The Swedish Transport Administration's Climate Requirements in the Procurement of Infrastructure and Bridge Projects

Master's thesis in the Master's Programme Design and Construction Project Management

JOHAN NÄSWALL
LUDVIG ÅBERG

DEPARTMENT OF ARCHITECTURAL AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

MASTER’S THESIS ACEX30

The Swedish Transport Administration´s Climate Requirements in the Procurement of Infrastructure and Bridge Projects

Master’s Thesis in the Master’s Programme Design and Construction Project Management

JOHAN NÄSWALL

LUDVIG ÅBERG

Department of Architecture and Civil Engineering

Division of Construction Management

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2025

The Swedish Transport Administration´s Climate Requirements in the Procurement of Infrastructure and Bridge Projects

Master's Thesis in the Master's Programme Design and Construction Project Management

JOHAN NÄSWALL

LUDVIG ÅBERG

Examensarbete ACEX30

Institutionen för arkitektur och samhällsbyggnadsteknik

Chalmers Tekniska Högskola, 2025

Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology

SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Department of Architecture and Civil Engineering

Göteborg, Sweden, 2025

The Swedish Transport Administration´s Climate Requirements in the Procurement of Infrastructure and Bridge Projects

Master's thesis in the Design and Construction Project Management

JOHAN NÄSWALL

LUDVIG ÅBERG

Department of Architecture and Civil Engineering

Division of Construction Management

Chalmers University of Technology

ABSTRACT

In line with increasing climate ambitions, the Swedish Transport Administration (STA) has introduced stricter climate requirements in its procurement of infrastructure and bridge projects since 2015. Requirements for climate reductions are gradually increasing until the final goal of climate neutrality is achieved in 2040, which is pressuring contractors and consultants to change their working methods, choice of materials, and technical solutions. This thesis investigates how STA's climate requirements are currently perceived and managed by contractors and consultants, in order to explore potential improvement measures in setting climate requirements in public procurement of infrastructure and bridge projects. There is limited previous research in this area, which makes this thesis a valuable contribution to the ongoing transition for industry stakeholders. The aim of the study is to provide valuable information to the client, the Swedish Transport Administration, in order to gain a better understanding of how contractors and consultants experience their climate requirements and thereby identify obstacles to improve their formulation of climate requirements. An abductive research method was chosen, where an interview study was conducted in combination with the development of a theoretical framework. A total of twelve semi-structured interviews were conducted with various actors active in the construction sector. Two infrastructure and bridge projects were selected as contextual examples, where one representative from each party – client, contractor, and consultant – was interviewed. The remaining six interviewees were selected based on their extensive experience and expertise in the construction sector, with a particular focus on issues related to climate requirements in public procurement. The results show that climate requirements which are material- or fuel-specific are perceived as clear and feasible, whereas the percentage-based reduction requirements are considered complex to implement and difficult to follow up. Consultants request guidance and more standardized calculation tools, while contractors call for clearer incentives that better reflect the additional costs imposed by the climate requirements. The conclusion emphasizes the importance of involving climate aspects early in the projects, increased collaboration and knowledge exchange between actors, and more flexible and innovation-promoting climate requirements. The study provides key recommendations for improving the effectiveness of climate requirements to reduce emissions and contribute to a sustainable construction sector.

Key words: climate requirements, climate neutrality, contractors, consultants, Swedish Transport Administration, public procurement, infrastructure, bridge projects

Trafikverkets Klimatkrav vid Upphandling av Infrastruktur- och Broprojekt

Examensarbete inom masterprogrammet Organisering och Ledning i Bygg- och Fastighetssektorn

JOHAN NÄSWALL

LUDVIG ÅBERG

Institutionen för Arkitektur och Samhällsbyggnadsteknik

Avdelningen för Construction Management

Chalmers tekniska högskola

SAMMANFATTNING

I takt med ökade klimatambitioner har Trafikverket sedan 2015 infört hårdare klimatkrav i sina upphandlingar av anläggning- och broprojekt. Krav på klimatreduktioner ökar successivt fram tills det slutgiltiga målet av en klimatneutralitet är uppnådd 2040, vilket pressar entreprenörer och konsulter att ställa om sina arbetsmetoder, materialval och tekniska lösningar. Denna uppsats undersöker hur Trafikverkets klimatkrav upplevs och hanteras av entreprenörer och konsulter i dagsläget för att utforska potentiella förbättringsåtgärder i ställandet av klimatkrav i offentlig upphandling av Trafikverkets anläggnings- och broprojekt. Det finns begränsat med tidigare forskning på området vilket gör den här uppsatsen till ett värdefullt bidrag till den pågående omställningen för branschaktörerna. Studiens mål är att bidra med värdefull information till beställaren Trafikverket för att få en bättre förståelse hur entreprenörer och konsulter upplever deras klimatkrav och på så sätt identifiera hinder för att förbättra sitt ställande av klimatkrav. En abduktiv forskningsmetod valdes där en intervjustudie genomfördes i kombination med att ett teoretiskt ramverk framställdes. Totalt genomfördes tolv semistrukturerade intervjuer med olika aktörer verksamma inom byggsektorn. Två bro- och anläggningsprojekt valdes ut som kontextuella exempel, där en representant från respektive part – beställare, entreprenör samt konsult – intervjuades. De övriga sex intervjupersonerna valdes ut baserat på deras gedigna erfarenhet och expertkunskap inom byggsektorn, med särskilt fokus på frågor relaterade till klimatkrav i offentlig upphandling. Resultaten visar att klimatkrav som är material- eller bränslespecifika uppfattas som tydliga och genomförbara, men att de procentuella reduktionskraven uppfattas som komplexa att implementera och svåra att följa upp. Konsulter efterfrågar vägledning och mer standardiserade beräkningsverktyg, medan entreprenörer söker tydligare incitament som bättre speglar merkostnaden klimatkraven innebär. Slutsatsen betonar vikten av att tidigt involvera klimatfrågan i projekten, ökad samverkan och kunskapsutbyte mellan aktörerna och mer flexibla och innovationsfrämjande klimatkrav. Studien ger centrala förbättringsrekommendationer för effektiv utvecklingen av klimatkraven som kan bidra till minskade utsläpp och en hållbar byggsektor.

Nyckelord: klimatkrav, klimatneutralitet, entreprenörer, konsulter, Trafikverket, offentlig upphandling, infrastruktur, broprojekt

Contents

Acknowledgements

This master's thesis is the end of our studies in civil engineering for the master Design and Construction Project Management at Chalmers University of Technology at the Department of Architecture and Civil Engineering. The thesis was completed during the spring of 2025 in Gothenburg, Sweden.

We would like to thank our supervisors Rasmus Rempling and Mats Karlsson at Chalmers University of Technology for guidance and support throughout the work.

We would also like to thank our supervisors Magdalena Larsson and Sebastian Arneland at the Swedish Transport Administration who have provided us with a large amount of interesting material for our work and supported us with the interviews, questions and concerns.

Finally, we would like to thank all of the participants in the interviews who have shared their enormous knowledge and expertise in the field. Also, thanks to our opponents Wilma Stålarm and Markus Forsberg for constructive feedback on how we have been able to improve our work.

Johan Näswall

Ludvig Åberg

Gothenburg, 2025

Notations

List of Figures

List of Tables

List of Acronyms

BIM	**Building Information Modelling**
CD	**Climate Declaration**
CO_2e	**Carbon Dioxide Equivalents**
DB	**Design Build**
DBB	**Design Bid Build**
EPD	**Environmental Product Decleration**
LCA	**Life-Cycle Assessment**
PPA	**Public Procurement Act**
SCM	**Strategic Choice of Measures**
STA	**Swedish Transport Administration**

1 Introduction

This introductory chapter summarizes the background to the thesis, its purpose and aim together with the research question, its limitations, and the composition of the report.

1.1 Background

Sweden strives for climate neutrality by the year 2045, where the greenhouse gas emissions shall be net zero and subsequently negative (Naturvårdsverket, 2024). The goal of climate neutrality by 2045 is divided into several milestones, with 1990 as a year of reference. By 2020, the greenhouse gas emissions should be 40 per cent lower than the year 1990, 63 per cent lower by 2030 and 75 per cent lower by 2040 (Naturvårdsverket, 2024). The construction sector accounted for approximately one-fifth of Sweden's national greenhouse gas emissions during the year 2022 and needs to move in a more sustainable direction (Boverket, 2025).

The Swedish Transport Administration's climate goals in infrastructure projects are in line with Sweden's goals for climate neutrality, and somewhat higher than Sweden's national goals. Their main climate goal is to be climate-neutral by the year 2040 from construction, operation, and maintenance of traffic infrastructure. By 2025, the goal is to lower the emissions by 30 per cent, which gradually increases until it reaches 100 per cent by 2040. These reductions are in comparison to the year 2015, the same period when STA introduced their climate requirements in the procurement of investment and maintenance of infrastructure projects. The climate requirements guidelines came into motion on the 15th of February 2016 (Trafikverket, 2024). However, the STA feels a need to minimize the climate impact and carbon dioxide emissions of their current and future projects further to be able to achieve the set goal of climate neutrality. Together with consultants and contractors, the STA wants to come up with a solution that constantly strives to reduce climate emissions where there is room for improvement, regardless of whether the requirements are already met.

Sweden's construction, operation and maintenance of traffic infrastructure release approximately 5-10 per cent of the total greenhouse gas emissions of road and railway transport. During construction, the materials that contribute the most to greenhouse gas emissions are concrete and steel, which are mainly used when building bridges. For this application, STA sees great potential for climate reduction. To succeed with the climate goals, it's important that all actors, clients, consultants, contractors and suppliers cooperate to find innovative solutions throughout the construction process of bridges to minimize climate impacts. Potential measures to be taken could be using materials such as climate-smart concrete and fossil-free steel, and optimizing the material use by implementing Building Information Modelling (BIM) to design the bridge according to standard measurements etc (Uppenberg, Ekström, Liljenroth, & Al-Ayish, 2017).

One of the biggest challenges with implementing climate requirements is that the industry is profit-driven, where climate requirements are seen as a cost rather than a competitive advantage. Since the procurement strategies are short-term profit-oriented, the cost is prioritized over sustainability, which hinders climate-driven solutions. Another challenge is that climate requirements today focus more on the construction phase rather than the early decision and design phase. Implementing climate reductions early can have a large impact on the overall carbon footprint and also drive innovative climate solutions later in the project (Rempling, Lagerkvist, Karlsson, Ekström, & Larsson, 2024).

1.2 Purpose and Aim

The aim of this thesis is to investigate how the Swedish Transport Administration's climate requirements are designed for major infrastructure and bridge projects and analyze potential consequences for contractors and consultants. The purpose is to contribute to a deeper understanding of how the climate requirements can be designed and implemented in a more effective way and thereby provide practical recommendations for how the STA can design its procurements with climate requirements.

1.2.1 Research Questions

Three research questions were formulated to systematically investigate the purpose. Firstly, there is a question that addresses the current situation of climate requirements. The second question is formulated to map and understand how climate requirements affect contractors and consultants. Finally, the third question is aimed at the development and improvement of the Swedish Transport Administration's setting of climate requirements.

RQ1 *How does the Swedish Transport Administration apply its climate requirements in contracts today?*

RQ2 *How are consultants and contractors affected by the Swedish Transport Administration's climate requirements*

RQ3 *How can the Swedish Transport Administration's climate requirements be further tightened or improved to maximize the reduction of carbon dioxide emissions, while giving consultants and contractors realistic conditions for implementing the requirements?*

1.3 Limitations

The study is limited to focusing on the Swedish Transport Administration's climate requirements when procuring large infrastructure and bridge projects. The study only analyses Swedish procurement processes and regulations, which means that international comparisons are used as reference material only.

The study only includes the Swedish Transport Administration's procurements and does not include municipal projects. The purpose is not to develop new requirements, but to map existing perceptions among consultants and contractors and identify where there may be potential areas for improvement. The study is carried out with the current situation and current developments in the area, considering that changes can occur quickly, thus making it outdated.

The empirical findings have been based solely on interviews, where the 12 interviewees have been chosen by the authors and supervisors specifically for their knowledge and expertise on the subject, which may have made it biased. Complementing the work with, for example, more interviewees, a comprehensive case study or a survey could have broadened the results. The interview questions were also written by the authors and supervisors at the STA, which may have made the questionnaire biased in favor of the client. Sources of error may be found in the Teams transcription tool, where data could have been missed or interpreted in the wrong way.

2 Methodology

This chapter describes and justifies the methodology used to conduct the study. The purpose of the methodology chapter is to clarify how the study was conducted and to explain the reasons why the chosen methods were used to answer the study's questions.

2.1 Literature Research

This thesis was conducted using an abductive approach, where we moved back and forth between the theoretical framework and the empirical findings, allowing them to complement each other. To address the research questions and complement the interviews, information on the Public Procurement Act and different types of contracts had to be gathered. It was also imperative to understand the Swedish Transport Administration's guidelines on their climate requirements and how they work with infrastructure projects to continue to the empirical part of the study. As the study was initiated together with the STA, documents and reports were provided by them to create a foundation of information on their working methods and climate goals as a starting point. Relevant information was then gathered by searching for literature on Google Scholar, Chalmers Library and Scopus to help build a theoretical framework in order to conduct the interviews and analyze the results. The search for literature went on through the entire project to complement the empirical findings.

2.2 Selected Projects for Contextual Reference

To complement the theoretical framework, two projects with different characteristics were chosen. These projects have not been researched as a case study, since the focus has been on the interviews and getting a generalized picture of the STA's climate requirements across all infrastructure projects. Instead, the projects provided contextual grounding for the interviews, which included one representative from each of the main project stakeholders (i.e. client, contractor, and consultant). The projects are summarized in Table 2.1.

Project 1, located in Västra Götalands county, was an infrastructure project with the extent of approx. 20 km expressway and 14 construction works, including a fauna bridge and several smaller bridges. Mainly the infrastructure project involved new construction of 2+2 lanes. The climate requirements for this project were reduced climate impact on products and materials and reduced climate impact on fuel and Zero-emission vehicles and machinery. The penalties if these requirements were not fulfilled were for the product and material requirements, a specific sum per ton or cubic meter depending on the material. For the requirements on zero emission vehicles, a specific sum depending on if it was a passenger car or a light truck, and for the fuel requirements 0,5 per cent of annual invoiced amount between 2023–2025 and 0,75 per cent of annual invoiced amount between 2026–2029. However, the maximum penalty for all requirements in total was limited to 10 MSEK. For the zero-emission vehicles requirements, the bonus for every 10 per cent higher share than required was a specific sum depending on vehicle type granted.

Project 2, located in Västmanlands county, was an infrastructure project with the extent of approx. 24 km of expressway. The infrastructure project involved reconstruction of the road with additional lanes, construction, reconstruction and maintenance of bridges as well as demolishing and rebuilding bridges across the stretch of road. The climate requirements for this project were per centage based reduction requirements where the climate impact compared to the baseline could not fall below 30 per cent. If this requirement was not fulfilled the penalty was 0,1 per cent of the total contract amount for every per centage point worse performance compared to the reduction requirement. The maximum penalty was limited to 1 per cent of the total contract amount. The bonus was paid linear for every whole percentage point up to and including 15 per centage points that the contractor reduces the climate impact beyond the specified reduction requirement. The maximum bonus was limited to 0,25 per cent of the total contract amount.

Table 2.1. *Summarization of the projects.*

	Procurement form	***Contract form***	***Climate requirements***	***County***
Project 1	Public procurement	Design Build (DB)	Products and materials Fuel and zero-emission vehicles and machinery	Västra Götalands county
Project 2	Public procurement	Design Build (DB)	Per centage based reduction requirements	Västmanlands county

2.3 Interview Study

The interviews carried out were semi-structured, where the interviewee received the questions in advance so that they could answer, reflect and possibly seek further information about the questions asked. This ensured that the interviewees felt understood by the questions and had the chance to prepare well for the interview. The semi-structured method required us as interviewers to actively participate and ask follow-up questions continuously during the interview. This interview method also allowed for discussion of additional questions that may have felt relevant and that the questions could develop during the interview. The interviewees were kept anonymous to encourage as honest answers as possible.

A total of three interview guides were (see Appendices A, B, and C) designed specifically for the respective selected actors: clients, contractors and consultants. The beginning of each interview consisted of general questions about the person's education, background and experience in the field, followed by five main themes: *Understanding, Practice, Economic and Time-related, Follow-up,* and *Improvement*

Potential, which together capture key aspects of how climate requirements are handled in infrastructure projects. At the end of each interview, broader questions are asked about how the industry and STA should change their climate requirements to have a greater impact.

Understanding focuses on how different actors perceive and interpret the climate requirements in practice. The questions aim to capture the experience of clarity, feasibility and the extent to which guidance and support is offered from STA. Particular attention is paid to how the climate requirements are communicated from STA to consultants and contractors, and how these in turn translate them into practical action strategies for each actor.

Practice examines how climate requirements affect the work of actors in practice – from design to production. The focus is on changes in material choices, technical solutions, logistics and transport, production methods and collaboration with subcontractors. It also includes the scope for innovation and alternative solutions, as well as obstacles that may arise due to existing regulations or conflicting requirements.

Economic and Time-related highlights the impact of climate requirements on project costs and schedules. The interview questions seek to understand what financial incentives are or are not present within the project, how climate measures affect calculations and tenders, and whether there are risks or uncertainties associated with the requirements. It also includes how different actors weigh climate benefits against cost-effectiveness and technical feasibility.

Follow-up is about how climate requirements are followed up, verified and communicated during the course of the project. This addresses issues of responsibility, transparency, documentation and control. Particular emphasis is placed on collaboration between the Swedish Transport Administration, consultants and contractors – both in the project planning phase and during implementation – and how learning from previous projects is utilized.

Improvement Potential captures the interviewees reflections on possible improvements to the climate requirements. The questions include whether the requirements are challenging enough, how they can be further developed to drive innovation and emission reductions, and what type of support and incentives would facilitate more sustainable practice. There is also room for comparisons with other clients and projects, and for the interviewees' own initiatives and suggestions.

The interviews had a set time of 60 minutes per interview, but there was room to go overtime if necessary. All interviews were recorded using Microsoft Teams' own transcription program and then analyzed and divided under each main theme after the interview was completed. The interviews took place under continuous notes to collect the information during the interview, where the answers to the questions sent out in advance were also collected to make it easier to handle the amount of information that arose. The selection of interviewees was done in conjunction with our supervisors from the Swedish Transport Administration and Chalmers University of Technology to have the opportunity to find suitable people for the interviews. The first interviewees helped find more suitable people, which created a snowball effect in finding reliable experts in this research area. The study deals with relatively new and continuously developing topics with limited research, which made it important to select interviewees who have the knowledge, experience and position to answer the interview questions. Our research questions are currently being investigated in new rounds by some of the people we have chosen to interview, who also point out that not all the new information they possess can be shared at this time.

