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Too Hot to Handle?

Performance of large-scale infrastructure projects in a Swedish district heating company

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by

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Master of Science Thesis TRITA-ITM-EX 2022:225
KTH Industrial Engineering and Management
Industrial Economics and Management
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För heta att hantera?

Utfall av storskaliga infrastrukturprojekt inom ett svenskt fjärrvärmebolag

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Abstract

Large-scale infrastructure projects are risky ventures, often subjected to poor performance. Time and cost are often escalating beyond estimation while quality and benefits remain unchanged. However, little is known about the project performance in the district heating sector, which serves as basic infrastructure and plays an important role in regional energy transitions. This thesis aims to explore the project performance of large-scale infrastructure projects within the energy sector, particularly the district heating setting to enhance the knowledge of large-scale project performance, and further explore what factors contribute to explaining the performance of large-scale projects within this setting. To fulfil the purpose of this thesis, a multiple case study was conducted in a Swedish district heating setting. A review of relevant literature served as a complement to the primary data retrieved from the cases, laying a theoretical foundation for analysis. The empirical study consists of three parts. The first phase consisted of 18 interviews conducted with people at various positions within the case company to get a holistic picture of the problem and to select the nine cases focused on within this study. The second phase consisted of gathering qualitative and quantitative data on project performance, while the last phase consisted of nine in-depth interviews with the project managers of the nine selected projects.

This thesis found a varying project performance, with a mean cost escalation of 12.9 percent and a time increase of 140 days on average. Similar to other studies, large-scale energy infrastructure projects have a tendency to fail rather than succeed when compared to the Iron Triangle criterias, cost, time and quality. Insufficient planning and procurement, weak leadership and ill-performing contractors are significant factors that have a large negative impact on performance. In addition, scope change, environmental context and luck are also shown to impact project performance. Limited evidence on whether political factors have a substantial impact on project performance has been found, in contrast to a large segment within earlier literature. Strong teamwork, both internally within the project team and externally with contracting parties can help neutralise any poor performance caused by any of the above-mentioned factors.

The thesis contributes to the literature by discussing large-scale energy infrastructure performance. It is known that large-scale projects are complex and uncertain endeavours and by analysing project performance, knowledge can be enhanced not only on *what went wrong* but also on *what went right*. With a global sustainability transition and decarbonisation, energy infrastructure is going to experience large investments in the years to come. With this in mind, developing the most sustainable best practices and prudent project objectives can help project managers to embrace uncertainty and make the right decisions to enhance project performance.

Keywords

Project, Project performance, Large-scale infrastructure, District heating, Energy sector

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Sammanfattning

Storskaliga infrastrukturprojekt är ofta riskfyllda, och levererar sällan i linje med uppsatta mål. Både projektens tid och kostnad eskalerar långt bortom de initiala estimeringar som gjorts medan kvalitén och investeringens förmåner förblir oförändrade. Fjärrvärmesektorn är en viktig del i Sveriges energisystem men behöver ständigt tackla dyra investeringar med låg lönsamhet. Syftet med denna uppsats var att undersöka storskaliga infrastrukturprojekt inom energisektorn, i synnerhet med fokus på fjärrvärme, för att öka kunskapen om projektens resultat gällande tid, kostnad och kvalité samt att utforska vilka faktorer som påverkar utfallet av storskaliga projekt i denna sektor. För att uppfylla syftet med denna studie så valdes en flerfallsstudie med en kombination av kvalitativ och kvantitativ metod tillsammans med en genomgång av relevant litteratur. Litteraturstudien fungerade som ett komplement till den projektspecifika informationen som samlades in och la grunden till det teoretiska ramverk som användes under analysen. Den empiriska studien bestod av tre delar. I den första delen utfördes 18 intervjuer med anställda på olika positioner inom företaget, syftet med dessa intervjuer var att få en holistisk bild av problemet samt att välja ut de nio projekt som analyserades vidare. Fokus för studiens andra del var att samla in kvantitativa och kvalitativa data för de nio projekten medan den sista delen bestod av intervjuer med projektledarna för de nio utvalda projekten.

Studien visade på ett varierande resultat gällande projektens utfall där medelvärdet för kostnadsöverskridningar var 12,9 procent och medelvärdet för tidsfördröjningar var 140 dagar. I linje med tidigare studier så har storskaliga energiprojekt en tendens att misslyckas gällande att uppfylla både tid- och kostnadskriterier. De främsta faktorerna som påverkade projektens utfall var otillräcklig planering, en ofördelaktig inköpsstrategi, svagt ledarskap samt entreprenörer som presterade dåligt. Utöver dessa så påverkade även förändringar av projektets omfattning, projektets omgivande kontext och ren och skär tur projektens utfall. Politiska faktorer var ej en framträdande faktor i denna studie, till skillnad från tidigare litteratur där politiska faktorer ofta är i fokus. En sammansvetsad projektgrupp, både internt och externt med avtalade parter, visade sig kunna neutralisera de ovan nämnda faktorerna så att det övergripande utfallet ändå blev bra.

Storskaliga energiprojekt är både komplexa och osäkra investeringar. Genom att studera projekts utfall och prestation kan insikter fås inte bara kring vad som gick fel utan också kring vad som gick rätt. Stora investeringar kommer att krävas inom energisektorn under kommande år för att möjliggöra den hållbara omställning som krävs på global nivå. Att etablera bra och hållbara metoder med försiktiga projektmål kan hjälpa projektledningen att flytta fokus från att minimera riskerna till att istället omfamna osäkerheten och fatta rätt beslut på bra grunder.

Nyckelord

Projekt, Projektutförande, Projektgenomförande, Storskalig infrastruktur, Fjärrvärme, Energisektorn

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Abbreviations and Explanations

CHP	Combined Heat and Power
DB	Design-build
DBB	Design-bid-build
PPP	Public Private Partnership
PMO	Project Management Organisation
IB	Investment Board
KPI	Key Performance Indicators
TG	Tollgate
GTR	General Technical Requirements
EPCM	Engineering, Procurement, Construction and Management

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Emma Fält
Julia Gunnarsson

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1 Introduction

The thesis begins by giving a short introduction to project performance of large-scale infrastructure followed by a description of the energy sub-sector of combined heat and power while highlighting the Swedish district heating context. The purpose of the study and the research question developed in order to answer the purpose is clearly described and motivated. The chapter ends with an outline of the thesis.

