al.'s (2020) framework by introducing the need for proportionality in meta-governance instruments. Further research could take a more quantitative approach to exploring what meta-governance instruments and institutions are proportional in regard to the extent to which meta-governance helps solutions for governance failures in planning.

In forming theory of connecting governance theory to integral planning, this thesis found that it could be beneficial to further explore potential connections between integral planning and other disciplines. This thesis found that integral planning often leaves parties in ambiguity with regard to their role in planning processes. Behavioral sciences and change management could for example shed more light on the role of parties within integral planning processes. Since integral planning entails a complex network of actors and processes, further inductive, explorative research from different perspectives could shed light on yet unknown foundations for failures and potential in integral planning.

Societal contribution

This thesis focused on integrating rail- and energy infrastructure, in the light of the broader societal issue of the energy transition. There is an increasing body of literature and plans for integral plans to accelerate the energy transition (Çiçek et al., 2022; Kaleybar et al., 2023; Kaleybar et al., 2024). This thesis contributes to the feasibility of these plans, by pointing out the importance of new governance modes, rather than a pure technical look at integrating different infrastructures. Since current literature tends to focus more on the technical aspects, this thesis chose to focus mainly on the governance aspects of integrating rail- and energy infrastructure. Further research could seek to combine these two elements, and see how the technical solutions and challenges, and (needed) governance structures relate.

The societal relevance of this thesis is more than just a contribution to ideas of integrating rail- and energy infrastructure. The conceptual framework that resulted from the literature study, showed the need for a shift in governance, following the shift from sectoral to integral planning. Further research could explore other instances of integral planning that require meta-governance. This thesis concluded that meta-governance structures can easily become too complex for the limited impact integrating rail- and energy infrastructure has on net congestion. However, it is interesting for further research to explore the possibility of one meta-governing entity guiding multiple of these integral planning efforts among various sectors.

Finally, this thesis identified coordination failure as major failure in integral planning, while it is crucial for success (Rahman, 2015; Liu, 2018). However, with a more coordinating entity like a meta-governor, a question that still needs to be answered is the distribution of decision-power. If the meta-governor is also the decision-maker, the distinction between meta-governance and a traditional hierarchy becomes vague. Further research could look into Evers & De Vries' (2013) notion that re-introducing hierarchy and joint-decision making do not form a dichotomy. This would expand the idea of introducing meta-governance in integral planning, by adding the idea of joint-decision making to the process. Although joint-decision making in integral planning is one direction, further research could explore conditions for different modes of power distribution in integral planning more thoroughly.

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Appendices

Appendix A: Quickscan case selection

ProRail (The Netherlands)

Cause for this thesis were signals from the Dutch rail infrastructure operator, that planning processes regarding integrating energy- and rail infrastructure faced major governance challenges. Since the Netherlands is a densely built country, with the busiest used railway system, this thesis chooses to take the Dutch rail infrastructure operator ProRail as starting point, as first case included in the study.

DB Netze (Germany)

Comparability: In Germany there is a lot of solar power available in the south, and wind power in the north. This leads to a high demand of energy transport capacity from north to south and vice versa. DB has a separate 110 kV energy grid, between the public energy grid and the grid that delivers power to the traction net. There is collaboration to use this 110 kV energy grid for transporting energy through the country, that is not necessarily needed within the rail sector (Hülk et al., 2017).

Although this is an interesting case, the German rail infrastructure is massive compared to the Dutch system. Although certain aspects of collaboration could provide new insights, it is hard to copy best practices, due to the difference in scale between the networks.

Feasibility: At ProRail, there is a variety of collaborations with DB. However, it deems hard to connect to the right person. Due to the tight planning of this research, it could become a challenge to reach the right person on time.

Conclusion: The German integral planning processes regarding rail- and energy-infrastructure show interesting characteristics. However, due to the difference in network size and uncertain feasibility, DB Netze will not be included in the case study.

Infrabel (Belgium)

Comparability: The Belgian railway infrastructure network shows many comparisons with the Dutch railway infrastructure network. Infrabel and ProRail face similar questions regarding collaboration with parties outside the rail-sector in integral planning processes. In Belgium, the railway energy grid is used for charging vehicles on a trial basis.

Feasibility: ProRail has many contacts with Belgian colleagues. Colleagues are willing to participate in research, as long as both parties benefit from results.

Conclusion: Based on the good comparability and feasibility, Infrabel will be included in the case study.

Správa železnic (Czech Republic)

Comparability: In the Czech Republic, there is a developed railway network. The Czech railway network is a dense network, making it comparable to the Dutch network (Taczanowski, 2012). Although the country is modernizing its railway infrastructure, from the quick scan it remains unclear whether the country faces the same challenges regarding collaboration in integral planning processes with the energy sector.

Feasibility: Since the Czech Republic is often overlooked in research regarding infrastructure planning, people are eager to participate in research. The contacts with the Czech

Republic and ProRail are more indirect, making it possibly more time consuming to find the right participants.

Conclusion: Although Správa železnic could be interesting to include in the research, based on the risks in feasibility and unclarity on the challenges it faces, it will not be part of the case study.

Trafikverket (Sweden)

Comparability: In Sweden, railway infrastructure operations is part of the ministry of infrastructure, along with air-, water-, and road transport (Trafikverket, 2024). In combining these sectors, infrastructure planning is often integral in nature. This makes it harder to compare it to ProRail, since the governance structures in place differ. However, it could also serve as an example for how integral planning processes are well-guided, suggesting that some sort of meta-governance is in place.

Feasibility: ProRail has many contacts with Swedish colleagues and they are likely willing to participate in research.