Table 2.1. *List and short description of interviewees.*

Interviewee	***Background***	***Role***	***Date***	***Interview Format***
A	Expert in the construction and civil engineering sector with background as leading positions in contractor organisations and STA.	Subject-matter expert (STA/Contractor)	2025-03-18	Microsoft Teams
B	Senior Advisor, National Coordinator for Climate and Infrastructure	Subject-matter expert (STA)	2025-03-20	Microsoft Teams
C	Expert within climate requirements and carbon management	Subject-matter expert (Consultant)	2025-03-28	Microsoft Teams
D	Climate Specialist, Swedish Transport Administration, Investment – Technology and Environment	Subject-matter expert (STA)	2025-03-25	Microsoft Teams
E	Project Manager and Bridge Engineer	Subject-matter expert (Consultant)	2025-03-18	Microsoft Teams
F	Division Manager	Subject-matter expert (Contractor)	2025-04-10	Microsoft Teams
G	Project Manager, Swedish Transport Administration	Client - Project 1	2025-03-13	Microsoft Teams
H	Site Manager	Contractor - Project 1	2025-03-24	Microsoft Teams
I	CEO/Project Manager	Consultant - Project 1	2025-03-25	Microsoft Teams
J	Technical Specialist, Swedish Transport Administration	Client - Project 2	2025-03-17	Microsoft Teams

K	Site Engineer with a focus on climate	Contractor - Project 2	2025-03-21	Microsoft Teams
L	Bridge Designer and Project Manager	Consultant - Project 2	2025-04-11	Microsoft Teams

2.3.1 Empirical analysis

The interview data was analyzed using a qualitative approach where the main analysis method was based on thematic analysis. As mentioned, the interviews were recorded via Teams' transcription tool, which both records and transcribes the interview. Because of the thematic semi-structured interview questions, the transcription data was already vaguely divided into the main themes. However, discussions and follow-up questions resulted in somewhat scattered data across the interview, where search for keywords and coding the transcription became a central part of the analysis. The coded data were categorized and structured thematically into the five themes for each interview and then gathered accordingly to each selected actor: subject-matter expert, contractor, and consultant – to provide insights on contractors and consultants perception of the climate requirements. The finalized themes have been changed and altered throughout the analytical procedure to match our empirical findings and answer our research questions. The analysis is presented in Chapter 4. To complement the empirical findings, the results were also contextualized and discussed together with the theoretical framework, presented in Chapter 5.

2.4 Ethics, confidentiality and AI disclosure

Material provided by the Swedish Transport Administration within the framework of each project is confidential and subject to confidentiality provisions. In order to ensure the greatest possible openness and honesty from key people within the projects, the interviews are conducted anonymously. Despite this, it should be taken into account that the interviewees, who hold high positions within their respective organizations, may still have a tendency to maintain a professional appearance. As a result, there may be some reticence when it comes to highlighting any mistakes or problems that have arisen in the implementation of the project.

Furthermore, the interviewees have access to sensitive and strategic information within their organizations, which means that, even under anonymity, they are limited in what they can share about future strategies and operational decisions (Bryman, 2018). This can affect the insight provided in the interviews and should be taken into account when analyzing the data collected. Therefore, it is important to supplement the interview material with other sources to get a more nuanced picture of the project implementation and challenges (Kvale & Brinkmann, 2014).

AI has been sparingly used throughout the study to help improve the report. To help with translations of particular academic words and industry-specific terminology, as well as sentence formulations, ChatGPT have been used. For the interviews, Microsoft Teams' transcription tool uses AI to transcribe the spoken words automatically into a searchable transcript, which has been useful in the coding and summarization of the interviews. The Teams' transcription tool also records the interviews, and the recordings are only available for 120 days when they are deleted automatically. The recordings have only been used fill the gaps when the transcription was illegible.

3 Theoretical Framework

The theoretical framework mainly consists of the public procurement process and the types of contracts that are usually used in these procurements, as well as the key stakeholders within the projects and their importance. The core of the theoretical framework is the Swedish Transport Administration's climate tools, which are then followed up with how other countries handle climate requirements.

3.1 The Public Procurement Act (PPA)

The Public Procurement Act (2016:1145) is the legal basis for how public authorities should conduct procurement of goods, services and construction contracts in Sweden. This law aims to ensure that public funds are used efficiently, while maintaining the principles of equal treatment, transparency, proportionality and open competition (Sveriges Riksdag, 2016). The Swedish Transport Administration's (STA) climate requirements for bridge procurement LOU plays a crucial role in how climate requirements can be imposed on contractors and consultants, and how these requirements affect the implementation of infrastructure and bridge projects.

3.1.1 Main Principles of the Public Procurement Act

The laws governing all public procurements are based on five basic principles, which have their basis and origin in European law and are laid down in the Public Procurement Act (2016:1145). These principles must always be followed when carrying out a procurement and ensure a fair, open and competitively neutral process for all suppliers (Konkurrensverket, 2024).

The Principle of Non-Discrimination means that it is prohibited to directly or indirectly discriminate against suppliers on the basis of their nationality. The authority that procures may not set requirements that only Swedish companies are aware of or can meet. Preference may also not be given to local companies.

The Principle of Equal Treatment means that all suppliers should be treated equally and given as equal conditions as possible. For example, all suppliers should receive the same information at the same time during procurement, no supplier shall receive contract-related information before the other suppliers.

The Principle of Proportionality means that the requirements and conditions set in public procurement should be reasonable and not more extensive than necessary so as not to create unnecessary obstacles for suppliers. The aim is to avoid unreasonable requirements that limit competition, which can lead to increased costs or reduced opportunities to find the best possible supplier.

The Principle of Mutual Recognition means that if a company has a certificate from an authority in one EU country, it must also be valid in other EU countries. Authorities cannot require suppliers to obtain new, national documents if they already have approved documents from another EU country. This makes it easier for companies to participate in procurement throughout the EU.

The Principle of Transparency means that the contracting authority must provide clear and complete information about the procurement, its implementation and the requirements set. The procurement documents must be clear and easy to understand, so that all suppliers have the same conditions to submit tenders. This creates a clear and predictable process that shows on what grounds the contract will be awarded.

3.1.2 Climate Requirements and Legal Framework within the PPA

The PPA provides conditions for contracting authorities to have the opportunity to include environmental requirements in their procurements, which is a central part of the Swedish Transport Administration's strategy to reduce carbon dioxide emissions in infrastructure and bridge projects. According to 4 chap. 3§ (SFS 2016:1145) contracting authorities may set specific requirements for environmental consideration and sustainability, provided that these requirements are compatible with the principle of proportionality (Sveriges Riksdag, 2016).

This means that the Swedish Transport Administration can specify, for example, the use of climate-improved concrete & reinforcing steel, recycled materials or energy-efficient construction methods in the procurement process as long as these requirements do not result in the number of bidders being too few. These requirements must be reasonable and proportionate, so that they do not unnecessarily prevent certain actors from participating, which limits competition (Konkurrensverket, 2022).

3.1.3 Criteria for Contract Award

According to 16 chap. 1§ (SFS 2016:1145) the contracting authority shall award the contract to the supplier offering the most economically advantageous tender in public procurement. The assessment of the tender may be based on three different grounds: *Price Alone, Cost Based and The best price-quality ratio*. The contracting authority has an obligation to clearly specify in the procurement documents which evaluation basis will be used, in order to ensure transparency and equal treatment of suppliers.

Price alone - It is the direct amount that a supplier offers in its tender. If the procurement is assessed solely on price, this means that the lowest price offered wins, provided that other requirements are met. This method is simple and transparent but does not take into account other factors that can affect long-term economics, such as quality and operating costs (Konkurrensverket, 2024).

Cost based - This concept is broader than price and can include life-cycle costs, such as operation, maintenance, repairs, energy consumption, waste management and any external environmental effects. According to 16 chap. 4§ (SFS 2016:1145) environmental effects may be included in the assessment provided that these can be determined in monetary terms and in an objectively verifiable manner. In cost-based procurement, the authority analyses the economic impact of the tender over the entire life cycle of a good, service or construction contract. This method allows for a more realistic picture of the total expenditure for the authority (Konkurrensverket, 2024).

The best price-quality ratio - The most comprehensive evaluation basis where both economic and qualitative factors are considered. Criteria such as function, innovation, environmental performance, technical support and guarantees can be included. This method is often used for complex procurements where price or cost alone does not provide a sufficiently fair assessment (Konkurrensverket, 2024).

3.1.3.1 Added value calculation of contract award

The procurement of infrastructure projects is a complex process that must balance cost-effectiveness with qualitative implementation of the project. The Swedish Transport Administration uses an absolute evaluation model in its procurement of Project 1 to ensure that the contract is awarded to the most economically advantageous tender. Unlike purely price-based evaluations, this evaluation model considers added value criteria, which assess both economic and qualitative aspects. The Swedish Transport Administration will accept the most economically advantageous tender in their procurement for projects. Unlike purely price-based evaluations, this evaluation model considers added value criteria, which assess both economic and qualitative aspects. The Swedish Transport Administration will accept the most economically advantageous tender in their procurement for projects. The most advantageous tender means the tender that has the best price-quality ratio, the tender that has the lowest comparative sum according to the evaluation model. In the case of tenders with the same comparative sum, the tender that has the highest value of added value offered will be accepted. The evaluation model used by the Swedish Transport Administration involves setting a price on qualitative characteristics (added values) that are valued in the procurement. The evaluation model can be described according to the following formula where the lowest comparative sum wins (Trafikverket, 2024):

$$Comparative\ Sum = Tender\ Sum - Added\ Value$$

The evaluation is carried out according to the criteria "Organizational Structure" and "Mass Handling" and is evaluated by a group within the Swedish Transport Administration consisting of among others, project managers, design managers and coordinating construction managers/BPU as well as specialists in quality, work environment and road technology. An average value will be calculated per award criterion. Points with one or two decimals may occur and a maximum point of three per added value criteria (Trafikverket, 2024).

$$Added\ Value = \sum \frac{Maximum\ Added\ Value \times Average\ Points}{3}$$

Organizational Structure

In this case, the organizational structure has a maximum added value of 70 MSEK and for the client, the added value is based on how the bidder can describe its organizational structure, staffing and its conditions over time. This enables the bidder to demonstrate that it has a good understanding of the contract as well as the resources and knowledge to carry out the assignment with high quality, within the timeframe and at the right cost. The added value is also based on the bidder's ability to cooperate with the client during the course of the project with a strong focus on the work environment and associated coordination (Trafikverket, 2024).

Mass Management

Mass management has a maximum added value of 30 MSEK and is aimed at how the tenderer effectively and sustainably manages the masses generated in the project in terms of time, cost and content. When assessing the tender's description regarding mass management, the client will evaluate the tenderer's understanding of the project's complexity and conditions. A large focus is on how the tenderer's ability to plan, follow up and manage the masses within the project. For example, how the organisation plans and follows up mass management, use of existing masses and minimisation of transport. Also what method the organisation uses to report its mass management on a monthly basis (Trafikverket, 2024).

In this fictitious scenario, which can be seen in Table 3.1, tender D is awarded the contract because it has the lowest comparative sum, even though all tenders had the same initial tender amount. This illustrates how the Swedish Transport Administration uses value-based procurement to reward high-quality solutions that partly involve environmental aspects through mass management.

Table 3.1. *Examples of evaluation models with fictitious numbers.*

Tender	*Tender amount (SEK)*	*Points Organizational structure*	*Points Mass Management*	*Total added value (SEK)*	*Comparison total (SEK)*
A	500 000 000	0	0	0	**500 000 000**
B	500 000 000	1	1	33 333 333	**466 666 667**
C	500 000 000	2	2	66 666 667	**433 333 333**
D	500 000 000	3	3	100 000 000	**400 000 000**

3.1.4 Abnormally Low Tender

According to 16 chap. 7§ (SFS 2016:1145) when awarding a contract, abnormally low tenders must also be handled. If a contracting authority considers that a tender is abnormally low, it must request an explanation from the supplier. Possible explanations may include, for example, cost-effective production methods, innovative technical solutions or particularly advantageous business conditions. If the supplier cannot provide a satisfactory explanation, the authority may reject the tender.

If a tender is abnormally low due to non-compliance with statutory requirements on labor law or environmental protection, the authority may decide not to award the contract to that supplier. This is an important measure to prevent unfair competition and ensure that public procurement does not lead to social or environmental dumping (16 chap. 9§ SFS 2016:1145).

3.2 Different Types of Contracts

Within the construction sector, there are different forms of contracting that can affect the project's implementation, division of responsibilities and financial outcome, since the form of contracting controls the responsibility for the final product. The form of contracting determines how responsibility for design and execution is distributed between the client and the contractor. The two main forms of contracting are Design-Build (DB) and Design Bid Build (DBB) (Boverket, 2024).

3.2.1 Design-Build

In Design Build, the contractor is responsible for both design and construction, which means that the client only specifies the functional requirements. This allows the contractor to optimize both the design and construction process to meet the requirements. One of the advantages of design-build is that the contractor often has specialist knowledge, which can lead to cost-effective solutions. At the same time, it means that the client has less insight and control over the details of the project design, which can pose a risk if the client does not have sufficient experience, technical competence and resources to clearly define the functional requirements (Boverket, 2024).

Design-Build creates a great opportunity and freedom for the contractor to choose materials and working methods, which makes this form of contract a greater opportunity for the contractor himself to contribute with climate-improved measures, provided that previous design, contract agreements and planning regulations allow this. An example could be that different building systems are allowed on this project, which can be an advantage for an innovative environmentally minded contractor. This higher level of freedom for Design Build also means broader opportunities for the client to set their climate requirements in the procurement, for example, the client can set a requirement for an overall climate impact for the project. With lower degrees of freedom for the contractor, such as the Design-bid-build contract form, the client must have greater knowledge and experience to set reasonable climate requirements for the project with the given conditions (Thrysin, o.a., 2020).

3.2.2 Design-Bid-Build

For the Design Bid Build contract form, this means that the client is responsible for the design and provides detailed construction documents, while the contractor is only responsible for carrying out the work according to these documents. This model requires that the client has sufficient experience, technical competence and resources to handle the design. The advantage of this form of contract is that the client retains a high degree of control over the design and quality of the project. The disadvantage is that any shortcomings in the design fall under the responsibility of the client, which can lead to increased costs in the event of changes or errors in the planning phase (Boverket, 2024).

In design-bid-build, the client has a significantly greater responsibility than in design-build, which requires competence and experience. In this form of contracting, the client is responsible for producing construction documents and the possibilities can often be more limited in terms of which climate requirements can be imposed on the contractor. The climate requirements that are reasonable to set in the project are governed by the construction documents, which makes it extremely important that the client himself has taken climate performance into account at an early stage of the project when the construction documents are produced. Once the construction documents are complete, the client can at that stage determine what possible requirements for the overall climate performance of the project, which could, for example, be the project's total climate impact in the form of carbon dioxide emissions during its life cycle, which can be calculated through, for example, a Life Cycle Analysis (LCA). The client can also include climate-improved requirements in the procurement in the form of material selection, transport and energy use or the choice of efficient resource-use construction methods (Thrysin, o.a., 2020).

3.2.3 Other Forms of Contracting

In the Swedish construction and civil engineering sector, traditional contract forms Design-Build and Design-Bid-Build have often been characterized by separate processes and limited collaboration between project actors. To meet these challenges and promote effective collaboration, alternative models such as partnering and the alliance model have been introduced. These relationship-based contract forms aim to create a culture of openness, trust and shared responsibility, which can lead to improved project results and increased innovation (Eriksson & Hane, 2014).

Partnering or collaborative contracting is a form of collaboration that differs from the traditional DB and DBB contracting forms. Within this form of contracting, openness, innovation and joint responsibility between clients, contractors and other involved actors are promoted. Collaborative contracting can be advantageous in projects with climate impact because it is an effective method that creates flexibility and cooperation around environmental and sustainability goals. This can greatly facilitate projects in which it is difficult to fully define at an early stage how and which climate performance and climate-improved measures the project should contain. The project can define common climate goals instead of lots of detailed requirements in the procurement documents (Thrysin, o.a., 2020).

The alliance model means that the client selects from one to several of each planning partner, consultants and contractors. Together, they all come together in a joint contract where profits and risks are shared between the partners. This method creates incentives for cooperation and a high degree of transparency in decision-making. The alliance model has been applied in both the public and private sectors. An example of a project is the Finnish railway project Liekki, where the Finnish Transport Agency (Formerly Swedish Transport Administration) formed an alliance organization with a private actor between

2012-2015. In this project, the form of cooperation was able to contribute to the project being completed approximately two years earlier than planned, with a cost reduction of EUR 1.6 billion euros compared to the budget, while successfully achieving all predefined objectives (Trafikverket, 2024).

3.3 Industry Actors / Stakeholders

The project roles that this study will focus on are the client, the consultant, and the contractor. Many other roles are important as well, but these are the main actors in an infrastructure and bridge project and the ones principally affected by climate requirements, according to Ekström (2019).

3.3.1 Client

The client in this context is the STA, who is the owner and the one responsible for most infrastructure and bridge projects in Sweden. According to Ekström (2019), infrastructure and bridge projects consists of around six contractors and ten consultancy firms in addition to the STA as client, architects are rarely used in projects like this. The client is the one who initiates and funds the project and awards the contracts to consultancy firms and contractors (O'Brien, 1975). The owner also approves materials, ensures that the work site is available, and makes the final decisions.

3.3.2 Consultant

The consultants often consist of architects and design (structural) engineers, however, as mentioned before architects are rarely used in infrastructure and bridge projects (Ekström, 2019). Luth (2011) describes the definition of design engineers as the one who has deep knowledge and awareness of structural systems and designs and applies this knowledge to make the design reliable and reasonable in economical, secure, and practical purposes. They are responsible for the optimal combination of choosing materials and defining the structural systems, which has a direct effect on the construction execution (Ekström, 2019).

3.3.3 Contractor

According to Ekström (2019), the contractor is the one in charge of executing the construction, which can involve many activities such as planning, project management, site logistics, resource allocation etc. Luth (2011) defines a construction engineer as the one who knows the fundamentals in construction engineering and architectural design and advanced knowledge in construction principles. They are responsible for planning, coordinating and executing the construction activities in a risk-free, economical, and efficient way to ensure high project quality and value.

3.4 The Swedish Transport Administration's Climate Requirements

STA's climate requirements are supported by their guideline TDOK 2015:0480 (Bengtsson, 2024), which is specifically for the procurement of transport infrastructure. The climate requirement's outline is presented in Figure 3.1, where it is divided into different branches depending on the investment scope, type of contract, material and transports. Generally, the requirements are either material and fuel-specific requirements, or percentage-based reduction requirements depending on the project scope. The aim is to contribute to the Swedish Government's long-term goal of climate neutrality by 2045, therefor striving for a climate neutral infrastructure by 2040, as mentioned in Chapter 1. The reduction of emissions has a pace of 8% per year on average, compared to the starting position of 2015, which is defined in STA's Climate Calculation Tool.

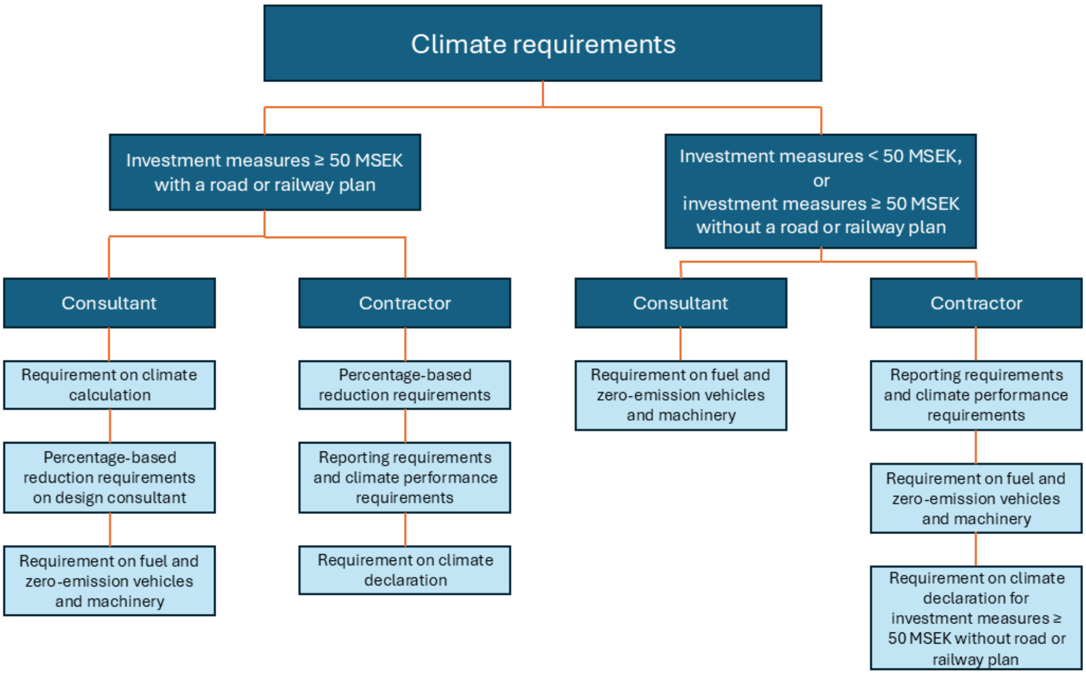

Figure 3.1. *Overview of the Swedish Transport Administration's climate requirements, modified from Bengtsson (2024).*

The STA has different phases with different milestones when executing an infrastructure project, presented in Figure 3.2.