1.1 Background

Large-scale infrastructure projects are risky and have, historically, been subjected to poor performance such as time and cost overruns (Flyvbjerg, 2003; Odeck, 2004; Lundberg, 2011; Catalão, Cruz and Sarmento, 2019). However, literature on explanations and factors impacting project performance is still ambiguous and divided between two groups of researchers. According to Gil and Pinto (2018), the discussion between the two groups on what explains poor project performance appears to have been “stuck for more than 20 years” (p.717). One group focuses on behavioural explanations such as optimism bias and strategic misrepresentation, a more external standpoint, and the other on project management explanations, suggesting a more internal view with a focus on the management of information and risk (Ibid). These two perspectives are today the most common explanations for the poor performance of large-scale infrastructure projects. Nevertheless, the more external view named the Planning Fallacy, supported by Flyvbjerg et al. (2018) has received criticism lately (Eliasson and Fosgerau, 2013; Love et al., 2019), as projects can experience cost decreases to the same extent as cost increases.

Investments in large-scale infrastructure are often, if not always, costly. Literature on the performance of large-scale infrastructure projects, however, focuses mostly on the transport sector (e.g., Flyvbjerg, Skamris and Buhl, 2003; Odeck, 2004; Lundberg, 2011; Love et al., 2016). The district heating sector, which supplies approximately 8.5 percent of global residential heat demand and far more in European countries such as Sweden and Denmark (IEA, 2021), has so far received little attention. However, Sovacool et al. (2014) began to extend large scale project performance literature to also include energy infrastructure and found that cost and time escalations are a common feature of project performance within this setting as well. The complexity of large-scale infrastructure projects is a mutual feature and energy infrastructure is no exception (Ibid). Numerous contractors, many stakeholders and interrelated activities taking place simultaneously are just some of the activities increasing complexity (Islam et al., 2019). Therefore, meeting project objectives of time and cost become unrealistic as managers are forced to comply with risk, uncertainty and complexity.

Substantial investments will have to be made in energy infrastructure in the years to come, to ensure the decarbonization of the energy system and achieve the net-zero economy. The energy sector is facing the most acute transition since investments in low carbon technologies and renewables have to keep up with the decreasing capex in fossil fuels (Blackrock, 2022). District heating has an important role in ongoing sustainability transitions around the globe (IEA: 2019; IEA, 2021; IRENA 2017). If combined with renewable energy sources district heating could help meet increasing urban energy needs, and reduce emissions, while improving the efficiency and security of regional systems (IRENA, 2017).

In this thesis, a multiple case study of nine large-scale projects was conducted, all nine projects have been executed by a Swedish energy company in the district heating and cogeneration sector. Many companies within the district heating sector in Sweden are struggling to remain profitable while having high investments in both new and old facilities (Tidningen Energi, 2021). The main reason behind this lies in enhanced market competition for the 100 TWh heat annually produced in Sweden, divided between district heating, heat pumps, electric heating and biofuels. In addition, the heating demand is also no longer experiencing the same growth as before due to two main reasons. Firstly, energy efficiency measurements and new building standards have reduced the need for heating. Secondly, a warmer global climate reduces the need for heating, instead, it opens up new markets for cooling services (Sköldberg and Rydén, 2014). Due to the increasing competition, district heating companies have adopted market prices to be competitive against alternative heating technologies (Ibid).

The heating market is undoubtedly undergoing changes. Companies operating in this setting, therefore, have to keep up with changing market structures and transition pressures and with this in mind decide on how to invest for the future. Consequently, it is fundamental for district heating companies to understand project performance for their large scale investments to remain competitive as an asset driven company when future uncertainties and risks are more prominent than ever. Having a deeper understanding of causes and characteristics of project performance opens up for enhancing project management and profitability of businesses.

1.2 Purpose and Research Question

The purpose of the thesis is to explore project performance of large-scale projects within the combined heat and power and district heating sector to enhance the knowledge of project performance and explore the main factors influencing the performance of large-scale energy infrastructure projects within a district heating setting.

In order to fulfil the purpose of this thesis, the following research question was answered:

What factors influence the performance of large-scale energy infrastructure projects?

1.3 Contributions

Project performance on infrastructure projects have been researched and debated for several decades in literature (Cantarelli et al., 2012; Gil and Pinto, 2018; Ika, Love, and Pinto, 2020). However, little is known within the field of energy infrastructure, especially in Sweden. Therefore, this study provides knowledge and insights into the specific industry about the most common causes for different project performance. In addition, the thesis adds insights to the current debate on what causes large-scale infrastructure projects to be subjected to poor performance (Cantarelli et al., 2012; Love et al., 2021; ka, Love, and Pinto, 2020) by providing findings both supporting and questioning earlier identified factors.

Moreover, as district heating technology is evolving to decarbonise the heating sector globally (IEA, 2019), some findings of this thesis can be transferable to the context of other countries with similar energy infrastructure investments as well.

1.4 Outline of the Thesis

This thesis consists of the following seven chapters:

Chapter 1 Introduction: The thesis begins with an introduction to the district heating sector, and the current status of low profitability and increasing risks on investments. The reader is also introduced to the current debate in the literature regarding large-scale project performance which is finalised by a purpose and research question.

Chapter 2 Literature review: A literature review is performed to enlighten the reader on project performance and how it is measured. The literature review also summarises the current debate in the literature on what factors explain poor large-scale project performance.

Chapter 3 Research methodology: The research process and design is elaborated and described in detail together with data collection and analysis methods. Quality and ethics of research is also discussed here.

Chapter 4 Context description: The background of the district heating industry and the case company is described here. The company's internal processes for large-scale investments and the selected nine cases are also described in detail.

Chapter 5 Project analysis: Here the results are presented and the corresponding analysis of the findings. The nine cases are evaluated on project performance and then both main contributing factors and other factors explaining project performance are analysed.

Chapter 6 Discussion: The analysis from chapter 5 is discussed with the current literature on large-scale project performance. Contributions to literature are highlighted together with future recommendations for further research. Finally, implications for practice are discussed.

Chapter 7 Conclusion: A summary of chapters 1-6 to conclude the research findings.

2 Literature Review

This chapter covers the relevant literature on project performance, especially of large-scale infrastructure projects. It will begin with an introduction to the current societal view on projects and what constitutes a large scale infrastructure project. Following, project performance is reviewed based on the Iron Triangle: cost, time and quality. Lastly, the state-of-the-art on what explains large scale project performance and the current debate in the literature is described.