Conclusion: Based on the possibility of meta-governance in the Swedish governance structure and their integral approach to infrastructural planning, Trafikverket is an interesting case to include in the case study.

Appendix B: Quantitative expression of stakeholders mentioning topics

Infrastructure	BE	SE	NL
Transmission function of rail energy grid	-	+	-
Ability to connect renewable energy sources	-/+	+	-
Grid capacity in relation to public energy grid	-/+		-
Rail traction energy supply dependent on public energy grid	++	+	++
Rail infrastructure operator owning a high-voltage transmission grid		+	
Risks in broader use of current energy grid	+	+/-	+

Energy	BE	SE	NL
User's freedom of choice for energy supplier	--		
Collective purchase of energy	--		++
Rail energy entails a closed distribution system	+		+
Limited expansion capacity of public energy grid operator	-/+		+
Spatial challenges at the core of energy transition			++
Financial opportunities for public grid operators in net congestion issues			+
Distribution function of rail energy grid for third parties	+/-	--	-
Prioritizing core business over energy transition in rail sector	++	+/-	+

Current governance & stakeholders	BE	SE	NL
Relation with the state	-	+	-
Privatization of rail sector	-/+	+	-
Collective energy purchase	-/+		-
Legal room for collaboration rail- and energy infrastructure	--	-	-
Traditional character of rail sector	--	+	+/-
Unawareness of rail infrastructure operator also being an energy grid operator	-		
Separated responsibilities between layers of government causing governance failures	--	+	-
Lack of market regulation	--	-	-
Desire for cooperation with large-scale project developers	+		
Integrating expertise between different modalities		++	+
Rail infrastructure operators as executing agency	+/-	++	+

Main challenges for integrating rail- and energy infrastructure	BE	SE	NL
Net congestion	-	+	--
Expanding rail energy grid	--	-	--
Scarcity of space	-	+	--
Availability workforce (for maintenance and renewal)	--	--	-
Presence of a long-term vision	+/-	-	--
Cooperating in purchasing energy	--		++
Traditional character of the rail sector	-	+	
Backlog of maintenance	--	-	-
Limited access to busy tracks for maintenance		--	
Scarcity of available contractors due to privatization	--	-	
Short-term character of maintenance contracts	--	--	
Lack of long-term planning	-	-	-
Less European collaboration due to different phases of maintenance		--	

Limited power on catenary	-/+		--
Ecological and spatial challenges to expand rail infrastructure	-/+	+	--
Passive approach to regional policy changes	-		--

Meta-governance in integrating rail- and energy infrastructure	BE	SE	NL
Opening rail energy grid to third parties for distribution	-	--	-
Relation with train operating companies	+	+/-	+
Collaboration with charging infrastructure	++	+	+
Coordination within the rail sector	+/-	+	-
Ability to long-term invest	--	-	--
The state as coordinator (currently)	-	+/-	-
Desire for state to coordinate	+		++
Mobility sector as boundary for collaboration	++	+/-	+
Need for independent market regulator	++	+/-	-
Need for European coordination	++	+	
Lack of national coordination in infrastructure planning	+	+	+
Coordination between layers of government	++		+/-
Market failure leading to lack of long-term planning		-	
Collaborations for smarter, more efficient use of current infrastructure	+		+/-
Desire for state-coordination and infra operator as executive agency and advisor	+	++	++

Appendix C: Topic list interviews

Opening **5 minutes**

a. Consent questions & start recording
b. Informal talk, get to know each other
c. What is his/her function and role in the company?

TF Topic 1: Shift from sectoral to integral planning **10 minutes**

Goal: find out A) if the respondent sees a shift from sectoral to integral planning and B) if so, how the respondent thinks this affected the role of the railway infrastructure operator

1. What are the main challenges railway infrastructure operators face today?
2. How have these main challenges and the core business of railway infrastructure operators changed over the past decade?
3. *Depending on conversation:*
    a. What is the effect of the increased scale of problems on the railway infrastructure operator? OR;
    b. What collaborations does the railway operator seek in order to address these ‘wicked problems’?

TF Topic 2: Failures in integral planning **10 minutes**

Goal: Find out how railway infrastructure operates deal with the shift to the more integral approach to infrastructural planning processes and how they cope with governance failures of integral planning in practice.

4. What parties, outside of railway companies, are involved in the railway infrastructure operations *(examples: policy-makers, energy sector, other sectors)*
5. To what extent do you feel parties are aware of the needs of railway infrastructure operators?
6. How do stakeholders collaborate in the coordination of national energy- and railway infrastructure planning?

TF Topic 3: Meta-governance in integral planning **15 minutes**

Goal: A) which stakeholder(s) show characteristics of a meta-governor and B) how does the railway infrastructure operator relate to the possible meta-governor or parties that show characteristics of a meta-governor.

Evaluating the stakeholder field

7. What do you think of the parties that are collaborating in national infrastructure plans regarding energy- and rail infrastructure and their relations?
    a. How is power distributed among stakeholders? Do you feel that certain parties have (inappropriately) more or less influence than other parties?
    b. How clear is it which parties have which interests in energy- and railway infrastructure planning?

c. What other parties should be included in the stakeholder field or get a more important role?

8. How would you reflect on your company's contribution to national infrastructure plans regarding energy- and rail infrastructure?
    a. What is your influence?
    b. How clear are your interests (to yourself and other)?

Relation railway infrastructure operator and meta-governor

If not answered already in previous conversation:

9. How does your company relate to the meta-governor?

OR

10. How and when does your company take on the role of meta-governor?

11. What would you say are the main challenges and opportunities for enhancing the role of railway operators in issues regarding the national energy infrastructure?

Closing **5 minutes**

a. Any other topics to discuss
b. Follow-up, closing & end recording
c. Thanks