The first phase is the *Strategic Choice of Measures* (SCM), and it's implemented early in the design phase. The SCM is based on a dialog between STA and the client, mostly municipalities and regions, and it considers all combinations of traffic types and measures to find a cost effective and sustainable solution for community development. A climate calculation, C0, is established during this stage (Trafikverket, 2023).

The *Planning Process* has four stages with three different climate calculations (Trafikverket, 2024). *Consultation Basis* is the first stage in the planning process which includes climate calculation C1. These documents are the initial documents prior to decision on significant environmental impact. Thereafter, *Consultation Documents* are assembled by choosing a measure and establishing a climate calculation (C2) based on these options together with a financial update. The documents are then quality assured according to the construction cost estimate and a new climate calculation (C3) is established in preparation for *Review* and *Verification* (Miliutenko, 2022).

The final phase consists of finalizing the *Construction Documents* and *Production* of the infrastructure project. Together with the construction documents, a final climate calculation (C4) is done before procurement and as a part of the final delivery a climate declaration (CD) is established to show the actual climate impact of the construction (Miliutenko, 2022).

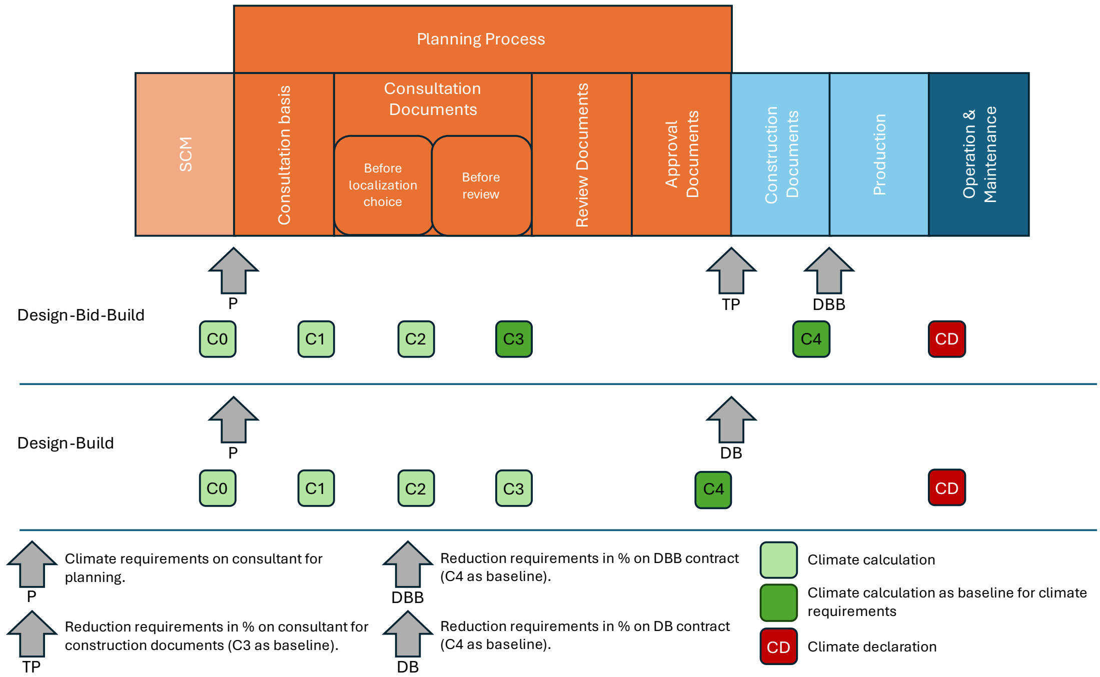

Figure 3.2. *Model of climate calculations, climate declarations and climate requirements during the building process, modified from Bengtsson (2024).*

The STA uses a work strategy called the four-step principle where each step covers different aspects and stages in the development of transport infrastructure. The principle is imperial in STA's work for ensuring sustainable and effective measures. *Rethink* is the first step in the four-step principle and it's about considering the measures that affect the need for transportation and choice of transportation. In this step, measures such as localization, land use, taxes and subsidies are considered. The second step is *Optimize*, which is about implementing measures that contribute to using existing infrastructure in a more efficient manner. These measures can be rearrangement of areas, intelligent transportation systems (ITS-solutions), and logistic solutions. When necessary, the third step *Rebuild* is being carried out, which means that limited reconstructions and renovations should be done. These reconstructions can be reinforcements, widening, trimming measures, and platform extensions. If the first three steps cannot be satisfied, a fourth step *Build new* is carried out. This step means new investments or larger reconstructions and renovations such as new roads and railways, new stations, or new bridges and tunnels (Trafikverket, 2021).

3.4.1 Climate Calculation Tool

The STA uses their own climate calculation tool to assess and present the energy usage and climate impact from construction, operation and maintenance during a lifecycle. This tool is used as a decision-making basis for the overall impact assessment and is reviewed and approved to be used in STA's organization. The STA has established the guideline TDOK 2015:0007 for the initiation and utilization of climate calculations in infrastructure. The guideline states for what types of projects and at what stages a climate calculation should be established, the connections between construction cost estimates and overall impact assessment, verification demands on the inputs, and boundaries in the system during calculations (Miliutenko, 2022).

Climate calculations should only be implemented for projects with investments or reinvestments measures above 50 MSEK. In the SCM-stage a climate calculation is implemented for projects above 50 MSEK if they include a simple or complete overall impact assessment. If the investment measure is below 50 MSEK in the SCM-stage and exceeds 50 MSEK during the planning process, a climate calculation is implemented. However, if the cost exceeds 50 MSEK at a later area of activity than planning, no climate calculation is required (Miliutenko, 2022).

3.4.2 Reduction Requirements on Climate Impact

According to guideline TDOK 2015:0480 (Bengtsson, 2024), percentage-based reduction requirements on greenhouse gas emissions are required from suppliers, contractors and consultants on investment measures equal to the criterions of climate calculations, as described in previous section. For investment measures below 50 MSEK or investment measures without a road or railway plan it is not a requirement to apply percentage-based reduction requirements. The climate impact reductions for each project that is completed yearly should follow the STA's long-term goal of climate neutrality with a reduction of 8 percent per year on average, as stated in Table 3.2.

Table 3.2. *The Swedish Transport Administration's interim goals (Bengtsson, 2024).*

Year	***Reduction goal compared to 2015 (%)***
2020	15
2025	**30**
2026	36
2027	42
2028	48
2029	54
2030	**60**
2031	64
2032	68
2033	72
2034	76
2035	**80**
2036	84
2037	88
2038	92
2039	96
2040	**100**

In the planning stage, the reduction requirements on climate impact entails basis on decisions affecting the greenhouse gas emissions and shapes the requirements set in later stages. In a DBB contract, the consultant shall propose reduction requirements for the consultant preparing the tender documents and construction documents. In a DB contract, the consultant shall propose reduction requirements to be set on the contractor. These proposals are based on the climate calculation done in accordance with TDOK 2015:0007, 'TP' for DBB contract and 'DB' for DB contracts in Figure 3.2. The STA can also choose to develop the reduction requirements themselves (Bengtsson, 2024).

In a DBB contract, the established requirements from the proposal in the planning stage are implemented in the procurement of the preparation of the tender and construction documents. Here the climate calculation C3 is used as a starting point. The consultant preparing the tender and construction documents should be able to propose actions which corresponds to the reduction requirements demanded by the STA in climate calculation C3. A proposal for the contract on the reduction requirements should also be presented together with climate calculation C4, which stands as a starting point for the final requirements asked in the procurement of the contractor. The savings from the final requirements imposed on the contractor will be achieved by material and fuel requirements, such as emission factors from suppliers delivering materials, and using renewable energy. By the year 2030, demands that all vehicles and machinery will be driven on electricity or certified sustainable biofuels, will apply. The difference in a DB contract is that during the planning phase or preparation of tender documents, reduction requirements based on climate calculation C4 are directly incorporated in the procurement of the contractor. The contractor is then responsible for both preparing the construction documents and executing the construction phase (Bengtsson, 2024).

The STA also have requirements on products and materials used in the project, these requirements consist of reporting requirements and climate performance requirements. The climate performance requirements refer to the maximum greenhouse gas emissions for a specified quantity. The products and materials these requirements refer to is reinforcement steel (passive reinforcement), other types of steel products, road and bridge railings, factory mixed concrete and asphalt, where an Environmental Product Declaration (EPD) is required. The reporting requirements alone are for investment measures above 50 MSEK, while performance requirements together with reporting requirements are for investment measures below 50 MSEK (Bengtsson, 2024).

STA's requirements on fuel and zero-emission vehicles and machinery applies to investment measures below 50 MSEK or without a road or railway plan. If applicable, these requirements can be included in investment measures above 50 MSEK alongside the reduction requirements; however, their inclusion is optional according to TDOK 2015:0480. The requirements include construction work and transportation of materials, as well as vehicles and machinery used in conjunction with consultancy services (Bengtsson, 2024).

3.4.3 Follow-up on Climate Requirements

The greenhouse gas emissions shall be presented before the end of a project together with the effect of the taken measures, by the consultant or the contractor. The climate impact is presented through the climate declaration according to TDOK 2015:0007, together with verifications on the materials and products, such as EPDs. With extensive changes during the project a revised baseline can be calculated to adjust the reference point, this is calculated using reverse calculation. By adding the climate reductions to the impact according to the climate declaration, a new reference point is determined for a more realistic picture of the actual reductions. STA uses reporting templates for fuel requirements, where receipts and invoice documents should prove the quantities and qualities of the fuel used in the project. The reporting is done annually. The procuring entity is responsible for the climate requirements and starting position in the tender documents, while the investing entity compiles the requirements and ensures that these are annually met according to the specified criteria. Greenhouse gas emissions and climate impact reductions are documented in the climate calculations, where the results of target fulfilment are reported to the planning entity (Bengtsson, 2024).

3.4.4 System for Bonus, Penalty and Added Value

In the tender documents, the level of bonuses, penalties and added value should be clear. These are used both for the procurement of consultants and construction contracts as an incentive to reduce climate impacts and exceed climate requirements. The bonus should be equal to the long-term cost of implementing the climate measures per kg CO_2e and the penalty should correspond to double the level of bonus. Therefore, the bonus should be between 1-1,5 SEK per kg CO_2e and the penalty between 2-3 SEK per kg CO_2e. The bonus is implemented when climate reductions are higher than the primary requirements during the construction phase. A bonus cap parallel to STA's climate reduction goals is implemented in the system, which makes it possible for the consultant or contractor to get a bonus up to a certain point, depending on the completion year of the project. The bonus cap reductions are compared to the year 2015 and follows the reduction goals each year, the milestones are presented in Table 3.3. The magnitude of added value from exceeded climate impact reductions should align with the bonus system (Bengtsson, 2024).

Table 3.3. *Bonus cap of reduction goals (Bengtsson, 2024).*

Year	***Reduction goal compared to 2015 (%)***	***Bonus cap compared to 2015 (%)***
2020	15	30
2025	30	60
2030	60	100
2035	80	100
2040	100	100

3.5 International Strategies for Climate-Based Public Procurement

This section highlights how Norway, the UK and the Netherlands have designed and implemented strategies to reduce emissions through public investment. The focus is on legislation, incentive models, innovation-promoting methods and practical tools that have been used to achieve ambitious climate goals, and how these strategies are linked to the respective countries' overall climate and sustainability goals.

3.5.1 Norway

Norway has recently systematically integrated climate requirements into its public procurement to minimize the climate impact of the construction and civil engineering sector. Through legislation, economic incentives and innovation-driven procurement models, public procurement is used as a tool to steer the construction industry towards sustainable development. Norway has this as part of its strategy to achieve climate goals according to the Paris Agreement and the national transport plans (Wiik, Flyen, Fufa, & Venås, 2020).

In Norway, public procurement is regulated by the Forsskrift om offentlige anskaffelser and Meld. St. 22 (2018–2019), which have been adapted so that contracting authorities have the possibility to include climate requirements in contracts as can be seen in Table 3.4. The requirements allow public developers to ask for environmental measures such as either a requirement specification, qualification requirement, allocation criteria, or contractual requirement. A significant change in the Norwegian Public Procurement Act (PPA) came into force on the 1st of January 2024, meaning that climate and environmental aspects must now constitute at least 30 percent of the evaluation criteria in public procurement. In many of the contracts, the weighting ranges between 40% and 60% (Wiik, Flyen, Fufa, & Venås, 2020).

Table 3.4. *Contractual requirements for material use, certification schemes and tools. Statsbygg, Norwegian Public Roads Administration (NPRA), and Bane NOR are key state-owned entities in Norway's infrastructure sector. Statsbygg manages government buildings, NPRA oversees the road network, and Bane NOR handles railway infrastructure (Wiik, Flyen, Fufa, & Venås, 2020).*

	Statsbygg	***NPRA***	***BaneNor***
Concrete	Low carbon class A max 240 kgCO2eq/m3	Low carbon class B/C	Low carbon class A
Insulation	max 6 kgCO2eq/m2	-	-
IHULT steel beams	min 70% recycled max 1.5 kgCO2eq/FU	min 80% recycled	min 85% recycled
Cold formed steel	-	min 10% recycled	min 15% recycled
Steel piling	-	1 kgCO2eq/kg	max 1100 kgCO2eq/t
Reinforcement steel	max 0.53 kgCO2eq/FU	max 600 kgCO2eq/t	max 600 kgCO2eq/t
Asphalt	-	max 60 kgCO2eq/t	
Aluminium	min 80% recycled		min 80% recycled
Certification	BREEAM Excellent		
Tools	CoBuilder, klimagassregnskap.no, OneClickLCA	EFFEKT 6.6, vegLCA.	Excel

To meet climate requirements, Norway has introduced several implementation strategies. Their most important tools are the requirement for Life Cycle Assessments (LCA) and Environmental Product Declarations (EPD). Statsbygg, which builds, manages and is responsible for all state-owned properties, has introduced requirements for reporting at least 20 EPDs per project. Norwegian Public Roads Administration (NPRA), which develops and manages the operation and maintenance of the road network, has introduced mandatory climate reporting for all its projects. Financial gains have also been introduced in the form of bonus-malus systems to motivate actors to reduce emissions. Contractors are rewarded if they use emission-free machinery or fossil-free workplaces and can be punished through fees if the project exceeds the emission requirements (Wiik, Flyen, Fufa, & Venås, 2020).

During an online meeting with Paulos Abebe Wondimu[1], a chief engineer at the NPRA, Wondimu shared his beliefs on the advantages and disadvantages with awarding climate criteria versus contract climate requirements. The climate awarding criteria, which came into force on the 1st of January 2024, often gives

[1] Paulos Abebe Wondimu, Chief engineer, Norwegian Public Roads Administration. Microsoft Teams online meeting 24th of February 2025.

unknown climate reductions, meaning that the clients never know what they will get. This can be risky since the reductions might not be in line with targeted climate goals since there is no strict requirement, but they may also exceed the expected reductions. On the other hand, climate awarding criteria can also drive innovation as there is competition based on the climate criteria to get the project, the more climate reductions the higher the award, resulting in higher competition in the tender bidding. The advantage with contract climate requirements is that the clients know what they get, however, it doesn't drive innovation in the same way if there is no motivation to deliver more than the climate requirements. To mitigate the chance for high prices and monopolies in infrastructure projects with awarding climate criteria, NPRA encourages collaborations between suppliers and contractors. This is accomplished through workshops to agree on relevant and suitable climate criteria before the preparation of tender documents. NPRA uses competitive negotiated procurement procedures, where the client and contractors have the possibility to clarify the climate awarding criteria.

Wondimu mentioned different tools and methods that have yielded good results in the Norwegian climate work. Bonus systems are used to motivate both contractors and consultants to reduce climate impacts, where the consultants get bonuses for using less material. The Norwegian consultants have a program that integrates LCA-calculations directly in the BIM-software in the design phase, which makes it easier to reduce climate impacts further as the climate-calculations are done simultaneously. Depending on the project, a climate pot can be used to encourage innovative ideas. Wondimu found that contractors and consultants, especially the bigger companies, want to be more challenged with climate requirements because of their own strategies and abilities.

3.5.2 United Kingdom (UK)

The UK has become a leading nation in reducing carbon emissions in infrastructure construction by setting ambitious policy targets, clear procurement requirements and innovative collaboration between the public and private sectors. Their strategy is based on a combination of legislation, market-driven incentives and technological innovation to drive long-term changes in the construction and civil engineering industry. The British government has been pushing for the minimization of carbon emissions in the construction sector through the Construction 2025 strategy, which had the goal and vision of halving carbon emissions in the construction sector by the current year 2025 compared to 1990 emission levels. The government's policy emphasized the importance of introducing 'stretching targets' and clear baselines to be able to measure and reduce the carbon footprint of large infrastructure projects. (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2021)

The UK has introduced several strategies to minimize emissions through public procurement. One strategy is to use certifications and standards to ensure that suppliers and contractors integrate carbon reduction into their construction projects. For example, contractors are required to be certified to the publicly available carbon reduction specification PAS 2080 within one year of contract award, and the asset will be certified to BREEAM Infrastructure. Reducing carbon emissions in infrastructure projects cannot be achieved by a single party but requires collaboration between all actors throughout the value chain. Performance-based requirements have also been a central part of the strategy, giving contractors great flexibility to develop innovative strategies to achieve carbon dioxide targets. One of the UK´s largest infrastructure projects called High Speed 2 (HS2) aims to minimize carbon dioxide emissions by 50 per cent compared to traditional construction methods. This project used Early Contractor Involvement (ECI), which means that contractors with their experience and knowledge are involved early in the planning stage to be able to influence design choices and material use before construction starts. In addition, the project uses low-carbon concrete and energy-efficient transport solutions. All suppliers involved in the project must report their carbon dioxide emissions and carry out life cycle assessments. (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2021).

Anglian Water, a private water company in the East of England, was founded in 1989 and has focused on carbon reduction for the past 10 years. The company has established long-term alliances with key suppliers for its major construction projects, which have successfully achieved carbon reductions of over 50 per cent. Their procurement strategy is based on financial incentives for suppliers who manage to reduce carbon emissions, combined with the use of standardized low-carbon materials (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2021).

3.5.3 Netherlands

The Netherlands climate goal is to reduce the greenhouse gas emissions by 95 percent by 2050, in comparison to 1990. The major road and waterways administration in the Netherlands is called Rijkswaterstaat (RWS), equivalent to Sweden's STA. According to Lingegård et al. (2021), RWS's sustainability goals and the Dutch government's climate goals have a direct link, where RWS wants to reduce its emissions with every large project towards the government's goal of climate neutrality by 2050. Various actors such as state, industry and non-governmental organizations have developed different collaborative agreements to the Dutch climate goals by reducing fossil fuel use. Initiatives like the Dutch Climate Coalition focuses on reducing carbon emissions, especially in large infrastructure projects using public procurement. While the DGW 2.0 deal, which is another initiative, brought together suppliers and clients within the infrastructure sector.

The CO_2 Performance Ladder and DuboCalc are two tools that have assisted in the development of climate requirements in procurement, specifically in the Dutch construction sector. The CO_2 Performance Ladder certifies construction companies based on their carbon management and is used in tender documents to sanction discounts, enlightening companies of carbon emissions in the industry (Lingegård, Alkan Olsson, Kadefors, & Uppenberg, 2021). The certification system was developed by RWS and the Dutch Public Procurement Expertise Center PIANOo with five certification levels, allowing for up to 5 percent tender discounts depending on the level the company is certified at (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2021). However, many large companies have achieved the highest certification making it pointless to discriminate between tenders. The DuboCalc tool is mostly used in large, privately funded projects based on carbon footprint and environmental performance, allowing for tender deductions and competitive dialogue processes. The Competitive Dialogue procurement model selects a winner of the tender, between parallel teams, based on environmental impact and climate reduction levels with tender discounts up to five percent (Lingegård, Alkan Olsson, Kadefors, & Uppenberg, 2021). Penalties of 1,5 times the tender discount is set on the contractor if the environmental goals for the project are not met (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2021).