2.1 The Projectified Society

With a world full of new fast-evolving technologies, the importance of finding new solutions to problems and rapid dynamic changes in competition, organisations need to adapt to the new fast-paced society. As a response, organisations, and thus society, are becoming “projectified” (Lundin et al, 2015), meaning that projects are the primary process of the business, where portfolio management is the primary means to new products and services (Turner and Keegran, 2001). Projects have evolved from being the management of extraordinary, seldom occurring tasks, to now managing a large, and increasing, share of ordinary business operations (Turner, 1999 referenced in Engwall, 2003). Today, contemporary organisations have projects as a significant feature (Clegg, 1990; Ekstedt et al.,1999; referenced in Engwall, 2003).

According to *A Guide to the Project Management Body of Knowledge* 4 th Edition, p5 (PMI, 2008a,; referenced in Weaver, 2010) the definition of a project is: “a temporary endeavour undertaken to create a unique project service or result”. Projects are associated with characteristics such as large-scale engineering, complexity, dynamic markets and high customer involvement that makes mass production difficult, or even impossible. Therefore, organisations that are conducting projects usually need a high level of flexibility, in order to incorporate these characteristics of changing customer demands or to perform complex, non-routine tasks which integrate different bodies of knowledge (Nightingale et al., 2011).

2.2 Large-Scale Infrastructure Projects

There is no united definition of what a megaproject or a large-scale infrastructure project is. However, there are common features on what they constitute of. Megaprojects usually refer to the model that aims to produce a large-scale and complex investment in the public and private sectors (Denicol et al. 2020). The complexity, large scale, adverse site conditions and socio-political environment make these projects risky and difficult ventures to plan, manage and deliver on expected budget, time and quality (Flyvbjerg, 2003; Wang and Yuan, 2011).

Projects within a district heating setting fit within this category of projects as these have a high complexity due to the mechanical and electrical components, complex civil engineering work, involvement of many stakeholders and contractors and constantly interrelating activities (Zegordi, Rezaee Nik & Nazari, 2012). When all these factors are present, there is a high-risk exposure and increased uncertainty regarding the project, unsurprisingly leading to projects failing to meet objectives (Sovacol et al., 2014). Despite this, global spending on large scale infrastructure projects is $6 to 9 trillion a year (Fyvbjerg, 2013)

2.3 The Iron Triangle and Project Performance

Ensuring that projects have an adequate performance is key in order for them to succeed (Al-Nabae and Sammani, 2021). Undeniably, project success can be seen as one of the most important aspects of projects overall. Without a chance of success, no project would ever be undertaken. However, success is multi-dimensional as projects could fail in some aspects and still succeed in others (Ghyoot and Kerzner, 1983). While projects can be measured objectively, success can have different meanings to different people. A maintenance engineer may view success as a perfectly performing end-product, while a project manager could interpret success as the delivery of the project as close to budget as possible (Silverman (1976) referred to in Ghyoot and Kerzner, 1983).

The central concept of success widely accepted both in project management research and within organisational practice is the *Iron Triangle,* sometimes called the *Triple Constraint*. The Iron Triangle represents the most fundamental criteria for measuring project success: time, cost and quality. If projects are delivered on time, within budget and with desired quality, they are considered successful. Typically, time, cost and quality are depicted as a triangle (hence the name) where the three criteria are on the vertices. If one criterion is changed, such as a time delay, it exerts pressure on the other two, possibly leading to project failure (Pollack, Helm and Adler, 2018). The Iron Triangle can be seen in figure 1.

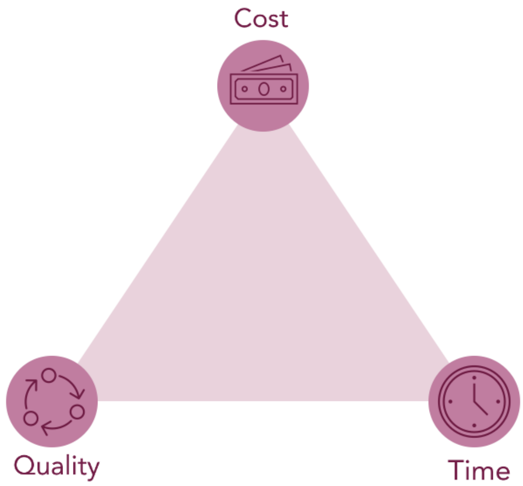

Figure 1: The Iron Triangle of project performance

Managing time, cost and quality effectively have been found central to achieving project success (Ghyoot and Kerzner, 1983). While many scholars have argued for the incompleteness of the Iron Triangle (Ibid) the tree constraints have been widely accepted as success criteria for several decades (Atkinson, 1999). Its popularity may be enforced by its simplicity to declare success, especially when projects experience increasing complexity and uncertainty. Larger and complex projects tend to increase the focus on time and cost control, to reassure simple measurements of performance (Papek-Shields et al., 2010).

The critique against the Iron Triangle focuses on how albeit the criteria of time, cost and quality are important for project success, they do not tell the whole story (Pollack, Helm and Adler, 2018). While these criteria could be seen as more short-term goals, they do not offer any answers to long term benefits. Ghyoot and Kerzner (1983) argue that the only parameter that is valid generally is project quality. Time and cost come secondary to quality, judged in relation to performance. An example of this is the Sydney Opera House, a project delivered extensively above budget and time. However, calling it a failure today would be misleading as Sydney now possesses a beautiful opera house which now is one of the city's more famous buildings. DeCotiis and Dyer (1977) (referred to by Kerzner and Ghyoot, 1983) observed that while project managers might know that projects are successful, they do not know what leads up to that success and thus they do not learn from the experience. They identified five dimensions to measure project success: (1) Business Performance of the end product; (2) Technical performance of the end product; (3) Efficiency of the project operations; (4) Personal growth of the project team; (5) Technical innovativeness. Accordingly, Atkinson (1999) stresses the importance of realising that time- and cost-objectives are based upon estimations or best guesses and that quality is a "phenomena" which is why too much weight should not be put on the Iron Triangle.

This can be extended by Gardiner and Stewart (2000) who estimates that projects experience budget or schedule overruns, thus drawing the conclusion that initial estimates are insufficient for evaluating success.

According to Baccarini (1999 referenced in Sue et al. 2019) project success is defined by two pillars: the success of project management and the success of the product. In order to cope with the increasing complexity and risk of infrastructure and construction projects, project management needs to be evaluated beyond the conventional Iron Triangle criteria of time, cost and quality. More important is to develop an understanding of emerging risks and challenges for project success and what competencies are required to overcome them to ensure future project success (Sue et al. 2019).

2.3.1 The Impact of Informal versus Formal Time of Decisions

A common problem when assessing project performance, whether it is over-or underperforming, is to determine the time when the decision to build (or invest) was taken. It is at this stage the project's objectives such as time, cost and quality are set in order to evaluate future performance. Informal decisions can often be made before the actual formal decision. Informal decisions can in turn be based on more informal forecasts, substantially less detailed and more optimistic. If projects were benchmarked against informal objectives of cost, time and quality, there is a higher chance of undesired project performance or even project failure. During more formal processes of planning and forecasting, better estimations are developed which in turn can lead to more conservative deviations of project output in relation to desired objectives (Flyvbjerg et al., 2003). Differences in such "point of reference" between studies lead to different results. Using the initial budget, advocated by Flyvbjerg et al., 2003 leads to overinflated values of cost performance (Love et al., 2015).

Below, each of the three criteria; cost, time and quality, are elaborated further. In summary, the most researched criteria in literature are by far the cost performance of large-scale projects. Time is not equally important, however considering that cost and time are not mutually exclusive, it is understandable that time is in the background of cost. Quality and the benefit of the project are not much researched, however, examples of large-scale projects in literature are usually portrayed as successful based on the quality and outcome.

2.3.2 Cost Performance of Large-Scale Infrastructure Projects

When investigating how projects perform, the most important variable from the Iron Triangle is cost. While poor cost performance is often expressed as "cost overrun" in literature, some scholars refrain from using cost overruns as projects also can experience cost underruns. Instead, cost performance, which includes both decrease and increase of cost is used interchangeably with cost overruns (Love et al, 2019). The cost performance is calculated as the actual cost, minus the estimated cost expressed as a percentage of the estimated cost. The estimated cost is the forecasted and budgeted cost of the project, calculated when the decision to build is taken. The actual cost is the real cost at the end of the project. (Flyvbjerg et al, 2003).

The Magnitude of Project Cost Performance

Cost performance of large-scale infrastructure projects have been investigated predominantly within the sub-sector of transport infrastructure. A majority of the research within the area has adopted a focus to determine the magnitude and specific factors (such as project type, geography and phase) influencing the cost performance of projects with statistical significance.

Odeck (2004) showed that in Norwegian road projects cost increases are on average 7.9 percent (ranging from -59 percent to 183 percent) and with a mean of 29 percent, amounting to 519 millions Norwegian Kroners. Of the total 620 projects investigated, 52 percent experienced cost increases, while only 35 percent were exposed to cost decreases. As for large Danish transport projects, Skamris and Flyvbjerg (1997) showed that cost overruns of 50-100 percent were common. To extend the literature, Flyvbjerg et al. (2003) studied 258 transport infrastructure projects with a geographic variation. The study concluded that "cost underestimations are much more common (..) and larger than cost overestimations". The average cost overrun in their study was 28 percent. One of the largest samples was studied by Catalão, Cruz and Sarmento (2019) who looked into 1091 transport infrastructure projects in Portugal. They found a mean cost deviation of 17.8 percent (range from -79.5 percent to 136.9 percent).

To get a more extensive view, Lundberg et al. (2011) provide a summary of the literature on cost overruns in transport infrastructure. He concludes based on previous studies that over time, cost increases have not declined. Lundberg et al. (2011) performed an analysis of 167 Swedish transport infrastructure projects and found that on average the cost overrun is 11.1 percent for road projects (range from -47percent to 134 percent) and 21.1 percent (range from -54 percent to 250 percent) for rail projects.
To get a different perspective opposing the extensive literature that advocates that cost increases are a common feature of large-scale infrastructure projects, Love et al. (2019) looked into 85 projects conducted in Hong Kong between 1999 and 2017. They found that despite a lot of variances, 47 percent of the projects were constructed on less than the estimated budget.

As for energy infrastructure projects, the literature is not as extensive. Sovacool et al. (2014) analysed a sample of 401 energy projects across 57 countries, the mean cost overrun was 66 percent, equivalent to $1 billion. Overall, three out of four projects underestimated costs. The differences in average cost escalation across each specific power source were: nuclear, 117 percent; hydro, 71 percent; thermal, 13 percent; wind; 8 percent and solar, 1 percent. While costs generally were higher per installed kW for wind and solar due to their smaller size, their modularity led to less risk which decreased the size of cost overruns. To summarise findings regarding the cost performance of large-scale infrastructure projects, it can be said that there is a well-confirmed trend toward cost increases being larger and more common than decreases. However, it should be remembered that there are large deviations from the mean. All studies include projects which perform well below estimated costs, meaning that projects also experience cost decreases.

2.3.3 Time Performance of Large-Scale Infrastructure Projects

Time overrun, or "slippage of project schedule" is the time a project exceeds its initial timeline. The time increase is the difference between the actual date of completion and the original completion date traceable to contractors (Kaming et al., 1997). If needed it can be expressed as a percentage of total project time. According to Antill and Woodhead (1989) referred to by Kaming et al. (1997) there are three types of time schedule overrun. Firstly, there are time overruns that neither party of the contract have any control over. Secondly, there are the time schedule overruns that the contractor has control over and thirdly, there are time schedule overruns over which the construction owner has control. Variables that cause time delays are many, such as bad weather and geological and geographical site condition, inaccurate estimates of material, labour and equipment, skill shortages, design changes and project complexity. Projects may be delayed partly or in whole and there is no certainty that different projects will be impacted similarly by common delay variables. However, what does combine all time delays is that they all usually cost money (Kaming et al., 1997).

The Magnitude of Project Time Performance

In the Indian Public Sector, Morris (1990) analysed 290 projects, of which 162 had or were anticipated to have time delays. The time increase was estimated to be 43 percent more than the original project time. Looking into construction projects in Malaysia, Rahman et al. (2012) conducted survey research on construction workers. It was concluded that few respondents found a time overrun of 0 percent (no time overrun) to be very uncommon. The most significant number of respondents (34 percent) claimed that a time increase of 10-15 percent was common. Additionally, 26 percent claimed that increases in time at 15 percent and above were common. 14 percent respectively 17 percent of respondents said that time increases of 1-5 percent and 5-10 percent were common. In total, only 8 percent of projects were completed within the original time frame.

Sovacool at al. (2014) looked into whether the same large-scale energy infrastructure projects that experienced cost increases also exceeded time schedule. On average, the total project time was over

70 months. Both hydropower dams and nuclear power plants had a high time schedule over, where 64 of all projects had an increasing time schedule. To remark here is that cost increases were more common. For thermal power plants and wind power, time delays were present in 10 percent of all projects, whereas no data was found for solar projects. To conclude, this implies that there might not be a monotonic relationship between time and cost. Time and cost are not mutually exclusive performance criteria (Love et al., 2015) as the cost could increase due to tight time schedules being very important. If that is the case, the workers could be paid for overtime duties, which increase costs.