In the Almere project, a part in a motorway project between the city of Almere and Amsterdam, DuboCalc was used to reward climate performance in the design phase. The contractor was responsible for the design, build, finance and maintenance of the project. By developing a baseline on climate performance, the tenderers could receive deductions on their bid price in relation to their climate reductions from the baseline. This resulted in that the contractor had to find their own solutions to meet the climate requirements. Since it is hard to balance climate reductions that are achievable and challenging enough to meet climate goals with functional requirements, using prescriptive requirements may prove useful when new technologies emerge to ensure adoption in future projects (Lingegård, Alkan Olsson, Kadefors, & Uppenberg, 2021).

3.6 Sources of Greenhouse Gas Emissions from Infrastructure Construction

The climate impact of infrastructure regarding construction, operation and maintenance has a significant impact in Sweden. A large part of the emissions come from the material production of concrete and steel used in the infrastructure's bridges and other structures which can be seen in Figure 3.3 (Uppenberg, Ekström, Liljenroth, & Al-Ayish, 2017). According Uppenberg et al. (2017) the reduction potentials for bridges and other structures are assessed to be large by only applying today's best available materials and construction techniques.

An increased focus and commitment to sustainability issues has developed in recent years, with the Swedish Transport Administration working to develop a range of initiatives to increase productivity and innovation in the construction and civil engineering sector. The STA emphasizes that a greater degree of industrial thinking, standardized products and processes, and a clearer focus on learning from experience are required to avoid previous mistakes and instead optimize processes. To successfully implement this, it is required that the entire construction & civil engineering sector should have a joint commitment to achieving closer and improved cooperation/collaboration in order to be able to minimize disruptions throughout the entire bridge and construction process and instead work towards an optimized process, everything from the start of design to the final stage of production (Uppenberg, Ekström, Liljenroth, & Al-Ayish, 2017).

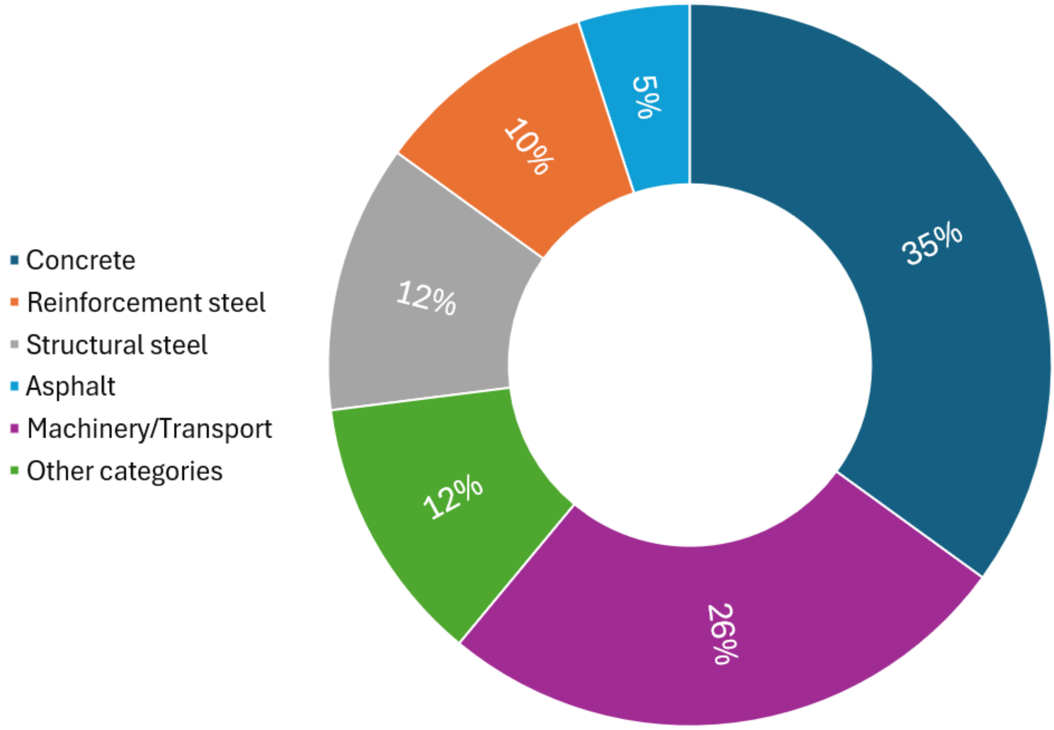

Figure 3.3. *Sources of greenhouse gas emissions (from a life cycle perspective) from infrastructure construction, modified from Uppenberg et al. (2017).*

3.7 Ability to influence climate outcome

The early and initial phases of a construction project play a crucial role in the quality and success of the project. Decisions made in the early stages of the project have a significant impact on costs, schedule performance and dispute resolution (Hasanzadeh, Esmaeili, Nasrollahi, Gad, & Gransberg, 2018). The opportunities to influence the project's outcome are greatest in the early stages and decrease as the project progresses to detailed design and then the start of the production phase (Laufer & Cohenca, 1990). This chapter examines the effects of early decision-making on projects, how Early Contractor Involvement (ECI) can impact the project, and also sustainability aspects such as climate-efficient building design.

The opportunity to make significant changes and influence the project is greatest in the early stages and gradually decreases as the project progresses. At the same time, the cost of changes increases as the project progresses (See Figure 3.4) (Song, Mohamed, & AbouRizk, 2009). Laufer & Cohenca (1990) identified that planning and key decisions made by the right key people with skills and experience at early stages are an important factor influencing final project performance. They also emphasized that decisions regarding subcontractor management, labour availability and environmental predictability must be considered at early stages.

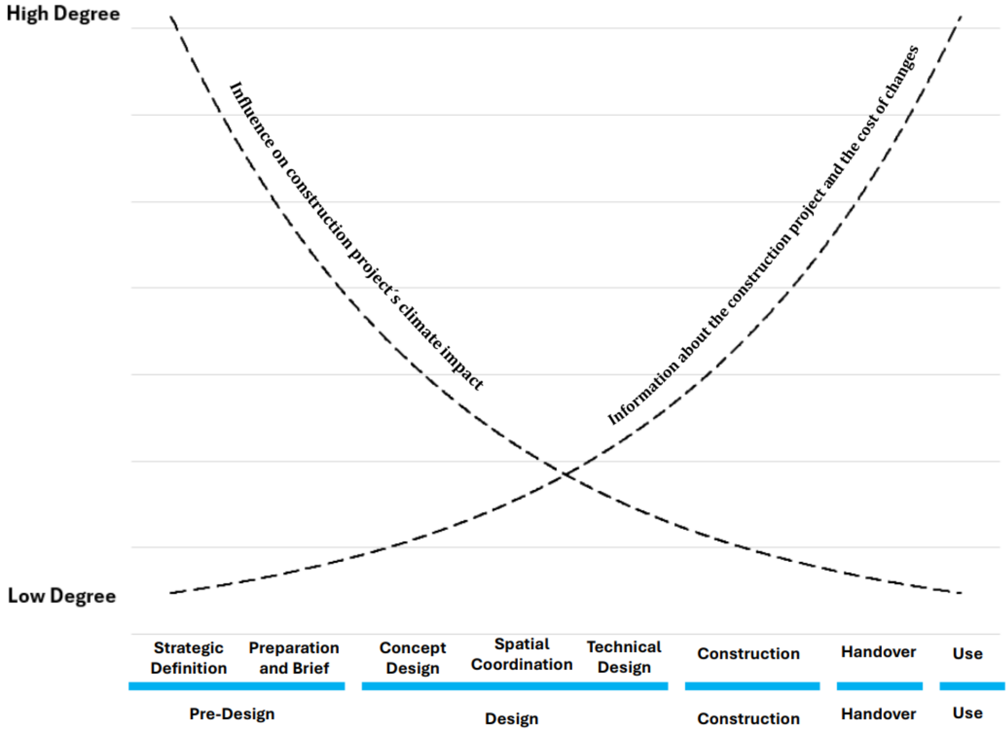

Figure 3.4. *Diagram of the possibility of influencing the construction project's climate footprint and available information about the construction project and the cost of changes over time, modified from Högberg et al. (2022) and Roberts et al. (2020).*

According to Högberg et al. (2022) in order for climate performance in the construction sector to become a guiding principle in procurement, higher competence in climate-adapted procurement is required among the client organisations. Several organisations often have their own purchasers, but lack the in-depth expertise required to steer the project towards more climate and sustainable solutions. It is necessary for the purchaser organisations to increase their understanding of climate and sustainability in order to have it as a central part of the procurement process. Furthermore, the PPA should also be adapted more to focus on building climate-efficiently and sustainably rather than lowest price. Climate-smart solutions may be more expensive initially but provide long-term savings in operation and maintenance (Högberg, Ingelhag, Perzon, & Berg, 2022).

3.7.1 Early Contractor Involvement

ECI is a project delivery strategy that includes contractors with high expertise in the design process. This creates opportunities to optimize constructability, cost-effectiveness and climate performance (Song, Mohamed, & AbouRizk, 2009). Research shows that projects that have used ECI achieve improved schedule performance thanks to increased coordination and proactive risk management (Högberg, Ingelhag, Perzon, & Berg, 2022).

Improved Schedule Performance occurs by allowing contractors to detect potential design errors or procurement issues early, thereby minimizing schedule delays.

Empirical data shows that ECI leads to better drawing quality, material procurement, and workflow efficiency (Song, Mohamed, & AbouRizk, 2009).

Improved Constructability and Climate Optimization occur when contractors contribute their knowledge and experience early in the design phase, thereby identifying cost-effective and climate-efficient construction methods and materials that reduce complexity and minimize waste (Högberg, Ingelhag, Perzon, & Berg, 2022).

Proactive risk management occurs when the contractor's expertise can more easily identify risks at an early stage, such as unforeseen ground conditions, design inconsistencies, or labor shortages. The contractor enables the development of contingency plans that prevent costly modifications later in the project life cycle (Hasanzadeh, Esmaeili, Nasrollahi, Gad, & Gransberg, 2018).

Mats Karlsson[2] believes that although ECI can be a good method for obtaining benefits such as shorter construction time, lower costs, reduced risk of design changes and improved quality, people with the right skills and experience in construction production and also environmental expertise must be included in even earlier stages of the project. It is recommended that this be done already in the investigation phase of the project, since the impact is greatest then (see Figure 3.4). It is important to point out that external organisations that may potentially bid on the project cannot participate in this early investigation phase as they are building an advantage for the upcoming tender stage. The project investigation team should instead recruit people with the right knowledge and experience to make the right decisions regarding the design, size and location of the project which in turn may affect the environment and biodiversity.

3.7.2 BIM and LCA Tools

The majority of BIM and LCA tools today are used separately and manually. Firstly, the BIM-model is developed, then the greenhouse gas calculations are calculated separately. This makes it more cost- and time-consuming, more difficult to follow-up, and to identify potential improvements. However, progress is being made to automatically integrate LCA-calculations into the model-based design. The Norwegian Public Roads Administration are developing a model-based LCA-tool which gives an overview of greenhouse gas emissions during the entire design process, both at project and portfolio level. Advantages with integrated LCA-calculations within the model-based design is that it’s cost and time effective, the potential of emission reductions are better utilized, uniform methodology and more comparable results (Statens Vegvesen, 2022).

According to Chen et al. (2024), there are five different methodologies for integrating LCA tools with BIM software. The first one is bill of quantities import, where the list of quantities from the BIM-model is imported into an LCA tool for calculation. The second method is IFC import, where IFC is a file format when exporting a BIM-model. The IFC-model is reformed to only necessary data and

[2] Mats Karlsson, visiting professor at Chalmers University of Technology, earlier director of investments at the Swedish Transport Administration. Microsoft Teams online meeting 11th of March 2025.

integrated into an LCA-template to map the data and calculate emissions. The third method is using a BIM-viewer to summarize a list of LCA files (building components etc.), which is then transferred to an LCA software for calculations in 3D. The fourth method is to calculate LCA directly in the BIM software using BIM plug-ins. The LCA database is obtained in the BIM software where building components can be added both to and through the LCA database, which can be very time consuming. However, third party LCA databases can be connected to the BIM software which can lead to a more seamless integration. The fifth methodology is called LCA plug-in calculations, where the plug-ins act as a bridge between the BIM software and the external LCA tool.

4 Empirical findings

This chapter presents the empirical findings from semi-structured interviews with key stakeholders in infrastructure projects. For each project, a representative from the contractors, consultants and the Swedish Transport Administration, was interviewed. In addition, key individuals within the construction sector were interviewed to gain further insight. In Figure 4.1, it is illustrated how the different themes answer the three Research Questions.

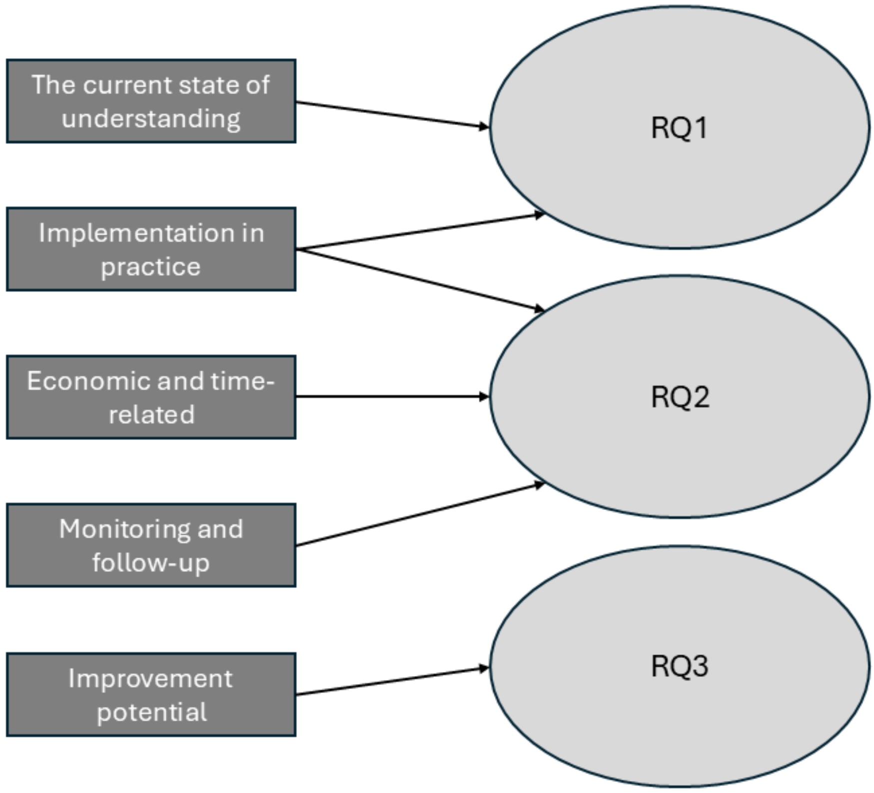

Figure 4.1. *How the empirical themes answer the Research Questions.*

4.1 The Current State of Understanding Climate Requirements

Since 2015, climate requirements have emerged as a central instrument for the Swedish Transport Administration's pursuit of a climate-neutral infrastructure by 2040. Through primarily material requirements and overall percentage reduction requirements, STA has attempted to steer its projects in both design and production towards a lower climate impact. Experience from practice shows that the understanding and interpretation of these requirements varies considerably, depending on the role, project form and organizational conditions.

4.1.1 Subject-matter Experts

Interviewed subject-matter experts unanimously agree that climate requirements have become increasingly established and accepted in the industry, but that significant challenges remain regarding clarity, follow-up and incentive structure in order to be able to set even stricter climate requirements in the future.

There is widespread agreement that material requirements, especially the specific material requirements regarding the use of climate-improved concrete, asphalt, reinforcing steel or the use of the climate-reduced fuel HVO100, are relatively clear, feasible and possible to follow up and verify. Some of these climate-reduced materials have already become standard in the market.

The requirements for percentage reduction that may be perceived as theoretically well-founded but are more difficult to handle in practice and are perceived as significantly more problematic than the material requirements. Material requirements provide a clear assurance that a certain amount of CO2 reductions will be achieved, while reduction requirements are highly uncertain as to what amount of reduction is achieved. Combining material requirements with reduction requirements means that an assurance that a certain amount of CO2 reductions will occur. A recurring criticism is that reduction requirements are based on comparing against uncertain assumed starting values that are often based on system documents in the Climate Calculation Tool with very rough estimates and are based on templates rather than project-specific data. This makes it difficult to assess whether the projects potentially achieved reductions truly represent actual climate reductions. This has led to some projects being able to report large reductions without necessarily having implemented any significant climate-reducing measures, because the starting point was exaggerated from the start. With percentage reduction requirements, there is a risk that resources are spent on calculation-based documentation rather than actual focus on reducing emissions in practice.

"The reduction requirements can be combined with specific material and fuel requirements, and then at least some reduction is ensured. But despite the combination, we often get stuck in discussions about the starting point instead of working together with the contractor to find possible, practical measures."

- ***Quote by Interviewee D***

Several respondents emphasize that the climate issue is often introduced too late in the project and is only addressed after important technical and economic decisions have already been made. Climate requirements are not integrated into the project's calculations from the beginning, which leads to climate mitigation becoming a marginal issue, rather than part of the early core strategy. At the same time, it is noted that a lot of time and resources are spent calculating, documenting and analysing climate impact and in some cases, it takes focus away from practical climate measures, which indicates that more flexible tools and working methods are needed to actually work towards climate-reduced measures.

4.1.2 Contractors

The contractors confirm that STA communicates its climate requirements in the form of overall targets and percentages for emission reduction. They have clearly formulated long-term goals with percentage reduction milestones from a defined reference value in 2015 to the goal of climate neutrality in 2040. Although there is this formal clarity, it is not always reflected in the implementation of the project, according to contractor H, K & L. It is felt that STA project organizations lack practical knowledge of how the climate goals are actually to be achieved.

They understand the goal itself but lack insight into which technical solutions are available on the market, what they cost, and what limitations exist on the market. This leads to a gap being created between STA's ambitions and the practical feasibility for the contractors. An example that contractor H mentions is a project where STA had set requirements for electric heavy vehicles but during the implementation phase of the project such machines were not available in the scale and performance to be used in the project. This results in situations where STA ambitions for climate requirements are formulated without taking into account the realistic availability of today's technology.

"They have a very good idea that you should save 38 percent. But how are we going to reach 38 percent? How do we do it? How should we work? What should we do to achieve this 38 percent? And also, what does it cost to achieve this 38 percent, for example? We have a procurement now where they have set a requirement that we have electric light trucks. They don't exist on the market and then they set a requirement that is not possible to achieve in that contract"

- ***Quote by Interviewee H***

The contractors feel that there are also structural problems and a shift of responsibility within the projects where the climate targets end up with the contractor to meet, without the conditions necessarily existing. The STA only sets various climate targets but lacks the knowledge to guide implementation in practice, while the contractor is given the responsibility to deliver the result without sufficient information, support and technical flexibility.

Interviewee K also believes that barriers arise within all levels of the contracting organization. Even though STA is clear about the climate requirements, the entire contracting organization needs to understand the climate requirements and get involved, which does not always work. Furthermore, Interviewee K believes that even if the climate requirements are clear at a strategic level, there is sometimes a lack of consensus and understanding in the STA project organization. For the climate targets to have a greater impact, there needs to be more than a formal framework through internal skills development within the client organization and increased integration between procurement requirements and actual design and production skills.