2.3.4 Quality Performance of Large-Scale Infrastructure Projects

There is a general consensus in the literature that cost and time are part of the iron triangle but the concept of quality is more uncertain. Defining quality is problematic and the concept is therefore not as frequently discussed in project success management literature as time and cost which are both more objective concepts by nature (Pollack, Helm and Adler, 2018). However, the quality of the project could be seen as more important than cost and time when measuring project performance since the quality should go beyond the project itself and also evaluate the end product. Time and cost should therefore be secondary and judged based on the criteria of quality (Ghyoot and Kerzner, 1983).

Even though the definition of quality is problematic, literature tries to describe or change the term to fit the project type so that the concept is not entirely left out. Even though Ika et al. (2022) does not mention quality as a performance measure of large-scale projects the discussion instead revolves around scope, strategy, process and benefits in relation to cost and time. Pollack, Helm and Adler (2018) mentions that when addressing the performance of large-scale projects, productivity was often used instead of quality and when power plant or energy infrastructure were evaluated the term quality management was more prominent.

The Magnitude of Project Quality Performance

Since large-scale infrastructure projects often have to be designed for their long-term benefits, the short-term benefits are often compromised. The projects may be seen as successful from a long-term perspective but fail to meet short-term objectives (Ika et al. 2022). Love et al. (2020) investigates how quality issues are managed within large-scale transport infrastructure and concludes that the risks associated with poor quality are often put on contractors. Contractors who, at the same time, have to assure all project objectives are met and that the safety during construction is not compromised, which influences the time spent on quality management and assurance.

2.4 Explanations of Large-Scale Project Performance

Factors explaining the performance of large-scale projects have been assessed by several researchers without any success in finding the main contributor to poor project performance. One of the earliest categorisations of causes and explanations was introduced by Flybjerg et al. in 2003, laying the foundation for several other studies. The explanations, further elaborated by Cantarelli, Molin and Flyvbjerg (2010) were; technical, economic, political and psychological. To summarise, the political explanations or behavioural perspective is said to be the most significant factor influencing project performance. These explanations have been argued by several authors such as Love et al. (2015) to only capture the external view of why projects perform poorly. Instead, a more balanced approach also referred to as the project management perspective is suggested as the main explanation. This perspective is including internal explanations more confited to factors of project management, focusing on technical issues such as changes in scope and order, mistakes in planning and errors,

Adding a similar perspective, a systematic literature review on causes and cures for poor megaproject performance has been conducted by Denicol et al. (2020). Their analysis found six themes to explain the main causes of poor performance "(1) decision-making behaviour; (2) strategy, governance, and procurement; (3) risk and uncertainty; (4) leadership and capable teams; (5) stakeholder engagement and management; and (6) supply chain integration and coordination".

The different factors found in earlier literature that explain why projects perform poorly have been placed on a continuum in figure 2 below. The continuum stretches between the more external or behavioural driven factors to the more internal, project management driven factors.

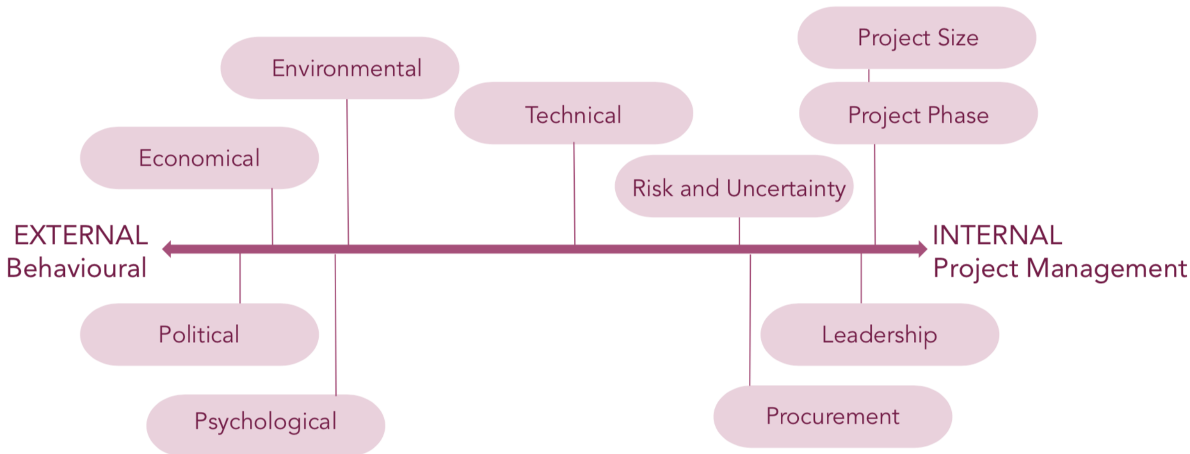

Figure 2: Continuum of factors explaining project performance (own elaboration)

Political and Decision-Making Behaviour

According to Cantarelli, Flyvbjerg and Molin (2010), political explanations are the most prominent in the literature. Political explanations are generally caused by deliberate cost underestimations and forecast manipulation. In order to increase the chance of project acceptance, costs are underestimated. This strategic misrepresentation can be driven by asymmetric information, lack of coordination, commitment and political pressure. In addition to strategic misrepresentation, project managers' cognitive bias can create overly optimistic forecasts due to cautious attitudes towards risk and a strive for maximising the utility of one's project. Decision-making behaviour is a result of the political and psychological behaviour of the project team and organisation. The main drivers discovered by Denicol, Davies and Krystallis (2020) are optimism bias, strategic misrepresentation and escalating commitment. Escalating commitment refers to the perception that once a large-scale project is started, it is too big to stop. Projects are allocated resources to ensure completion despite assessments indicating others. In this case, the benefit of the project might no longer surpass the investment cost.

Psychological

The psychological explanation is driving project performance based on the two concepts, the planning fallacy and optimism bias. These concepts regard people’s attitude towards risks and their cognitive bias when making project-related decisions. People are more often risk-averse than risk-tolerant and think about decisions in a short timeframe, decisions are taken one at a time and in isolation from other choices or future problems (Cantarelli, Flyvbjerg and Molin, 2010). The optimism bias is influencing their tendency to make optimistic forecasts and overestimate the project’s benefits (Denicol, Davies and Krystallis, 2020). These optimistic forecasts also influence the selection of projects since the chance of being selected increases when costs are low, which continues the underestimation of project needs (Cantarelli, Flyvbjerg and Molin, 2010).