"STA is clear about the climate requirements themselves ... But then it is all the more difficult to get the entire contracting team to understand that it also needs to be carried out"

- ***Quote by Interviewee K***

An interviewed representative J from STA describes how today's climate requirements often set a percentage reduction in relation to some starting point. If the starting point is wrong, it may be impossible to achieve the reduction requirement, for example if it is too small or too large, then the reduction will be too large. The starting point is the key to ending up right later. In a turnkey contract, it is a difficult task to arrive at a reasonable starting point because you do not know which solutions the contractor will choose since the facility is not fully defined.

Furthermore, the interviewee describes that they can take longer to build something that is climate smart. For example, situations can arise where it is cheaper and faster to do it in a certain way, but it has a higher climate impact. In these situations, the contractor may have to choose the faster way to meet a contract period or similar. Then you cannot initially assume to do what is best for the climate, but which cannot be done later anyway. STA usually builds bridges as short as possible, and then the degrees of freedom are limited. If the starting point is wrong, if it is too narrow, there will be no possibility of reducing emissions based on the starting point. When procuring a contract, the price is what is procured, which means that it is the costs that determine which climate improvements are applied. Climate requirements must be proportionate to the increasing costs.

"If the starting point is wrong, it may be impossible to achieve the reduction requirement... In a turnkey contract, it is a difficult task to arrive at a reasonable starting point because you do not know which solutions the contractor should choose."

- ***Quote by Interviewee J***

4.1.3 Consultants

The consultants' experience shows that STA's climate requirements are in many cases perceived as secondary in practical design work. A recurring observation is that the requirements are rarely controlling the consultant's everyday work, particularly when the assignment is as a sub-consultant to the main contractor. Both Interviewee I and L describes how climate related decisions are made before the design work begins, and that choices on for example material, is based on the client's directive rather than an initiative from the design team. In a specific case described by Interviewee L, the material choice for two bridges was based on STA's own life cycle analyses, however, the decision was not communicated as a climate requirement but rather framed as a technical requirement. The interviewee underlines that the climate dimension are seldom explicitly discussed in the design phase, especially if the consultants connect late in the project process.

At the same time, several interviewees point out that climate reductions often coincide with technical and financial optimization. For example, structural engineers are rarely faced with a choice where a solution is more expensive but more climate friendly. This is to some degree emphasized by Interviewee I – for the first 30 per cent of climate reduction. However, the interviewee sees great potential in reducing the climate impact further through thorough calculations and more resource efficient designs, but it will be more time and cost consuming. Something that both consultants and clients tend to avoid.

"As I mentioned earlier regarding structural design, the more calculations we do, the fewer resources are required – but this also increases costs for us as consultants."

- ***Quote by Interviewee I***

Interviewee I also raises a concern regarding the gap between what's communicated and what's actually materialized. The structural designs are often largely overdesigned and standardized solutions are rarely questioned, which leads to unnecessary climate emissions. In practice, this means that the climate ambitions from the client does not achieve the impact they're supposed to have. As long as the structural designs comply with applicable standards, their influence on climate reductions will continue to be limited. However, clients, contractors and consultants are cautious when using new materials and optimizing structures fearing it will negatively affect production or the final delivery. Interviewee A gives a vivid example of when a new cement recipe was introduced, where some projects were initially hesitant about the change. Then a large cement producer changed its recipe, and it became an industry standard that every actor accepted. Experience shows that material innovation often face resistance at first but are generally accepted when they are proven in practice.

When climate requirements are present, several consultants feel that the requirements are formulated in a way that does not give room for innovation. Interviewee E notes that the minimum requirements are relatively easy to achieve, but financial incentives are missing for consultants to reach further in climate reductions. In some cases, STA avoids demanding more sustainable materials, such as scrap-based steel, out of fear it may reduce competition. This fear of limiting bidding opportunities inhibits innovation, even if a more sustainable material results in large climate improvements. Generally, the mindset and knowledge of the project managers at STA are pivotal for prioritizing climate aspects and innovation in the projects.

Interviewee C confirms that there is an ambition within the STA to further strengthen the impact of climate requirements. The requirements are well-established, but there is still uncertainty in complex DB contracts where percentage reductions can be difficult to interpret. A recurring problem is that the climate measures are integrated too late in the process, and it makes the implementation difficult. Much of the focus falls on calculating, documenting and analysing the climate impact, instead of on practical climate measures. More support is being requested both within and outside the STA, not primarily around climate calculations but around decision-making. For example, what measures are reasonable to implement, how to handle late changes in the projects, and who takes the risk when choosing new materials and working methods? According to Interviewee C a new guideline or manual is not enough, it takes new working approaches and methods. Interviewee E also calls for targeted initiatives, such as funding for climate-smart solutions in selected projects to enable innovation despite higher initial costs. This way knowledge and methods can develop over time leading to more sustainable procurements in the future.

4.2 Implementing Climate Requirements in Practice

Sweden's construction sector is facing increasing demands to meet climate targets, but implementing these requirements in practice still poses major challenges. This section highlights how climate requirements are implemented in construction projects, based on insights from contractors, consultants, project managers at STA and subject-matter experts in the construction sector. The focus is on approaches, obstacles and possible areas for improvement.

4.2.1 Subject-matter Experts

It is apparent from the interviews that actors in the construction industry often associate climate requirements with increased costs. However, there are a number of projects that show that climate and economics are not necessarily in conflict. There is a connection that, for example, smaller bridges and tunnels, reduced mass handling and smartly planned localization not only have led to reduced emissions but also to reduced costs.

At an early stage of location investigation, tools such as Trimble Quantm can be used to simulate thousands of different line routes between point A and point B where several parameters such as climate impact, noise levels, Natura 2000 and construction costs are weighted against each other. A tool that can identify routes with low climate impact while balancing other important parameters. Interviewee C and E believe that such a working method requires resources, data bases and a committed project manager at the STA. They believe that it is not always the case that climate requirements govern this type of working method, but that an ambitious project organization with a driven and knowledgeable project manager can achieve smart solutions that include climate reductions. To achieve this working method in the construction sector, a new implemented working method in design is required that includes more time, clear evaluation matrices and coordinating goals for the consultants to strive for.

Here, the STA's role as client becomes a central part of the consultants' working methods. Consulting organizations generally lack both the mandate and financial space in projects commissioned by the STA to be able to take the initiative themselves for new climate-reduced working methods. In order for the consultants to have greater influence in their design, the STA should initiate finance and set requirements for this type of new working method. Current business models for consultants have a linear hourly-based compensation system that does not encourage innovation or value-based work. This creates a practical paradox: the greatest potential for climate impact is in the early stages, but there is a lack of ways to take advantage of it. However, it is highlighted through the interviews that it often takes double or triple the project time to climate adapt a project, which is rarely within the financial framework of the consultancy assignment.

"In order to optimize in the early stages, STA must think about how consulting assignments are formulated: What do we mean by optimizing? How much time and resources are required? How should the budget be distributed across the different phases of the project? We may need an increased budget in the design phase that we will make up for in the overall project. This requires strategic change, both in procurement form and budgeting."

- ***Quote by Interviewee C***

The role of contractors also appears as an untapped aspect in the early stages and during the design phase. It is mentioned and emphasized that contractors' practical experience of construction methods, cost control and material knowledge can contribute to sustainable concrete solutions, especially if this knowledge is used in an early design phase.

Interviewee A mentions that during his time as investment manager for the STA, one of his district managers in Gothenburg tried to involve the contractor already during the early planning phase for one of their railway projects in Västra Götaland. This in order to improve constructability and achieve efficient production, which was something that turned out very well for constructability and efficient production but also for the project's climate reduction. Despite these positive results, contractors were not continued to be involved in the early stages of other projects. Interviewee A believes that there should be greater requirements in consultancy procurements for the consultant to actually have construction technical experience and competence, either internally within the organization or external partners. Interviewee A further concludes that if the consultants possessed this expertise, it would have a major influence on the technical, financial and sustainability outcomes of the project.

Interviewee H has experience of early stages with contractors already involved in the location investigation and felt that the contractors were not used to being involved in such an early stage. According to Interviewee H, the contractors expressed difficulties in providing reliable cost estimates before the scope of the project was clearly defined, including what specifically would be built and what quantities would be included. The interviewee also believes that contractors who may have the knowledge, experience and technical competence to influence a siting investigation have a significantly greater value in production than as advisory consultants to the client on an hourly basis. This can make it difficult for the client to get contractors involved in early stages, such as the location investigation.

There is resistance within the STA according to Interviewee A, that they do not want to spend unnecessary resources in the early stages because they do not know whether the project will receive all the necessary permits and actually be initiated. The interviewee sees this as a sub-optimization because the right choice in the early stages can potentially affect the climate impact by tens of percent for the entire project. Instead of waiting with the climate issue until the production stage, where the contractors in the construction stage can achieve an improvement of perhaps 10 percent. Interviewee A points out that the increased cost in the early stages is small in relation to the total cost of a larger project that lasts for several years and believes that it is a reasonable cost even though there is uncertainty about the initiation of the project.

Interviewee C highlights Oslo in Norway as an example of how public procurement strategies can accelerate a technological transition, Oslo has gone from 0 to almost 100% electrified work machines between 2019 and 2024. Unlike Sweden's requirement ladder, Oslo in Norway has had a clear incentive model where contractors receive added value in the tender evaluation, which has been done consistently in all procurements. The model is anchored in Norwegian legislation for public procurement, where environmental criteria are weighted by 30% in all public procurements. Interviewee C has had contact with large contractors and suppliers who point out that if there are clear guidelines going forward, it is more economically justifiable to invest in new technology. Especially since this model allows the market itself to drive the pace of the transition instead of being governed by rigid requirement levels.

"It's also very important to consider the market signals... Oslo, for example, has transitioned from basically 0% electrification in 2019 to nearly 100% today. They achieved this by setting clear, long-term goals and by using a very clever evaluation model. In every individual construction contract tender, they apply a bid evaluation model where bidders receive added value based on the share of zero-emission machinery and transport they offer. This approach has enabled them to successfully move from zero to 100% electrified operations within five years".

- ***Quote by Interviewee C***

4.2.2 Contractors

According to the contractors interviewed, climate requirements have currently had a greater impact on material selection than on their production methods. Interviewee K also believes that many of their current climate reductions in production are a side effect of cost-controlled measures such as efficient mass handling and reduction of transport. These measures are motivated more by purely economic reasons than actual climate reductions, although it is good to see that economic reasons can be combined with climate benefits. It is difficult for contractors to see that climate benefits should receive their own focus without a combination with cost savings or at least cost neutrality at the present time.

"That could be the case and where there are clients who help highlight good climate performance and that could benefit us as contractors in our incoming procurement. It could actually be that they could require approximately this level of competence in climate reductions. For example, the client wants us to have a number of people with climate knowledge or that we have done one to five projects that have achieved the climate goals. If we don't have that, if we don't run an operation that is reduced this much, then we can't be involved in the procurement. ...Then finally, I think that if there is a bonus in the picture, it can drive a positive development of being able to afford to invest something, being able to afford to have an extra person, being able to afford to look at certain issues, being able to afford to test."

- ***Quote by Interviewee F***

From the perspective of the client, Interviewees G and J emphasize that the responsibility for innovation in climate-reducing projects largely lies with the contractor. However, for these innovations to be realized, clear and powerful incentives are required. When it comes to the design of any bonus and penalty models, the importance of the STA carrying out correct calculations is emphasized. Interviewee G describes a specific project where the STA had calculated and established a penalty that was too low in relation to the actual costs of achieving the set climate goals, which in this case referred to fuel requirements. The contractor who won the tender identified this incorrect calculation already during the tender phase and was therefore able to include the penalty as a calculated loss in its tender price instead of using the intended more expensive fuel. In this case, the STA chose to enter into dialogue with contractors and agreed to use the fine to help purchase as much climate-reducing fuel as possible instead of fining the contractor.

In the early stages of a project, there is a great deal of influence on the outcome of the project's climate emissions, says Interviewee F. It is also emphasized that contractor competence should be included earlier in the projects, and an increased degree of climate competence among design consultants is also required. Developing better cooperation and communication between clients, consultants and contractors from the early location stage to the end of the project could drive climate development.

Furthermore, Interviewee H highlights that companies and organizations have now started to learn the STA's Climate Calculation Tool and now include the costs of climate requirements in their tender calculations. Since their introduction in 2015, the requirements have been relatively easy to achieve, for example, those who were early to use climate-improved asphalt in road & civil engineering projects were able to achieve the climate requirements without making any more climate efforts in the project. As the requirements develop and the Climate Calculation Tool is updated, significantly more climate mitigation measures are now required to achieve the requirements, which is challenging for contractors because the STA's climate requirements will continue to be raised to the final climate goal of neutrality in 2040.

The Climate Calculation Tool itself can also be difficult to learn as it is a relatively new tool that is continuously updated with new versions, which can create frustration among contractors once they have adapted and learned the tool, a change occurs. Interviewee H also believes that the tool contains many uncertain parameters and values and that the project's climate reference level - the level that will be the basis for comparison with the actual climate emissions for the project - can be difficult to determine correctly. Some contractors try to push up and set a higher climate reference level because it creates greater margins to achieve the expected climate savings in the project then.

The climate requirements are clearly formulated by STA, but the project itself is often heavily regulated regarding construction methods and which materials may be used, which leaves little room for innovation and alternative solutions that may be more climate-reducing. This can create conflict between the ambitions to reduce climate impact.

Interviewee F mentions an example project when planning to use lime cement columns (LC) for soil stabilization in a railway project, a construction method and material that is well proven and works very well from a technical perspective but less well from a climate perspective due to the large proportion of cement in LC columns. To have less impact on the climate, there are, for example, multi-cement columns that contain alternative binders with a smaller proportion of cement that contribute to a lower climate footprint. The STA's regulations for technical requirements state that LC columns are to be used in the projects, but there is a small opening to allow alternative binders in the columns.

Interviewee F believes that even though it is possible to use alternative binders in the columns, extensive testing and documentation are required to gain acceptance, which makes the process both slow and costly. Support from the STA is available to some extent, but there is often a lack of practical guidance on how to actually achieve the climate goals. The responsibility is placed on the contractors to take the initiative and drive development forward with proven alternative sustainable solutions, which require a high level of expertise and specialists in the respective field. Something that is not always available to a sufficient extent in practically oriented construction organizations.

The cement crisis in Sweden that started in 2021 when the company Cementa was denied permission to mine limestone in Slite on Gotland made the STA, among others, think about the availability of cement. This created an opportunity to be able to communicate more easily with the STA regarding the use of alternative binders in LC columns, says Interviewee F. Something that was then utilized in Project 2, a motorway construction project that included several hundred thousand meters of LC columns. Here, several specialists were gathered around the same table to discuss solutions, and several tests were carried out for columns with alternative binders, which were approved. This led to a significantly lower climate impact, although it did not provide direct financial savings due to all the additional tests that were required.

"When the cement crisis hit and prices skyrocketed, it suddenly became possible to talk to the Swedish Transport Administration about using alternative binders. … Sometimes it takes pressure or a whip to get you to the surface, and that also applies to our customer who makes demands."

- ***Quote by Interviewee F***

The contractors are unanimous that innovative measures could theoretically reduce climate impact, such as shorter bridge spans, alternative products or slimmer structures, however, these often clash with other priorities at the STA, such as aesthetics or safety standards. Reuse is highlighted by respondents as a reduction of emissions with great potential, but where regulations and certification requirements stand in the way of being fully implemented. An example is that fully functional and functioning components such as lighting poles and road barriers are scrapped instead of being used in other, less demanding projects due to current regulations and certification requirements.

When it comes to tendering, climate competence should be rewarded, but not in a way that creates distorted competition so that the larger global organizations with greater resources and capacity can create market advantages. Interviewee F believes that the STA should have clear climate requirements for all actors and support for contractor organizations on how to achieve them. Bonuses can also be integrated into the project to act as a driving force to go beyond the requirements.

With private clients and customers, there is often greater scope for the contractor to propose and implement innovative solutions, says Interviewee H. These innovations are often driven by the desire to reduce costs, but at the same time result in a lower climate impact. This shows that sometimes solutions can be found that both save money and are good for the environment.

4.2.3 Consultants

Experiences from the consultants working with the STA's climate requirements reveals that there is a complex interplay between technical, financial and organisational conditions. Interviewee L points out that the requirements on bridge's technical service life is a governing factor to optimize designs, where a service life of 50 to 100 years are common. This usually means that the bridge will stand for 80 to 120 years and limits the use of wood as a construction material. The interviewee also mentions that the use of simpler steel culverts is limited by this, because of uncertainty around technical service life and inspection. In comparison to the residential and commercial building sector, requirements on for example concrete in the infrastructure sector are much stricter. This limits the use of alternative cement types in infrastructure projects.

The consultants unanimously agrees that it's difficult to identify if chosen solutions are climate driven or controlled by practical or financial factors. Interviewee E states that cost savings drives many decisions and often becomes dominating in projects, and that the financial requirements is experienced as harder to manage than climate requirements. Where there are room to streamline structural designs and reduce material quantities, Interviewee L points out that consultants often use rules of thumb for bridge designs that are strongly linked to work environment and recognition among contractors. In some cases, where concrete and reinforcement can be reduced, buildability and working environment weighs heavier than climate impact. The interviewee gives an example:

"You could take a frame leg on a bridge – ideally, to optimize it, you might design it with a varying thickness: thicker near the road deck and gradually thinner towards the foundation slab. That would mean the back of the frame leg would be sloped, so to speak. But this entails quite a bit of work for those who are placing the reinforcement and doing the framework. … So in such cases, considerations like work environment, labour effort, and cost tend to outweigh the climate impact."

- ***Quote by Interviewee L***

In a project described by Interviewee L, timber superstructures have been chosen for two bridges, where the use of timber can be considered as climate friendly. However, the choice of material is probably due to other practical reasons as well, such as the material weight and prefabrication capabilities. It is difficult to determine what actually controls the decisions in the projects, at first sight it can appear as a climate driven decision but in practice be rooted in technical or financial reasons.

Several consultants point out that DB contracts offer larger opportunities to affect the projects climate impact in the design phase than DBB contracts. Both Interviewee I and L means that the financial incentives on minimizing material use and optimizing the solution in a DB contract creates space for climate-conscious decisions. In relations to this, Interviewee I shares that large consultancy firms in traditional DBB contracts often focuses more on billing hours than finding the most resource efficient solution, which generally leads to over designed structures. When a consultant profits on rework and adjusting solutions at a later stage, it counteracts with efficiency and sustainability in the projects.

A recurring theme among the consultants is that the climate requirements are often implemented too late in the project process, which reduces its impact. Interviewee E describes that climate aspects are often postponed until after the system design documents have been developed, when feasibility and constructability already has been determined. Interviewee C expresses similar observations and means that climate requirements rarely drive the route selection process. Instead, the project organisation's ambition and resource availability determine if climate aspects are evaluated at early stages, which the interviewee confirms with the Trimble Quantm example mentioned in 4.2.1.

Several consultants agrees that a decisive factor in driving the climate requirements in practice is the collaboration between consultants, contractors and clients, especially in early stages. Interviewee L describes how close collaboration in Project 2 enabled optimized solutions and increased understanding between the actors, through joint technical and design meetings. According to the interviewee, this was made possible through already an established relationship with the contractor which simplified dialogue and decision-making. Interviewee I also emphasizes the importance of collaboration and describes an example of when the consultants together with the contractor replaced double-span bridges with single-span bridges, which led to both climate and cost reductions. At first, the contractor focused on the cost reductions but were encouraged to promote it as a climate action, where Interviewee I means that simply raising and discussing the climate issue is a step in the right direction and helps change the mindset. The interviewee also expresses a desire for better and more collaborative communication between the consultant, the contractor, and the STA to develop better and more sustainable solutions, which is crucial for driving progress forward.

The STA have different specialists that drive climate calculations and examine the consultant's solution, such as quantities and suggested measures. According to Interviewee J, the Climate Calculation Tool is unclear and very rough, where the user has to break it down to individual construction components in detail to achieve a reliable climate calculation. It's common in an early stage that the consultant wants to make it easy for himself and doesn't produce a good enough climate calculation, making it simple for the specialist to propose optimizations measures and reduce climate impacts.