Economical

The Economic explanation that drives project performance is deliberate underestimations. Underestimation itself can arise due to poor methods of financing and contracting, lack of incentives or resources to perform well-grounded estimations or strategic behaviour (Cantarelli, Flyvbjerg and Molin, 2010). Catalão, Cruz and Sarmento (2019) found evidence when investigating 1091 large-scale transport infrastructure projects in Portugal that inflation and economic growth were both relevant factors contributing to project cost performance. When public investments were high, so was also cost deviations.

In order to extend the literature on the cost performance of large-scale projects, Pham et al. (2020) identified the main factors contributing to cost increases in Vietnamese transmission line projects. By deriving comprehensive 52 factors, grouped into seven categories, causing cost increase from literature they found three economically linked categories to be significant. Economic risk, resources, and components, transportation and machinery costs are all contributing to increasing costs. One main reason for a price increase on materials, equipment and labour is the long bidding process (Xia et al., 2017). The often specialised field regarding components and equipment needed contributes to project performance if few suppliers are available (Pham et al., 2020).

Environmental

Project management research has for long studied projects as an individual phenomenon, neglecting a more open system approach. By analysing two large-scale engineering projects (hydropower dam and transmission line) from their historical and organisational perspectives Engwall (2003) addresses the importance of an open systems approach. He argues that to understand projects in-depth, it needs to be analysed in relation to past activities, parallel events, institutional norms, post-project future ideas and the politics during the pre-project phase.

When it comes to incorporating context into the varying explanations of cost performance, literature is mostly focused on project types, geographical location and procurement methods (Odeck, 2004; Flyvbjerg 2003; Lundberg et al, 2011). Moreover, different perspectives on what causes the cost increases have been debated (Flyvbjerg et al., 2018; Love et al, 2016) leading to different proposed strategies to curb cost increases: reducing bias and misrepresentation in estimations or implementing best-practices of project management. These one-size-fits-all strategies hence neglect the surrounding context (Ika, Love and Pinto, 2020).

With a lack of in-depth exploration of what context is and how it contributes to cost performance, Love and Ika (2021) adapted a sense-making approach to examine transport projects in Australia in order to provide a context to cost increases. By using a context-breakdown structure, they were enabled to provide a mapping of “contexts within contexts” contributing to increases in project cost.

To the above-stated debate on the root cause of cost overruns, Love et al. (2021) highlight the importance of how context influences and can help to explain cost deviations. In the face of uncertainty and complexity, determining the cost performance and recommendations to curb it has been ill-advised partly due to a lack of context exploration. To extend the literature on large-scale transport projects they conduct an in-depth exploration of the project's context, and insights about the reality of decision making and practice can be developed.

While context has been the starting point in some analyses within the project management field, there is still no clear notion of what constitutes context (Dohn et al., 2018). Brown (2010, p. 7) defines context as “the formal and informal setting in which a situation occurs; it can include many aspects and/or dimensions”. These dimensions include economical, legal, geographical, political, historical, environmental and socio-cultural circumstances and the continuous interaction between the setting and the analysed situation (Love and Ika, 2021). Project management literature differentiates between the context that is emerging during the project with respect to what prevailed or differentiates between the initial and the existing context of the project (Hirschman, 1967 referenced in Love and Ika, 2021).

To further clarify the notion of context, there are two features related to all contexts. First, the context has a supplementary role: by adding the context, the object studied can be fully understood. If no context is provided, there would have been inadequate analysis of the object. Secondly, the context is determined relative to the object. Thus, the context is not just a neutral layout near the object, nor is it an indefinite background or circumstances. The context and its relations to the object are what determine what characteristics of the surroundings that are relevant, thus part of the context (Dohn et al., 2018).

Therefore, as context is a constant unfolding of interactions, it is both existing, initial and emerging (Love and Ika, 2021) and always within a hierarchy of settings (Brown, 2010). Therefore, without fully understanding the context of projects, it might be impossible to fully understand the performance of it. By understanding the hierarchical context of project performance, a higher level of learning can emerge (Love and Ika, 2021).

Technical

Technical explanations can partly be explained by variables that drive changes in cost. Poor forecasting methods and the incompleteness of estimation, price rises and poor project design are considered to be the main driving variables (Cantarelli, Flyvbjerg and Molin, 2010).

Decision making on large infrastructural investment is often based to a large extent on ex-ante evaluations of cost with its corresponding benefits. Over time, improvements in inadequate forecasting techniques and inadequate data categorised as technical explanations by Cantarelli, Flyvbjerg and Molin (2010) should lead to decreasing cost increases if they were a contributing factor. Cost estimates of transport infrastructure projects have not improved over the last decades looking at studies conducted both on a global and national basis, showing that technical explanations can be rejected as a contributor to poor cost performance (Cantarelli et al., 2012; Flyvbjerg et al., 2003). On the opposite side, van Wee (2007) concludes that not enough research has been conducted on the quality of cost and benefits forecasting. In order to increase the level of accuracy, uncertainties should be more explicitly reported such as uncertainty regarding the forecasting models themselves, uncertainties with respect to policies and uncertainties with respect to the consumer.

The French nuclear Pressurised Water Reactor program conducted between 1970 and 2000 is one of the largest and most successful scaling-up of a very complex and expensive technology system.
Despite being credited as successful, cost overruns were substantial. While the industry itself usually refers cost increases to regulatory uncertainty or public opinions, the nature of the technology: large-scale and complex; limits mechanisms for cost reductions such as standardisation. The french program experienced negative learning, i.e cost increased over time, while looking at the theory of general learning curves it should have decreased. The complexity of the projects limited knowledge transfer from similar experiences and technology implications. Accumulating system complexity (such as increasing safety standards, load-following operational mode and fuel cycle management for nuclear reactors) inevitably leads to cost increases at the bottom line (Grubler, 2010).

Risk and Uncertainty

The most predominant factors associated with risk and uncertainty are technological novelties that are often introduced in large projects, flexibility and the ability to respond to changing circumstances and the complex features of large projects where parts and relationships are both many and intertwined (Denicol, Davies and Krystallis, 2020). The flexibility and environmental circumstances as a risk driver are also described by Love et al. (2015) but handle the process of risk management to a larger extent. Within risk management, common failures are calculating the project’s business case incorrectly and underestimating the potential disputes between people and different organisations involved in the project. The second is linked to the complexity mentioned by Denicol, Davies and Krystallis (2020).

There are different ways to handle project risks and it is common that these are not fully accounted for during planning. Assessing the risks and using state-of-the-art techniques during the planning stage is often to the project’s advantage, however time, budget or expertise limitations influence how prioritised risk management is (Siematycki, 2009).

Procurement

Procurement and contracts look differently for all large-scale projects. Commonly used project delivery methods are design-build (DB), design-bid-build (DBB) and the more recently common, public-private-partnership (PPP). In a DB delivery method, the project owner designs a conceptual plan before a bidding process of the design and construction. In a DBB, the project owner designs the basic blueprints of the project which is the foundation for the bidding process. A PPP is a cooperative partnership between the owner, typically a public entity, and a private entity that is responsible to design, build and operate the construction. The procurement and selection of project delivery methods often take place at the beginning of projects (Denicol et al., 2020). At this stage, cost estimates are the most vulnerable as political, economical, psychological and other organisational pressures are the highest to selecting project delivery method, pathway and technology (Love et al., 2015).

Some of the most prominent causes of why projects perform poorly are the poor understanding and balance between the capabilities of the organisation versus the ones outsourced to the market (Denicol et al., 2020). Lack of standardisation, poor risk allocation, slow approvals and poorly defined works are some systematic weaknesses of the project delivery method identified by The National Audit Office 2004 (referred to by Love et al., 2015). Moreover, disputes from scope changes and inadequacy of the business case are problems with the procurement process. To increase efficiency and improve performance, project delivery methods have moved from more conventional methods such as DB and DBB to PPPs. Fixed-price contracts and competitive contexts often lead firms to reduce margins in order to win the bidding and obtain the contract for large-scale infrastructure. Engineering consultants may reduce their effort for these critical activities associated with the project delivery method due to workload, pressure or optimistic schedules to produce well-designed schemes (Love et al., 2015).

Another difficulty with the project delivery method is the inadequacy of engineering design. It is almost impossible to create original complete design documents that projects could be constructed after. Instead, insufficient documentation is the foundation for procurement which adds a cost uncertainty and leads to few projects completed within their price at quotation (Chang, 2002). Moreover, errors in fixed-price contracts are not always taken into account in risk assessment, which can influence project performance (Love et al., 2015).

To control the progress of contracted parties and ensure that the time schedule and budget are kept, fines and penalties are commonly used. However, while these fines might save the project owner some costs, they might put pressure on the contractor to achieve ambitious project plans. For instance, keeping the schedule comes only at the contractors' expense which can lead to conflicts late in the project or even after completion. Too rigid control of execution could increase the need for flexibility at the end to address financial issues. In large-scale projects, penalties for time delays may be ineffective due to the uncertainty and many change orders (Szentes and Eriksson, 2016).

To ensure alignment between project owner and contractor, a shared risk-reward model can be a helpful instrument. Establishing a contract that specifies the sharing of cost increases and decreases can create positive behaviour within the project team and contractors and ensure performance outcomes and engagement for the entire project life cycle (Love et al., 2015).

Project Phase and Length

Common for all large infrastructure projects is that there are differences between the construction phase and the pre-construction phase. Overruns of costs tend to be more common during the pre-construction phase (Love et al., 2019; Cantarelli et al., 2012). Not only are cost overruns more frequent in the pre-construction phase, but they are also larger than cost overestimations. While projects in construction phases tend to underrun costs, albeit smaller than earlier cost overruns (Cantarelli et al., 2012). An overall comparison of twenty studies on cost escalations within transport infrastructure by Lundberg et al. (2011) found the main contributing determinant among all studies is the length of the project (including delays).

Project Size and Type

Project size as a determinant of cost increases remains debated. Some authors found that smaller projects tend to experience higher overruns (Odeck, 2004; Lundberg et al., 2011) as opposed to Flyvbjerg et al (2004) and Singh (2009) who showed that a larger project is subjected to larger increases. Catalão, Cruz and Sarmento (2019) found no evidence that larger projects increase the likelihood of poor cost performance. Love et al. (2015) suggest that rather than the size of the project, it is the level of complexity that influences cost overruns. When projects become more complex, traditional project management with its top-down structure on leadership [*A Guide to the Project Management Body of Knowledge* 4 th Edition (PMI, 2008a) referenced in Weaver, 2010] might be ineffective and insufficient to reduce project failure.

Furthermore, several authors such as Flyvbjerg (2003) have shown that different project types, such as rail, road and tunnel transport infrastructure projects have different performance. This moves on beyond transport infrastructure as Sovacool et al. (2014) shows large differences between various energy infrastructure such as nuclear, hydro, wind and solar. One common explanation for variations among project types is the differences in the amount of underground electrical and utility work. Site conditions might not match what is contracted which can lead to cost increase and schedule overrun (Love et al., 2015).

The differences between different project types have led Flyvbjerg et al. (2005) to develop reference class forecasting (RCF) as an attempt to reduce optimism bias and strategic misrepresentation. A database of comparable projects and their performance based on type is used to create an objective reference point on which to base the forecast. This method has received criticism both based on its statistical methodology (Love et al., 2013) and the fact that large-scale infrastructure projects are typically unique, so no such thing as a reference point might exist (Liu and Napier, 2009).

Leadership and Teams

The incompetence of parties, such as managerial weakness of both contractors and consutants and the project manager have been shown to impact project performance in Vietnamese transmission lines (Pham et al., 2020).

Catalão, Cruz and Sarmento (2019) found that good project management is becoming a more relevant issue than before. To establish correct organisational structure and possess construction knowledge such as good relationships and clear agreements with contractors are important to develop critical skills needed. Knowing when to act at the first signs of poor performance is key to delivering high performing projects. This is established by an adequate control mechanism for management regarding the design and forecasting process.

2.5 The Current Debate: Project Management Perspective versus the Behavioural Perspective

To canalise several explaining factors, Love et al. (2021) divide earlier literature findings into two groups: one group, with a focus on optimism bias and strategic misrepresentation as the main explaining factors and the other focusing more on the project management paradigm, suggesting best practices to handle economical and technical causes of underperformance. According to Gil and Pinto (2018) the discussion between the two groups appears to have been "stuck for more than 20 years" (p.717). In literature, these two perspectives now stand out as the explanation for poor cost performance of projects. The more internal project management view focuses on how management processes information which will influence the management of risk (Love et al., 2016). The more external view, supported by Flyvbjerg et al. (2018) suggests that the Planning Fallacy *(consisting of strategic misrepresentation and optimism bias)* is the main explanation for poor cost performance.