4.3 Economic and Time-Related Aspects of Climate Requirements

The implementation of climate requirements in construction projects has significant consequences for both financial management and schedule planning. This section aims to analyze how climate-related measures affect project budgets and schedules, with a particular focus on the challenges and areas for improvement identified within the Swedish construction sector.

4.3.1 Subject-matter Experts

A recurring theme in the interviews is how economic and time-related pressures constitutes to framework conditions that both limits and enables climate adopted solutions in infrastructure projects. Several respondents highlighted that tight time schedules and limited financial framework in consultant and construction contracts often makes the development of innovative and climate friendly solutions difficult. Interviewee E emphasizes that consulting assignments rarely allows for innovation and experimentation, as the design layout tends to presume trouble-free processes without room for alternative technical choices. This results in innovation often being relegated to the construction phase, where the contractor to a greater extent can find creative solutions, especially in DB contracts with thorough requirements.

Similar problematic is described by Interviewee A, who points out that technical solutions are mostly put together separately from the climate and cost aspects, which makes the overall optimization more difficult. The interviewee emphasizes the need for integrated methods, such as set-based design where alternative solutions are simulated and evaluated in parallel. However, this type of approach is still unusual in practical applications. The interviewee also accentuates that STA's requirements on fossil free fuels can result in higher costs initially but is at the same time a strategic driver towards an extensive and cost-effective sustainability transition. This is supported by Interviewee F who says that even if the costs are higher initially, it strengthens the relationship with the client and will become profitable over time as these requirements are inevitable. A particular need for demonstration projects as a tool to adopt new climate requirements without reducing competition, is pointed out by Interviewee A.

Interviewee C and D both expresses the uncertainty of how climate related additional costs should be handled within the budget. Interviewee D describes how STA's internal control signals have become more cost focused, which in practice often leads to climate measures being downgraded if they entail increased expenses. As the climate aspects are often introduced late in the project, the image of climate measures as additional costs increases rather than being cost-effective streamlines. A clearer mandate and new procedures are needed to enable prioritization of climate measures in case of high initial costs, especially if these initial costs eventually lead to savings or system changes in the long term.

From STA's perspective, the climate requirements have so far led to both reduced climate impact and reduced costs, which has been made possible by identifying and reconsider technical solutions. However, according to Interviewee B, these "low hanging fruits" are now largely exhausted. To reach climate neutrality by 2040, major structural changes and system restructuring are required, where costs will increasingly become a reality. STA predicts an average cost increase by approximately 2 percent of the budget in the upcoming planning period as a consequence of both national ambitions and new EU regulations, such as expanded emissions trading systems.

Interviewee C confirms that new incentives for electric vehicles and working machines with bonuses for electric operation of 2,5 SEK per kWh have been introduced to facilitate the transition. However, established models for value-based remuneration in the consulting industry is still missing, which constitutes an obstacle to rewarding climate-smart solutions that are not directly linked to hours worked.

"This gives rise to entirely new questions and challenges – should consultants instead be compensated based on the value they create? The industry is largely unfamiliar with this approach, as payment is traditionally tied to hours worked. In all our assignments, invoices are scrutinized in detail – 'what was that hour for and what was that about?' – which creates significant challenges in shifting toward a value-based model."

- ***Quote by Interviewee C***

In the example of Trimble Quantm mentioned in 4.3.1, Interviewee C emphasizes the need for giving the consultant more time to carry out the design work, where in this example it was hard to find how the consultants should be compensated. The interviewee asks for a strategic restructuring on procurement methods and budgeting: How much time and resources are required? How should the budget be distributed across the different phases of the project?

4.3.2 Contractors

The contractors are consistent in that the climate requirements above all affects the construction costs. Climate-smart materials such as climate-improved concrete, eco-friendly asphalt, and HVO100-diesel often results in additional costs compared to traditional alternatives. Interviewee F and H both agree that HVO100 is a particularly cost-driven climate measure, as it has a higher price per liter and increased fuel consumption. However, Interviewee F highlights that climate measures often becomes profitable over time through environmental bonuses and strengthened business relationships, despite higher initial costs. The interviewee gives a fresh example of when using HVO100 in a large infrastructure project, in which the business relationship with the STA was reinforced as they demonstrated an understanding of increased costs associated with climate efforts.

Regarding the time aspect, the contractors are unified that the climate requirements generally do not extend construction time if they are clear and known from the planning stage of the project. Interviewee K emphasizes that climate-smart materials can in some cases have longer delivery times, something that can be planned for ahead and is a manageable challenge rather than a structural problem. According to Interviewee G, presenting the climate requirements and planning for them early will not only help reduce the construction time, but it will also reduce the costs that comes with the requirements, instead of starting to capture climate emissions at the production stage, which is expensive. It is underlined by Interviewee F and H that it is about integrating sustainability in already existing working methods rather than adding new production elements. Instead of seeing climate requirements as something that comes in addition to regular work, they are considered part of how production is organized and carried out.

Interviewee F generalizes the climate requirements into three parts: competence requirements, sanction mechanisms, and incentive systems. Firstly, the contractor must be ready to have the competence required to participate in procurements at all to fulfil the climate goals. Interviewee F states:

"We have to be at least as competent as required for the Swedish Transport Administration to even want us. It's very beneficial that these requirements are being introduced; it's beneficial that today I see environmental specialists and similar people as a resource, not a burden. In other words, we have to raise our level of competence, because imagine if the Swedish Transport Administration gets strict and says – 'if you don't know this, in three years you won't even be allowed to submit a tender'. … So we need to have a basic level of competence to meet mandatory requirements."

- ***Quote by Interviewee F***

Secondly, penalty systems have an important purpose as it establishes a clear minimum standard and creates a sense of accountability. Thirdly, incentive systems are underlined as very effective, as it makes it possible to test new methods, invest in new solutions, and strengthen sustainability work. Among the contractors, bonus and penalty systems are described as a central tool in achieving the climate goals in the contracting sector. According to Interviewee H, financial incentives in the form of bonuses and penalties are crucial in this early stage of climate transition the industry is in. Historically, the bonuses were relatively attainable, but as the requirements have become increasingly stringent, it is often challenging for contractors to merely avoid penalties. Clear and realistic incentive models are therefore important, particularly in a market where procurement is often awarded based on the lowest bid. A focus on clarity in bonus and penalty systems is requested, as well as a development of procurement models in which added value and climate ambitions are more clearly considered. Interviewee K states that they mainly strive to avoid penalty and that bonuses are seen more as prestige and public relations, and that the extra income usually just covers the costs of the climate-smart solutions. The bonus is not enough to cover a larger climate transition, therefore internal investments are still required, according to Interviewee K. At the same time, concerns are raised that overly strict requirements may lead to fewer submitted tenders and thereby reduce competition.

All of the contractors emphasize the importance of fulfilling the climate requirements to remain competitive in future tenders. Interviewee K describes how the company's management is aware that past climate achievements can be decisive for the ability to submit tenders in future projects, although this strategic insight does not always reach the production level. Furthermore, Interviewee H and K advocates increased application of value-based evaluation criteria in public procurement where previously demonstrated climate responsibilities and strong collaboration skills could be rewarded. This could encourage long-term climate development, however, these "soft parameters" are still unclear, and the bidders are often rewarded equally, which could be out of fear to appear biased or risk appeals. Interviewee H describes a slightly different perspective on value-based criteria where the contractor has to qualify environmentally in a prequalification phase before they can even begin estimating the project. It is very cost-driving to estimate a project from a time perspective, and if the requirements in the prequalification phase are too burdensome – it may result in no tenders being submitted at all.

Interviewee J describes how the climate requirements drive the development forward as they become clearer and clearer. However, due to the long lead times, the impact of them may take five years to notice. To accelerate these questions, climate issues have to be worked with and tightened in ongoing projects and contracts, and the STA might have to pay for a solution with lower climate impact. To make the bonus and penalty system more effective, measures such as HVO100 and climate improved concrete should become standardized in every project.

4.3.3 Consultants

In the interviews with the consultants, a clear but also complex picture emerges of the economic and time-related aspects regarding climate requirements in infrastructure projects. It is emphasized as a common opinion that the potential for climate optimization is greatest in the early stages of the project, but that the business and structural conditions of the client STA often counteract such a way of working. In early stages in practice, there is often little room for innovation, partly because the consultants are procured on an hourly basis where the technical function is often given the highest priority and every hour spent is reviewed by the client. But above all because the procured client STA tends to formulate requirements that largely standardize solutions before they reach the consulting organization. This means that the consultants must act within technical frameworks that have already been specified by the client, where room for innovation normally does not exist. There are neither incentives for innovative design nor timelines within the project that allow for anything other than the highest possible degree of a frictionless process.

Collaboration can drive innovation, especially in Design-Build where contractors can have a little more freedom to choose a technical solution based on functional requirements compared to pure Design-Bid-Build, says Interviewee I. However, several interviewees also believe that this prime space for innovation in Design-Build often clashes with STA's reluctance to try out new alternative solutions and deviate from proven solutions. Several interviewees are calling for a new type of collaboration model between STA, contractors and consultants, where innovation work is not only allowed but specifically requested with proactive support from STA. For example, that one is given the space and opportunity to develop better solutions for the climate that are not directly profitable in the individual project but in other future projects it may be profitable for both the budget and the climate.

"The Swedish Transport Administration is not that keen on innovations, they want the old tried and tested."

- ***Quote by Interviewee I***

The fact that financial incentives exist is very unusual and in the few odd projects that have occurred, they are far too weak to drive innovation to a real change. The consultants agree that the transition in the production phase with, for example, electrified work machines and vehicles and new emission-reducing materials in the form of concrete, steel and asphalt has a major impact on the climate. What the consultants find as an interesting potential climate reduction measure is optimized constructions. However, it is emphasized that STA should set clearer steering signals that have a long-term perspective within the construction and infrastructure industry to get the actors to change. A certain change is about to happen as, for example, Interviewee I mentions, where their consulting organization has introduced internal climate reduction measures of 10%, which will be reduced from their initial bid.

4.4 Monitoring and Follow-Up of Climate Requirements

In the Swedish construction sector, monitoring and follow-up of climate requirements has become a central part of ensuring reduced climate impact from construction projects. Despite increased awareness and ambition within the industry, several challenges remain that make effective implementation and follow-up of climate requirements more difficult. Based on insights from interviewees, the section highlights structural, process-related and operational aspects where improvements can strengthen both goal achievement and ensure that climate ambitions are not only formulated but also implemented in practice.

4.4.1 Subject-matter Experts

Follow-up is a central part in STA's climate strategy, but several interviewees highlights that the current design is characterized by shortcomings in both systematicity and efficiency. There is consensus that the climate requirements only can have actual effect if they are trackable, where uniform procedures are missing in most projects.

It is emphasized that the follow-up process becomes an end in itself, where focus on measurability overshadows actual climate actions. Especially for the percentage-based reductions requirements, which according to interviewee D, has been introduced partly because they are trackable, rather than being the most effective control tool for reducing climate impacts. There is a lack of efficient systems to verify compliance of the requirements, particularly for the material and fuel requirements as well as who's in charge of the follow-up, which creates uncertainty in the project implementation. Several interviewees express the lack of clear and standardized guidelines of what a climate calculation should include. Interviewee D mentions Boverket – who have clear specifications on what the construction industry's climate declarations should contain – and highlights that the lack of a standardized procedure leads to individual projects having to design their own follow-up strategies. This results in varying approaches, especially for contract variations and additional work, where certain projects exclude these from the climate impact, and others include them at the starting point. Both of these options entail large utilization of resources and complications with comparability of the starting point and the climate impact.

Interviewee B also emphasizes that follow-up and verification is imperative for the legitimacy of the climate requirements and describes how the Climate Calculation Tool continuously develops based on feedback from both internal and external users. To strengthen the follow-up on material requirements, STA has established a function that gathers and stores EPD:s which makes it possible to reuse earlier assessments. Interviewee C refers to it as an "EPD mailbox", and it acts as a knowledge bank that both improves quality and reduces duplication of work across projects. The importance of industry dialogues is also highlighted to generate climate and verification requirements that are as reasonable, fair and transparent as possible, particularly since EPD standards still contain grey areas.

Technical limitations in the follow-up work recurs in several interview responses. Interviewee D highlights that there is no efficient connection between BIM-models and the Climate Calculation Tool, resulting in quantities having to be imported manually. This makes the work more difficult, particularly in DB contracts where the STA has limited insight in procured materials compared to DBB contracts, where quantities are often open and traceable through bill of quantities. A digital solution is required where quantities and data can be exported directly from for example Revit plug-ins, which is something that already exists in the residential and commercial building sector.

Digitization can be used as a potential solution for many of the identified problems. Interviewee B highlights that STA has an ongoing digitization work within a project called ELSA, where digital delivery notes will be introduced in the projects according to the industry standard BEAst. Initially, this will help to facilitate the follow-up on fuel and zero-emission vehicles, but in the long term potentially include other climate aspects through digital flows. Interviewee C points out the STA's project called Financial Contract Follow-up, that wants to replace manual cost controls such as Excel with a web-based follow-up system, which can be connected to climate data as well. The interviewee means that the ELSA-system together with this web-based follow-up system can be used to connect quantity data to climate impact and thereby create long term learning between projects. At the same time, it is underlined that STA's long project cycles mean that changes often take up to a decade to implement, something that requires patience rather than being viewed as a failure.

Lack of continuity is a recurring theme, particularly in large and protracted projects. Interviewee C points out that staff turnover over time complicates both the follow-up process and the final climate reporting. To counteract this the interviewee suggests annual climate reconciliations as a way to create better conditions for continuous control. Interviewee A agrees on the need of more systematic and clear routines for collecting, analysing and feeding back follow-up data from different projects. It is often what the STA demands in the follow-up process that is prioritized in practice, which further emphasizes the importance of clear control signals from the client. Interviewee A answers a question about why follow-up procedures differ significantly between different project:

"It really comes down to a lack of governance – if I'm being direct – on the part of the Swedish Transport Administration's project managers. They're supposed to follow up on these issues, but then it's not done in accordance with the agreement. So ultimately, it's a governance issue. And there aren't really any follow-up routines at the Swedish Transport Administration either, at least not when it comes to monitoring across projects on an aggregated level. … It's like someone once said: what gets asked for, gets done."

- ***Quote by Interviewee A***

Structural barriers for change are pointed out, where Interviewee C and D describes how STA's linear processes tend to work against innovation, even when both ambition and guidelines for climate action and innovation are in place. This also applies on the consulting industry, where the business model is largely based on streamlining existing methods rather than developing new ones. In practice, innovation is something that is often driven by passionate individuals rather than by organizational structures.

4.4.2 Contractors

The contractors express a broad consensus that STA's follow-up procedures on climate requirements needs to develop, both in scope and quality. A recurring theme among the interviewed contractors is that the climate requirements usually are followed up too late in the process. Interviewee F highlight that climate calculations often are done in the beginning and the end of a project and calls for ongoing follow-up during the project. The interviewee emphasizes the importance of making the results visible and communicating success to boost the commitment and pride of the climate work in the project organization. Climate savings should not only be reported but also recognized and celebrated, as a part of building a positive climate culture.

Interviewee H also describes that the follow-up is done through climate calculations and joint briefings with the client, while pointing out that the frequency varies depending on the project's characteristics, requirements and the knowledge level of the involved actors. Interviewee K gives a similar description but highlights that the development is moving toward more frequent follow-up. Previously, climate impact was often followed up annually, but in newer projects the follow up is done more frequently – in some cases, on a monthly basis. However, the interviewee explains that there are complications to determine what should be included in the climate calculations, particularly when it comes to additional orders. There is a risk that such additions may worsen the result, despite the majority of the project having been climate smart.

The need for improved climate calculations is a recurring theme among the interviewees. The STA's Climate Calculation Tool is experienced as technically complex and is criticized by Interviewee F because it relies on standardised input data which often results in excessively high reference values and can give a false estimation of climate reductions. A more precise and context specific baseline is requested to ensure that the follow-up is fair and meaningful. Interviewee K confirms the need for a developed Climate Calculation Tool and gives an example of a new project where they're going to produce two separate climate calculations at the end of the project – one showing the actual outcome and on including improvement measures. According to the interviewee, this is perceived as more transparent and fairer, as it clearly shows the actual climate savings achieved rather than being compared to hypothetical scenarios in an initial calculation.

Several contractors emphasize the importance of early collaboration to create conditions for an effective follow-up. Interviewee K believes that involving both contractors and material suppliers in an earlier stage can contribute to better decision making. However, the interviewee points out that there is a sensitivity around this, as early involvement can be perceived as a competition advantage. Interviewee K also believes that DB contracts provide greater opportunity to influence climate impact in comparison to DBB contracts. There is more flexibility to make climate-smart solutions in a DB contract, without compromising on quality. Because the contractor can choose both what methods and materials to use in the project, while being the one responsible for the outcome. Interviewee F points out that contractors are rarely involved in the site selection phases and design planning, which means that important opportunities for climate optimization are often missed. To reach the climate goals, especially the last 20-30 per cent, close collaboration is required with innovative procurement methods and a culture where the clients, consultants and contractors work together from the start.

4.4.3 Consultants

For the consultants, follow-up is often done primarily through quantity reports to compare actual output compared to the contractors' initial calculations with the aim of ensuring financial precision in quantity calculations, rather than following up on the climate footprint, according to Interviewee L. Interviewee I confirms this and points out that the smaller projects their organization is involved in do not follow up on climate requirements at all. It is only in the larger projects that climate issues can begin to be discussed and followed up. At present, however, there is a lack of a clear structure for follow-up and feedback.

A recurring theme among the interviewed consultants regarding follow-up is the importance of good cooperation between STA, consultants and contractors. In one of Interviewee L's projects, close cooperation has led to open communication between the actors in the project. Throughout the course of the project, technical consultations and meetings have been held that create a working climate where all parties strive in the same direction. This also leads to well-established relationships between STA, consultants and contractors, which creates strong clarity in the project and its people's responsibilities, making it easier to follow up on climate requirements.

Despite an optimistic view of climate requirements, reality often reflects poor systematicity and a lack of resources to follow up on climate requirements. Although STA has a certain structure, there is often a lack of continuity and commitment, especially in large projects that extend over a long period of time with high staff turnover, which means that climate goals risk being blurred as staff are replaced. In these projects, it is proposed to carry out annual climate reconciliations instead of saving everything until the end. Standardized processes and a digital system where quantity data for materials and transports shows an associated climate impact that can be followed up in the same system should be implemented as standard instead of separate Excel files and manual checks, according to Interviewee C.

4.5 Improvement Potential in Climate Requirements

Despite increased efforts to integrate climate requirements into construction projects, several challenges remain that make it difficult to fully meet the climate goals. This section highlights the improvement potential identified within the Swedish construction sector, based on insights from contractors, consultants, project managers from STA and key individuals with high expertise in the construction industry.

4.5.1 Subject-matter Experts

A key area of development mentioned during the interviews is the sustainability in projects transition from pure climate bonuses to integrated climate criteria in tender evaluation. Today's climate bonuses are often an external incentive that lies alongside the core evaluation, which risks reducing its impact. It is proposed that climate performance and sustainability standards should be incorporated directly into the evaluation matrix for consulting & contractor organizations, which would increase the various organizations' incentives to compete on sustainability. For this to be possible, a standardized methodology for climate evaluation and functional follow-up of transparent and verifiable climate data must be introduced.

This type of value-added evaluation model can put the sustainability issue in great focus within projects but requires a high degree of maturity in the clients, contractors, consultants, suppliers, and organisations. Interviewee B believes that it is essential that the climate improvements proposed in the tender stage are realistic, feasible and verifiable, otherwise there is a risk of losing legitimacy in the procurement process.

"Of course, it becomes a little more complicated in the evaluations, and the reason to begin with why the requirements were not formulated that way and instead formulated as contract conditions was for two main reasons: The first was that at the tender stage you don't know exactly what climate improvements you can make. ... The other reason is purely legal... there is a risk of appeal if one contractor wins over another."

- ***Quote by Interviewee B***

Another area that has potential for improvement is how technical climate requirements are designed. Interviewee C emphasizes that climate requirements should not only be formulated as rules but must include a clear strategic sustainability plan that signal to the market what is expected in the future. With a clear strategic sustainability plan, it will be easier for companies and organizations in the construction sector to perceive the transition to a more climate-adapted construction sector, where climate-adapted solutions are a long-term and inevitable part of the industry's development. This creates greater incentives to switch to more sustainability and motivate investments in, for example, computer programs such as Trimble Quantm, development of climate-smart materials such as concrete, steel and asphalt or expensive electric vehicles and machines, even though these have high initial costs and long payback periods. Climate requirements that include predictability and continuity help reduce uncertainty for the various industry players and facilitate strategic decisions for sustainable climate investments.

4.5.2 Contractors

The recurring theme in the interviews with contractors is the limited scope for alternative solutions within STA's current procurement and regulatory framework. Interviewee F believes that STA's regulatory framework often limits contractors' ability to introduce more climate-smart alternatives, such as multicement as a binder in foundation columns, which is discussed in Chapter 4.3.2. This is also confirmed by Interviewee K, who believes that STA's approval structure sometimes becomes an obstacle for contractors instead of a support for the implementation of climate-improved measures.

Here, the interviewees believe that STA should create a clearer and more practical path for alternative materials and construction methods in its regulatory framework so that there is no resistance to testing innovative solutions that can be climate-reducing. Contractors also need to develop and provide robust verification systems for the quality and sustainability of alternative solutions so that it becomes easier for STA to approve these.

Another barrier is the organizational slowness that exists both with the client STA and the contractor organization. Interviewee H emphasizes that STA organizations often lack a practical understanding of how their climate goals are to be achieved in practice, even though their goals are clearly defined. Here, there is a risk that the requirements and follow-up will become formalities rather than a driving force for innovation that achieves climate goals. Interviewee K also believes that there are internal barriers within the contractor organization, such as older supervisors who tend to rely on old working methods and use exclusively their own traditional supplier contacts. The younger generation is more inclined to consider climate parameters in purchasing and work processes.

In order for you to be allowed to bid on this project at all, you have to have met the climate requirements in previous projects. And that's perhaps not something that the supervisors or the guys on the construction site really think about. ... They call someone they know. We need some reinforcement. Can you fix it? Sure, and then they don't think about what kind of requirements we have for this project, but they already have their contacts who they think are really good and that's not wrong, but it's difficult to add the climate perspective.

- ***Quote by Interviewee K***

One area for improvement here is to increase investment in continuous training and skills transfer within construction contractors' organizations, not only for individual environmental experts but for the entire production chain. The climate issue should be integrated as a horizontal responsibility across the entire organization, rather than in a single specialist function. Knowledge in climate-reducing construction methods and materials should be systematized, for example by documenting, standardizing and sharing successful climate measures internally as well as within the industry says Interviewee K.

Something that all interviewed contractors emphasize is the lack of incentive structures at the STA, discussed in Section 4.3.2. The current incentive structures should be reviewed as it is something that can control the contractors' actions regarding climate reduction. At present, the incentive structure is not perceived as sufficiently motivating and too uncertain by the interviewed contractors to really drive change with climate reduction measures at the rate at which STA has set its climate reduction targets compared to 2015 levels. Today, bonuses can be seen as a prestige for the contractor organization rather than an economic driver because the bonuses barely cover the contractors' additional costs for the climate reduction measures. Regarding the penalty, it depends on what amount the client STA has set for the penalty; in Section 4.3.2 it is described how the STA calculated a penalty amount that is too small and how the contractors can include it in their tender amount and thus win the tender and ignore achieving the set climate requirements.

One suggestion from the interviewees is differentiated bonus models that include, for example, process innovations and proactive climate measures in the early project stages. Something that can create incentives for broader engagement and innovation within the projects. The contractors also believe that it is not only the bonus that needs to be developed, but also how the contractors' climate competence is valued in the procurement. Interviewee F believes that a development towards value-added procurement would mean that climate reductions within the project would receive greater focus. Because if contractors' previously documented climate performance, experience of alternative solutions and innovation capacity were taken into account in award decisions and not just the lowest bid price, construction organizations would start to see climate reductions as part of their business strategy.

4.5.3 Consultants

The consultants are unanimous that the STA's current procurement practice limits the possibilities of implementing climate improvement measures. The traditional DBB contract, where technical solutions already are established, inhibits both innovation and effective knowledge exchange between stakeholders. Interviewee L highlights that DB contracts, where a function is procured rather than a specific solution, opens up for innovation and flexibility. The interviewee adds that if the constraints were more flexible, additional knowledge, ideas, and alternative solutions could be contributed to the project at an early stage, which might otherwise be overlooked. Interviewee E develops this by pointing out that even when consultants identify alternative solutions or improvement suggestions that reduce climate impact, there are often no contractual or financial means to implement these within the scope of the contract. A suggestion to the STA is to dare move beyond traditional procurement models and create more flexible contracts that enable more innovative and sustainable solutions. Consultants should also be procured based more on competence rather than solely on price, although it may increase the risk of appeals and longer procurement processes. Clearer incentives, such as financial bonuses connected to actual climate reductions, are emphasized by Interviewee I to strengthen consultants' commitment to climate issues. The climate requirements are often unspecific in the procurements and design processes, which leads to the climate issue being marginalized in daily design work.

The consultants point at the value of involving the industry at an early stage of the project. Interviewee E emphasizes that the climate requirements can become more realistic and achievable if both contractors and consultants can contribute with technical and practical knowledge before the requirements are formulated. In a similar spirit, Interviewee L highlights the importance of STA not solely defining completed solutions, but rather formulating requirements for the industry to answer with solutions of their own. Such openness would, according to the interviewee, make more ideas and value creating innovation possible.

"If I think from my own perspective, if I were to build something here at home, then it would have been wise to give a challenge and then a fairly free framework to more people – that way, you might get suggestions and solutions you wouldn't have picked up yourself. … I do believe quite a lot in collecting the knowledge that exists in the industry, because there is a lot of it, and trying to involve as many people as possible."

- ***Quote by Interviewee L***

Several consultants return to the value of collaboration and shared responsibility. Interviewee L believes that increased collaboration between consultants, contractors, and clients, where all parties work towards the same unified goal, will achieve greater overall benefit. In many cases, the STA hands over a finished substrate to the contractor, who then forwards it to the consultant without closing the loop back to the client, which often leads to that climate and cost-effective solutions are missed. Interviewee I agrees that if we are going to reach the ambitious goal of climate neutrality by the year 2040, joint efforts from the whole industry are required to even get close.

Another central aspect is material reuse, which Interviewee L points out is larger within housing construction than bridge construction because bridges are often more fatigue-loaded and require more thorough knowledge about the component's load history. According to the interviewee, the improvement potential lies in reusing materials used in buildings on bridges, and the other way around.

Interviewee I describes how there is a technical and organizational slowness in implementing new methods and material requirements, something seen as an area with great potential. The interviewee means that individuals at the STA who are ready to take responsibility for trying out new methods and materials are missing. Material suppliers often reach out to present new solutions, but these rarely gain traction, particularly in projects where the contractor is an intermediary and where the STA requires approved solutions with long service lifespan. However, this is brought up by Interviewee J, who says there is a risk of taking the material requirements too far. The interviewee states:

"The durability may suffer from it; you realize that the materials we use here were not of the right quality over time. So it's kind of in the nature of things that one should be a bit conservative here and take it slow, I think. But still not be inflexible – what works, we should go with."

- ***Quote by Interviewee J***

Interviewee J continues with an example of how they today rebuild many bridges that were built in the 1970s, where much older bridges are in better condition. Even if today's bridges are built of very high quality, there is still a risk of ending up in the same situation. However, Interviewee L mentions positive exceptions and takes Project 2 as an example where the STA were actively involved and open to decisions that deviated from previous standards. Some of these decisions were to accept different exposure classes and choose more expensive but more climate-friendly materials. According to the interviewee, these exceptions are unusual but welcome as they show that openness and flexibility can lead to better decisions.

Interviewee C has a slightly different perspective on the improvement potential for STA's climate requirements where material and fuel requirements should be the overall foundation. These must be updated in line with developments and the industry's transformation. It's not all about rules and strict requirements, the STA needs to send clear signals to the market with expectations. The interviewee believes that reduction requirements for entire projects are risky and impractical, especially for projects that last 10 years. Here, the STA should formulate threshold requirements where they focus on where they have the largest impact, for example electrification and climate-improved concrete and steel, with progressively higher requirements during the construction time. This provides stability and drives competition without major cost increments. New European frameworks, such as EU Emissions Trading System (EU ETS) and Carbon Border Adjustment Mechanism (CBAM), will help drive the climate transition and harmonize the Swedish climate requirements in the right direction. However, according to Interviewee C, climate requirements will not solve the most complex challenges; collaborative processes with a focus on innovation between the STA, consultants, and contractors are pivotal. There is a need for new working methods, business models, and deeper digitalization with collaborative tools and processes built on, for example, AI and BIM. This is also supported by Interviewee J, who thinks that optimization algorithms using AI will be used to help find the most optimized solution, by for example recalculating the same thing over and over again.

5 Discussion

The empirical results are combined and verified with the theoretical framework that will be summarized in this discussion chapter. The discussion starts with the current state of understanding and how the requirements work today. This is followed by the current state of how consultants and contractors are affected by the requirements. Finally, potential future improvement measures are discussed.

5.1 Current State of Understanding the Climate Requirements

Since 2015, the Swedish Transport Administration has gradually introduced climate requirements in its procurements with the goal of achieving climate neutrality in infrastructure projects by 2040. These climate requirements mainly consist of material-specific requirements, such as the use of climate-improved concrete, steel, asphalt and climate-reducing fuels, or of general reduction requirements for emission reduction expressed in percentage. The empirical analysis shows that material-specific requirements are perceived as clear, feasible and verifiable, while the reduction requirements are characterized by low precision, uncertainty in reference levels and a weak practical connection to the project's actual climate impact.

The theoretic starting point on the Swedish Transport Administration's climate requirements is based on the Public Procurement Act (PPA), where the possibility of setting the climate requirements depends on them being proportional, transparent, and non-discriminating. This legal basis stands as a foundation for the requirement implementation to not jeopardize legal certainty, but also as a limitation in introducing more ambitious climate measures. The conditions provided by PPA give the STA room for maneuvers to include these requirements as long as they are reasonable and proportionate and do not limit competition in an unnecessary way. However, the empirical analysis shows that this room for maneuvers is not fully utilized. Respondents express that the STA tends to be too cautious of what is legally possible and senses fear from the STA of reducing competition, which leads to climate requirements often stop at technical minimum requirements rather than driving for innovation.

Contracting state authorities, such as STA, are obliged to accept the tender that is most advantageous according to the specified criteria. Often the lowest price is the governing factor, provided that they meet the qualification and technical requirements. In practice, this means that tenderers who offer innovative and sustainable solutions, but at a higher cost, risk not winning the project. This creates a challenge for the STA, which has set these ambitious climate targets for its infrastructure projects. Despite the desire to drive climate change, the possibility of choosing climate-friendly alternatives is limited by the law's requirements for competition and cost-effectiveness.

Another aspect is the Swedish Transport Administration's own target of achieving a certain number of tenderers per procurement, usually between four and six actors, in order to ensure healthy competition. This goal may clash with the ongoing transition in the construction industry, where contractors who want to invest in, for example, electrified machine fleets or fossil-free production risk making investments that do not pay off in the procurement outcome. This does not drive the transition, which should take place at a high pace. There is therefore a clear need to develop solutions and procurement models that better harmonize with the STA´s climate goals, while at the same time preserving competition and legal certainty in the process.

The empirical findings further display a lack of technical insights and knowledge in how to implement climate measures in practice, as well as a lack of consensus and understanding, within the STA project organization. A need for internal skill development in the client organization and increased integration between the contracting authority's requirements and the knowledge of contractors and consultants is desired. This stands in line with Högberg et al. (2022), who points out that higher competence within the client organization is required in order for climate performance to become a main principle in construction procurement.

The theoretical framework shows the importance of clear requirements in the tender documents, something the interview study believes is not always complied with. The requirements have a clear goal and are generally well-established but lacks practical clarity and knowledge around implementation which weakens the requirements already in the procurement stage. It is also emphasised in the empirical data that the climate issue is often introduced too late in the project, where technical solutions and financial decisions already have been determined, such as land claims, design, location and layout of the project. This contrasts with the STA's guideline on climate requirements, which highlights the importance of early implementation of climate calculations and reduction requirements already in the planning phase.

The reduction requirements are perceived in the theoretical framework as a way forward for achieving the goal of climate neutrality by 2040, where the Climate Calculation Tool is in the middle. The requirements were supposed to guide projects towards innovative solutions but lead in practice instead to a focus on administration and calculations rather than developing concrete climate-reducing measures. In the empirical findings, these reduction requirements are criticized as both difficult to understand and to implement, where uncertainty derives from the Climate Calculation Tool. As climate calculations set the starting point to which the final climate impact is compared to, it makes it the key to achieving emission reductions using this system. According to the interviews, it is very difficult to produce accurate calculations, especially in DB contracts where the contractor's solution is not yet fully established. This indicates a need for educational efforts and the development of the tool to make it more user friendly and accessible.

The application of climate requirements differs between different contract types, where DBB contracts tend to lock in technical solutions before climate requirements are addressed. This means that one has to try to achieve climate reductions in an already determined design of the project afterwards. DB contracts potentially have greater space for the contractor, together with the consultant, to develop innovative climate reduction solutions before the project design is locked in. However, there is still a lack of institutional support, proper structures and sufficient incentives to effectively utilize the space that DB contracts have.

5.2 How climate requirements affect contractors and consultants

Contractors and consultants find themselves in a structural paradox, where they are expected to deliver climate reductions that increase steadily over the years without having the opportunity to influence them from the beginning. The theoretical framework emphasizes the difference between contracts, in DB contracts the contractor gets a bigger responsibility over technical solutions and material choices from a climate perspective. Where in DBB contracts, the STA themselves bear the primary responsibility for climate-related design choices, which are then outsourced to consultants to complete. However, the consultants feel that the climate issue is not a central part of the design assignment, especially in projects with a DBB contract where the solutions are already predetermined. Their hourly-based compensation model discourages alternative sustainable solutions because the focus is high on delivering functional technical solutions over possible climate-reducing solutions. This leads to conventional solutions being used to a large extent despite technical possibilities for climate optimization.

The contractors in DB contracts expresses, on the other hand, that the freedom of choice is large, but so are the responsibility. This can create uncertainty regarding how much leeway there actually is to make climate-driven decisions. It is also emphasized in the empirical findings that the procurement criteria often prioritize cost over climate impact, despite that the theory highlights weighing in climate as a criterion through, for example, best price-quality ratio. The contractors feel that the STA has set ambitious goals that lack practical support. There are shortcomings in the technical guidance from the STA on how the goals are actually to be achieved in practice. There are also shortcomings in the understanding of market conditions and access to relevant resources required to achieve specifically set climate requirements.

Highlighted by both the empirical findings and theoretical framework is the Norwegian Public Procurement Act as a successful example and something to strive for. The theory explains how Norway introduced climate requirements legally to its public procurement which means that at least 30 per cent of the evaluation criteria must be of climate and environmental aspects. This is confirmed in the empirical part where Oslo in Norway have gone from 0 to 100 per cent electrified machinery in just five years. Large contractors also find this financially justified to invest in green technology to become more competitive, which allows the market to drive the sustainable transition.

A common key factor is good collaboration between the project's involved actors. Projects where clients, contractors and consultants work together with an open, transparent and early dialogue have been shown to contribute to better climate results. The theoretical framework confirms this through, for example, Early Contractor Involvement (ECI), where contractors enter at an early stage to optimize the project's climate outcome together with the client. However, even more entrepreneurial knowledge is needed within the STA organization to be able to make the right decisions in the early stages, instead of correcting incorrect decisions in the production stage. In the empirical part it is mentioned, on the other hand, that some contractors experienced difficulties in being involved in the localization stage when trying to provide cost estimates, what to build and what quantities to be used. It is also emphasized that contractors who may have the competence to influence a localization investigation have greater value in production than as a consultant on an hourly basis to the client.

It is clear from the empirical data that financial aspects are very central in infrastructure projects. The contractors emphasize how the material and fuel requirements above all effects costs, but at the same time highlights how these initial costs help to become more profitable in the future by increasing their competition and strengthening business relationships. These requirements also drive the sustainability transition by becoming standardized, where focus will shift to other climate-friendly measures. The importance of bonus and penalty systems recurs among the contractors, who describe it as a central tool in achieving the climate goal. The increasing or decreasing profitability is not the main argument for bonuses and penalties. Bonuses are seen as a sort of prestige and can be used to further finance climate measures and penalties as something to be shameful and take responsibility for. This stands in line with the STA's guidelines, but clearer systems and the development of procurement models where added value and climate ambitions are evaluated is something that is requested. To encourage long-term climate development, value-based criteria in public procurement is considered as a step forward by the contractors, where previously demonstrated climate responsibility could be rewarded in tenders, or even be decisive for the ability to submit tenders. The theory explains the Dutch CO_2 Performance Ladder, where Lingegård et al. and Kadefors et al. (2021; 2021) describes how the tool certifies companies based on carbon management to sanction discounts in the procurement with five different certification levels.

Consultants emphasize that developing optimized solutions requires more time, which increases the overall cost. But in return, a much cheaper and more climate-friendly design can be produced. However, many of the consultants feel that there is little room for innovation in the early stages, as technical solutions already have been determined with a standardized design and every hour is reviewed by the client. The empirical findings emphasize that financial incentives are very unusual for consultants, and where there are incentives, they are too weak to drive innovation. This counters largely with the theory, which states that bonuses and penalties are used for both procuring contractors and consultants. Although, the system focuses more on the construction phase. It is highlighted that the STA should initiate financial means and requirements for consultants working in early stages of the projects to give them higher influence of the design which requires strategic change in both procurement and budgeting.

Regarding follow-up, both the theoretical framework and empirical data shows that it is a critical weak point. It is mentioned that the reduction requirements are partly introduced just because they are trackable, but uniform procedures are missing with an absence of both systematicity and efficiency. One of the main problems with the follow-up procedure is that standardized guidelines for what the climate calculations should include are missing. This results in varying approaches to how the actual follow-up should be done, where contract variations and additional work are sometimes included, and sometimes not. This stands partly in line with the theoretical guideline, which says that extensive changes should be calculated backwards using reversed calculation. However, this can be interpreted in different ways.

The empirical findings emphasize technical limitations in the follow-up process, where a digitalization is requested. An efficient connection between BIM-models and the Climate Calculation Tool that imports quantities automatically is required. Something that already exists in the residential and commercial building sector, where for example Revit plug-ins are used. According to the interviews, there is ongoing digitization work within the STA where digital delivery notes will help to facilitate follow-up on fuel and zero-emission vehicles, with the potential to be used for other climate aspects as well. There is also a financial follow-up system being developed, which has the potential to connect quantity data with climate impact in the long run. The theory chapter shows that connecting BIM with Life Cycle Assessment (LCA) is an ongoing development, where the Norwegian Public Roads Administration (NPRA) is developing a tool to simultaneously integrate LCA-calculations into the BIM-model. Creating an overview of greenhouse gas emissions during the entire design process gives the ability to compare results in a much more cost and time efficient way, as well as making the results more accurate and utilize the climate reductions. The theory also brings up other types of LCA-BIM integrated tools, where Chen et al. (2024) displays five different methodologies. To develop the follow-up procedures, these techniques may be the way forward.

Staff turnover over time is emphasized as a problem in follow-up work, where a potential solution is to reconcile climate aspects annually to create and achieve continuous control. In contrast to this, the STA’s guideline TDOK 2015:0480 (Bengtsson, 2024) actually describes the follow-up to be reported annually, something that seems to be commonly disregarded. This is also supported by the contractors, who highlight that climate emissions are often followed up only at the end of a project and calls for ongoing follow-up during the project. However, Interviewee K believes that the development is moving to a more frequent follow-up, where in some projects it’s annually and other projects even on a monthly basis. For consultants, follow-up is rarely done on the climate footprint, instead it is often for financial estimation of quantities. Generally, follow-up on climate requirements for the consultants are done in larger projects, never in the smaller project organizations. Here, standardized processes and digital systems are called for to not risk the climate requirements being blurred out during the project.

5.3 Future Potential Improvements

A project manager at the STA handles an enormous number of issues, where the focus is often on managing challenges related to technical and economic requirements. As a result, the focus on possible climate reductions risks being overlooked. Since sustainability development is moving so quickly and the construction sector is in a phase of transformation, it is easy for the project manager to not have time to update their knowledge in the development of the sustainability area. The STA's project organization should therefore include a special updated sustainability consultant who can support the STA's project manager in alternative sustainable construction methods and climate-reducing materials.

A recurring common improvement potential from the empirical data is to involve the climate issue at an early stage of the project and ensure that all decisions, for example by choosing materials, fuels and construction methods, take climate goals into account. This is further strengthened by the theoretical framework where Laufer & Cohenca (1990) believes that the greatest impact on the climate is in the early stages of the project.

Since the STA has very ambitious climate goals that are beginning to be perceived as difficult to achieve by actors in the construction sector, including the STA themselves, other solutions should be looked at. Something that has been successful for Norway and its capital Oslo are changes to their public procurement law, where 30 per cent climate added value is weighed into their procurements. This has meant that they have switched to almost 100 per cent electrified work machines in only 5 years. The empirical data suggests that Sweden should consider including added value in public procurement for climate-smart design and construction methods. Something that would have given clear signals to consulting and construction companies to invest in climate-reducing measures that may also prove to be financially profitable in future procurements.

The STA should review its bonus and penalty systems. The empirical data shows how contractors can expect penalties for failing to take climate action in their tenders because the STA has calculated a penalty too small compared to the costs to actually achieve climate reductions. As a result, contractors can choose to take penalties instead of implementing climate reductions. Bonuses should also be reviewed, so that companies feel that there is an economic gain in trying to achieve more climate savings than what is required. Trying to invest extra resources and time in achieving extra climate reductions involves a risk because it is not certain that they will actually achieve it. But if there is the right financial gain, it is possible to be willing to take the risk.

Across the empirical findings there is an emphasis on allowing more innovation among the consultants and contractors in the projects. To provide this space for innovation, clear and powerful incentives, more transparent communication and early collaboration with contractors and consultants are required, which can ease up the early regulated construction methods and determined technical solutions. The STA needs to be more open-minded towards alternative solutions, and the contractors need to develop certification systems that prove the alternative solution. The consultants feel that they should be procured not solely for designing already completed technical solutions, but instead being able to provide the technical solution based on more open requirements, enabling for new ideas and value creating innovation. This stands in line with the STA's goal of climate neutrality by 2040.

One of the most important improvement areas that permeates the entire empirical part is being able to create an accurate starting point for the reduction requirements. If the starting point is not accurate, the calculated reductions will not be either. It is also problematic that the calculation of the starting point takes up a lot of focus where the time and resources could have been used on actual climate measures instead. A new and updated tool is requested to monitor, follow-up and report the climate impact in real time during the entire project. It is also imperative that everyone working with the Climate Calculation tool uses it in the same way, as the project durations can be up to ten years with high staff turnover.

As the tool is used as a decision-making basis, clearer guidelines, education and collaborative development to standardize how it should be used across the stakeholders is essential.

Close communication and good cooperation between the client, consultants and contractors has proven to be a winning concept for driving the climate issue forward in projects according to the empirical data. Instead of working on individual fronts and only delivering what has been asked to be delivered, cooperation and good dialogue can lead to innovative solutions. However, this requires great knowledge, expertise and a certain courage on the part of STA project managers to dare to listen and try alternative solutions. A shared responsibility for the climate issue in the projects will result in greater commitment and willingness to focus on climate reductions.

6 Conclusion

This thesis examined how the Swedish Transport Administration's climate requirements are applied in the procurement of major infrastructure and bridge projects and how these requirements affect contractors and consultants. The aim was to contribute to a greater understanding of how climate requirements can be designed and implemented more effectively, and to provide practical recommendations for how STA can develop its procurement routines.

The construction and civil engineering sector in Sweden accounts for a significant share of the country's climate impact, with transport and materials such as concrete, asphalt and steel being particularly emission intensive. The Swedish Transport Administration aims to achieve climate neutrality by 2040, with successive reduction targets until then. Achieving these goals requires innovation and collaboration between all actors in the industry.

The study is based on an abductive research method that combines literature studies with an interview study consisting of 12 semi-structured interviews with representatives from clients, consultants and contractors in two major infrastructure projects, as well as industry actors with extensive experience and expertise in the climate issue. The focus is on understanding climate requirements, practical applications and challenges, economic and time consequences, monitoring and follow-up of climate requirements and future improvement potential.

Based on the aim of the thesis, the following research questions were formulated:

> **RQ1** *How does the Swedish Transport Administration apply its climate requirements in contracts today?*
>
> **RQ2** *How are consultants and contractors affected by the Swedish Transport Administration's climate requirements*
>
> **RQ3** *How can the Swedish Transport Administration's climate requirements be further tightened or improved to maximize the reduction of carbon dioxide emissions, while giving consultants and contractors realistic conditions for implementing the requirements?*

The results show that the STA has a clear ambition to reduce climate impact with the goal of achieving climate neutrality by 2040, but the application of the climate requirements is often limited in practice. Today, STA sets its climate requirements through either material requirements or percentage reduction requirements. Climate requirements that are material- or fuel-specific are perceived as clear and feasible. The reduction requirements, which are expressed in percentage reductions compared to the 2015 reference level, are considered unclear and difficult to follow up. Contractors and consultants feel that they are expected to reduce emissions over time but have limited influence early in the projects. Consultants highlight that the climate issue is not a central part in their tasks and contractors accentuate a lack of guidance from the STA in how the climate measures are actually to be achieved, despite their ambitious climate goals. Contractors and consultants both believe that STA should support them more in individual projects to be able to work towards climate requirements and provide more accurate calculation tools for the reference point in which the climate impact is compared to. The interviewees were given the opportunity to reflect and recommend potential improvements for the climate requirements to have a greater impact, which the authors analyzed and discussed in conjunction with the theoretical framework to give recommendations in the next paragraph.

The recommendations for the STA from the empirical findings and discussion is summarized in five central measures. Firstly, it is important to integrate the climate issue in early decisions to influence the choice of materials, fuels, technical solutions and working methods, to allow space for innovation and enable a stronger impact from the climate requirements. Secondly, investigating the opportunity to implement climate benefits as an evaluation criterion in the procurement to steer towards more sustainable solutions. Further, a review of today's bonus and penalty system is recommended, to give clearer signals to the industry that innovative and climate-smart solutions will be rewarded in the long run. The fourth proposal is to develop a more realistic and correct Climate Calculation Tool, where digital tools are standardized and used to follow up the climate requirements. Finally, promoting early collaboration, sharing knowledge, and developing sustainability competencies within the project organization – including the introduction of a dedicated sustainability consultant – will create a common driving force towards the climate goals.

6.1 Future work

Further work could be carried out through similar questions but through surveys and a larger number of interviewees instead, which would have further provided a broader picture of how the Swedish Transport Administration's climate requirements are perceived by contractors and consultants in infrastructure projects.

Furthermore, it would be valuable to follow up on completed infrastructure projects over time to analyze how climate requirements affect actual carbon dioxide emissions in practice.

Finally, it would have been interesting to study the understanding of how climate requirements affect small and medium-sized companies in the contracting and consulting industry, and how these actors can be supported to meet the requirements in a competitive manner.

7 References

Bengtsson, E. (2024). *Klimatkrav i planläggning, byggskede, underhåll, och på tekniskt godkänt material (TDOK 2015:0480, version 8.0).* Trafikverket.

Boverket. (2024). *Entreprenadformer*. Retrieved from Boverket: https://www.boverket.se/sv/samhallsplanering/arkitektur-och-gestaltad-livsmiljo/arbetssatt/upphandling/entreprenadformer/

Boverket. (2025, January 29). *Utsläpp av växthusgaser från bygg- och fastighetssektorn*. Retrieved from Boverket: https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/vaxthusgaser/#:~:text=J%C3%A4mf%C3%B6rt%20med%202020%20har%20utsl%C3%A4ppen,4%20procent%20under%20samma%20period.

Bryman, A. (2018). *Social Research Methods.* Oxford: Oxford University Press.

Chen, Z., Chen, L., Zhou, X., Huang, L., Sandanayake, M., & Yap, P.-S. (2024). Recent Technological Advancements in BIM and LCA Integration for Sustainable Construction: A Review. *Sustainability*, 1-30.

Ekström, D. (2019). *Integrated structural and construction engineering - A study of project team performance in Swedish bridge design.* Gothenburg: Chalmers University of Technology.

Eriksson, P.-E., & Hane, J. (2014). *Entreprenadupphandlingar: Hur kan byggherrar främja effektivitet och innovation genom lämpliga upphandlingsstrategier?* Retrieved from Konkurrensverket: https://www.konkurrensverket.se/informationsmaterial/rapportlista/entreprenadupphandlingar---hur-kan-byggherrar-framja-effektivitet-och-innovation-genom-lampliga-upphandlingsstrategier/

Hasanzadeh, S., Esmaeili, B., Nasrollahi, S., Gad, G. M., & Gransberg, D. D. (2018). *Impact of Owners' Early Decisions on Project Performance and Dispute Occurrence in Public Highway Projects.* Reston: American Society of Civil Engineers (ASCE).

Högberg, A., Ingelhag, G., Perzon, M., & Berg, M. (2022). *Klimateffektiv Arkitektur, Konstruktion och Materialval.* Mölndal: Bengt Dahlgren Göteborg AB.

Kadefors, A., Lingegård, S., Uppenberg, S., Alkan-Olsson, J., & Balian, D. (2021). Designing and implementing procurement requirements for carbon reduction in infrastructure construction – international overview and experiences. *Journal of Environmental Planning and Management*, 611-634.

Konkurrensverket. (2022). *Att upphandla med miljöhänsyn – när, hur och varför?* Retrieved from Konkurrensverket: https://www.konkurrensverket.se/informationsmaterial/rapportlista/att-upphandla-med-miljohansyn--nar-hur-och-varfor/?utm_source=chatgpt.com

Konkurrensverket. (2024). *Upphandlingsreglerna – en introduktion (7th edition).* Stockholm: Konkurrensverket.

Kvale, S., & Brinkmann, S. (2014). *Den kvalitativa forskningsintervjun.* Lund: Studentlitteratur.

Laufer, A., & Cohenca, D. (1990). *FACTORS AFFECTING CONSTRUCTION-PLANNING OUTCOMES.* Reston: American Society of Civil Engineers (ASCE).

Lingegård, S., Alkan Olsson, J., Kadefors, A., & Uppenberg, S. (2021). Sustainable Public Procurement in Large Infrastructure Project - Policy Implementation for Carbon Emission Reductions. *Sustainability*, 1-21.

Luth, G. P. (2011). VDC and the Engineering Continuum. *Journal of Construction Engineering and Management*, 906-915.

Miliutenko, S. (2022). *Klimatkalkyl - Infrastrukturhållningens energianvändning och klimatpåverkan i ett livscykelperspektiv (TDOK 2015:0007, version 4.0).* Trafikverket.

Naturvårdsverket. (2024, Mars 12). *Sveriges klimatarbete* . Retrieved from Naturvårdsverket: https://www.naturvardsverket.se/amnesomraden/klimatomstallningen/sveriges-klimatarbete/

Naturvårdsverket. (2024, December 17). *Sveriges klimatmål och klimatpolitiska ramverk*. Retrieved from Naturvårdsverket: https://www.naturvardsverket.se/amnesomraden/klimatomstallningen/sveriges-klimatarbete/sveriges-klimatmal-och-klimatpolitiska-ramverk/

O'Brien, J. J. (1975). Managing construction projects. *Project Management Quarterly*, 17-21.

Rempling, R., Lagerkvist, J., Karlsson, M., Ekström, D., & Larsson, T. (2024). Can business-driven and climate-based contracting of bridges make us build climate-smarter? . *Procedia Computer Science*, 1-8.

Roberts, M., Allen, S., & Coley, D. (2020). *Life cycle assessment in the building design process – A systematic literature review .* Amsterdam: Elsevier.

Song, L., Mohamed, Y., & AbouRizk, S. M. (2009). *Early Contractor Involvement in Design and Its Impact on Construction Schedule Performance.* Reston: JOURNAL OF MANAGEMENT IN ENGINEERING (ASCE).

Statens Vegvesen. (2022, November 3). *KlimaDigital: ny teknologi for klimagassberegning i modellbaserte vegprosjekter*. Retrieved from Vegvesen: https://www.vegvesen.no/om-oss/presse/aktuelt/2022/11/klimadigital-ny-teknologi-for-klimagassberegning-i-modellbaserte-vegprosjekter/

Sveriges Riksdag. (2016). *Lag (2016:1145) om offentlig upphandling*. Retrieved from Riksdagen: https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/lag-20161145-om-offentlig-upphandling_sfs-2016-1145/

Thrysin, Å., Andersson, R., Ejlertsson, A., Erlandsson, M., Sandgren, A., & Green, J. (2020). *VÄGLEDNING – Klimatkrav vid upphandling av byggprojekt.* Stockholm: IVL Svenska Miljöinstitutet.

Trafikverket. (2021, December 10). *Fyrstegsprincipen*. Retrieved from Trafikverket: https://bransch.trafikverket.se/for-dig-i-branschen/Planera-och-utreda/Planerings--och-analysmetoder/fyrstegsprincipen/

Trafikverket. (2023, October 26). *Åtgärdsvalsstudie*. Retrieved from Trafikverket: https://bransch.trafikverket.se/for-dig-i-branschen/Planera-och-utreda/Planerings--och-analysmetoder/Atgardsval/

Trafikverket. (2024). *Administrativa föreskrifter - Totalentreprenad för utförande av E20 Götene-Mariestad.* Borlänge, Sweden: Trafikverket.

Trafikverket. (2024, June 14). *Klimat i infrastrukturprojekt*. Retrieved from Trafikverket: https://bransch.trafikverket.se/for-dig-i-branschen/miljo---for-dig-i-branschen/minskad-klimatpaverkan/klimat-i-infrastrukturprojekt/

Trafikverket. (2024). *Trafikverkets logistik och utveckling mot godstransporter med nollutsläpp – en förstudie.* Stockholm: Trafikverket.

Trafikverket. (2024, August 12). *Upprättande av väg- och järnvägsplaner*. Retrieved from Trafikverket: https://bransch.trafikverket.se/for-dig-i-branschen/Planera-och-utreda/upprattande-av-vag--och-jarnvagsplaner/

Uppenberg, S., Ekström, D., Liljenroth, U., & Al-Ayish, N. (2017). *Klimatoptimerat byggande av betongbroar (SBUF-PROJEKT 13207).* SBUF.

Wiik, M. K., Flyen, C., Fufa, S. M., & Venås, C. (2020). Lessons learnt from green public procurement in the Norwegian construction sector. *IOP Conference Series: Earth and Environmental Science*, 1-5.

DEPARTMENT OF ARCHITECTURAL AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY

Appendix A
Interview Guideline – Subject-Matter Experts

Interview Questions for Subject-Matter Experts

Name & Organization:

Background, Experience & Education:

Current Position and Main Responsibilities:

Understanding

- How clear and feasible do you find the climate requirements in practice?
- What are the advantages and disadvantages of the current requirements?
- How are the requirements applied in procurement today?

Practice

- How do you currently work with climate requirements, and how do you ensure that they are realistic and achievable for contractors and consultants?
- Are there collaborations between the Swedish Transport Administration, consultants, and contractors?
- How is communication functioning?
- How does it work in the early stages of projects?
- How do you assess how contractors and consultants currently handle and work with the climate requirements?
- Have climate requirements led to innovative solutions?
- Are there specific requirements or methods that work particularly well?

Financial and Time Impact

- How do you balance climate requirements with economic and technical realities in projects?
- How does Swedish Transport Administration manage the balance between climate requirements and cost-effectiveness?

Follow-up

- What role does follow-up and verification of climate requirements play in your projects?
- What lessons have been learned from previous projects?
- What feedback have you received from the market regarding the climate requirements?

Potential for Improvement

- How is Swedish Transport Administration working to improve its climate requirements?
- What are the opportunities and obstacles to making improvements?
- Is there flexibility for new solutions and innovations?
- Are there different ways to formulate the requirements? (e.g., Emission Reduction Targets, Function-Based Requirements, Material Requirements)
- Have you thought of any methods or requirements that could help further reduce the climate impact of projects?

Appendix B
Interview Guideline - Contractors

Interview Questions for Contractors

Name & Organization:

Background, Experience & Education:

Current Position and Main Responsibilities:

Understanding

- How clear and feasible do you find the climate requirements in practice?
- What challenges do you encounter in interpreting and understanding the requirements?
- What support and guidance have you received from the Swedish Transport Administration for implementing the requirements?

Practice / Production

- Have the climate requirements led to changes in your production methods and work practices?
- How have the requirements affected your bidding process?
- What impact have they had on material choices, logistics, and transport solutions?
- How is communication and collaboration with other stakeholders working in order to meet the climate requirements?
    - **Subcontractors and subconsultants?**
    - **Material suppliers?**
    - **Clients?**
- What alternative solutions or innovations have you implemented to meet the requirements?
- Are there limitations to using alternative construction methods or logistics solutions?
- Can you provide examples of past projects that have led to innovative solutions?
- Have you taken any initiatives beyond the formal requirements to reduce climate impact?

Financial and Time Impact

- How do the climate requirements affect construction costs and timelines?
- Are there financial incentives or bonuses that make it easier to meet the climate requirements?

Follow-up

- How do you view the opportunity to influence climate requirements during the procurement/early stages?
- How is the follow-up and monitoring of the climate requirements carried out?
- Is Trafikverket flexible and responsive to practical challenges that arise?

Potential for Improvement

- How would you like the climate requirements to be designed in order to further motivate emission reductions?
- Changes to procurement requirements?
- Should the requirements be more ambitious?
- More flexibility for new solutions and innovation?
- Any experiences from other clients?
- What do you need from Swedish Transport Administration to further reduce climate impact in your projects?

Appendix C
Interview Guideline – Consultants

Interview Questions for Consultants

Name & Organization:

Background, Experience & Education:

Current Position and Main Responsibilities:

Understanding

- How clear and feasible do you find the climate requirements in practice?
- What challenges do you face in interpreting and understanding the requirements?
- What support and guidance have you received from the Swedish Transport Administration regarding the implementation of the requirements?

Practice / Planning Phase

- How do the climate requirements impact your design and planning work?
- Are there materials or technologies that you believe should be used more but are currently restricted by existing requirements or regulations?
- Are there conflicts between climate requirements and other project requirements?
- Have you taken any initiatives beyond the formal requirements to reduce climate impact?
- How is communication and collaboration with other stakeholders working in order to meet the climate requirements?
    - **Clients** & **Contractors**

Financial and Time Impact

- How do the climate requirements affect the design phase in terms of cost and time?
- Are there any financial incentives or bonuses that facilitate compliance with climate requirements during the design phase?

Follow-up

- How do you view the opportunity to influence the climate requirements during procurement or early project stages?
- How is the follow-up and monitoring of climate requirements carried out?
- Are your material and design choices followed through by the contractor?

Potential for Improvement

- How would you like the climate requirements to be formulated in order to encourage further emission reductions?
- Changes in procurement requirements?
- Should the requirements be more ambitious?
- More flexibility for new solutions and innovations?
- Any experiences from other clients?
- What do you need from the Swedish Transport Administration to further reduce climate impact in projects?