The Planning Fallacy explanation has received criticism from different perspectives (Eliasson and Fosgerau, 2013; Catalão, Cruz and Sarmento, 2019; Love et al., 2019), mainly due to the fact large-scale infrastructure projects seem to experience cost and time decreases in the same extent as increases and other factors such as economical or governance have a higher impact on cost deviations than political. While all cost increases may not arise from optimism bias or strategic misrepresentation, having a balanced approach which acknowledges factors such as political, economical and psychological by Chantarelli, Flyvbjerg and Molin (2010) is important (Love et al., 2015). Understanding "why" and "how" projects have different cost performances both from a behavioural perspective but also from a more evolutionary perspective, acknowledging the project management view is key to reducing their impact on the project's cost performance (Love et al., 2016).

In order to move the debate on what causes poor project performance and cost increase, in particular, Ika, Love and Pinto (2020) propose a balanced theoretical approach. They debate over the two theoretical principles: the Planning Fallacy theory set against the Hiding Hand as the best theoretical explanation for poor project performance. The Hiding Hand focuses on being creative and flexible as one manages projects with high complexity and uncertainty. Even if projects are estimated at a too low cost and corresponding to too high a benefit, it can help projects to succeed in unforeseen ways as it opens up for creative solutions. Accordingly, the Hiding Hand can find projects successful based on benefits and quality even though they might be management failures regarding cost and time. The debate between the two main explaining factors is significant as it tries to answer whether human bias overruns explanations such as scope change, complexity and uncertainty for cost performance.

Ika, Love and Pinto (2020) propose a new theoretical principle for project behaviour: The fifth hand. The fifth hand reconciles error with a bias to adapt to greater uncertainty and complexity in order to empower teams. Pragmatically, projects are seen as more complex with many shades between success and failure but with the agency to make the best out of each project according to its context and learn from the experience despite uncertainty and complexity.

There are many methodological challenges to pursuing research in the Planning Fallacy debate. Firstly, it is always difficult to assess important variables such as creativity, complexity and uncertainty. In addition, measuring large-scale project benefits such as life-cycle costs is a challenge as information and data is generally incomplete. Secondly, it is hard to estimate the influence of optimism bias on estimates prepared in a team environment. Lastly, deviations of project plans usually are blamed on poor project management rather than complexity which makes the debate between the Planning Fallacy and Hiding hand hard to estimate empirically. It remains "whether or not the fifth hand can be assessed empirically (...) and how to empower managers with it". While the fifth hand may be a step forward, in theory, it is important to remember that it only may explain the performance of projects in hindsight, not foresight (Ika, Love and Pinto, 2020).

3 Research Methodology

This chapter describes the methodology used for the conducted research, such as design and approach as well as outlining the research process. The conducted literature review and data collection with corresponding analysis have been described in detail. Lastly, the quality of the research along with ethical concerns are discussed and presented.

3.1 Research Design and Approach

The thesis research was performed as a multiple case study due to the nature of the phenomenon being studied. To gain an in-depth understanding of a problem, a case study design is well established as a strategy. An in-depth inquiry helps to understand what is happening, and why, which can give implications of action and lead to theory development (Saunders, Lewis, & Thornhill, 2015, pp. 185). Moreover, the richness of the phenomena and its close connection to real-life context makes a case study approach suitable as a strategy (Yin, 2009). The cases consist of large-scale energy infrastructure projects that were selected due to their size and uniqueness. The projects were all embedded within the same single organisation, however, each individual project was the unit of analysis, which is why a multiple case study approach was used.

The purpose of the study was to conduct an exploratory study, in order to clarify the phenomena being studied. The lack of comparative studies and intention to explore the phenomena to understand its precise nature motivated this purpose (Saunders, Lewis, & Thornhill, 2015, pp.175)

The methodological approach to conduct research in the thesis was a sequential multi-phase method, seen in figure 3. Both qualitative and quantitative methods were used to expand the findings from each phase. The priority and focus during the research process was put on qualitative methods, to fulfil the exploratory purpose of the study (Saunders, Lewis, & Thornhill, 2015, pp.172) This method was also used to gain both an in-depth understanding but also a more objective description of each individual case studied.

Figure 3: The sequential multi-phase methodology

The research approach of the thesis was abductive since data and theory were reviewed continuously. The abductive approach allows the researcher to explore a phenomenon and identify and explain themes and patterns along the way (Saunders, Lewis & Thornhill, 2015). This approach was chosen because the problem formulation and theoretical framework were unknown and not defined before the start of the research. As explained by Saunders, Lewis & Thornhill (2015) the unknown characteristics and limited knowledge of the studied subject could make the researcher unable to create a hypothesis beforehand. Furthermore, the abductive approach allows for reflection of theory and empirical data which also enables the case study to incorporate the complexity of the studied problem (Conaty, 2021).

3.2 Research Process

The process consisted of a first phase of interviews, followed by the case selection with documentary research and second rounds of interviews. Furthermore, literature was reviewed simultaneously during the research process. The different research processes are described in detail below.

3.2.1 Case Study

The research began with a first round of interviews in order to familiarise with the organisation and the problem. To get a holistic picture of the problem, the first round of interviews together with some documentary research was conducted. The first phase of interviews consisted of 18 unstructured interviews with the purpose to explore the case study context and the problem formulation. Furthermore, creating a deeper understanding of the problem also contributed to guidance to the theoretical foundation. All the first phase interviews were conducted internally with employees at Stockholm Exergi. The employees were selected from various positions within the company, from top management to project managers, to gain a differentiated picture and narrow down the problem formulation. Internal documents of the organisational structure and specific projects were researched to enhance the knowledge of the organisational processes and data collection.

Moreover, the first phase of interviews served to further investigate to what extent and in what form data could be extracted later on in the research process to minimise the risk of later difficulties.

Following the first phase of interviews, the main study was conducted. This phase consisted of the initial selection of projects from a large dataset of projects provided by the organisation. A total of nine projects were selected from this dataset to study further. The reasoning behind the selection can be found in section 3.4.1 *Qualitative Data*. To gather data on these nine projects the project manager and project controller assigned to each project were contacted in order to provide more extensive documentation. Documentation requested for each project were reports of the project outcome and lessons learned as well as presentations for decision-making from different project phases. Following this, document research was conducted where similar themes were identified and the performance regarding time and cost of each project was evaluated. The project performance consisted of analysing quantitative data to generate an objective description of time and cost. The overall purpose of the document research was to get a deeper understanding of the projects, the context and overall performance and secondly to guide the following interviews. Lastly, a second round of interviews was held with the project managers of the nine selected projects. The purpose of the interviews was to further increase the in-depth understanding of each project's performance and the reasons behind it.

3.2.2 Literature Review

To increase the understanding of previously conducted research and direct the case study process a review of relevant literature was conducted. The review also served as a complement to the primary data retrieved from the case as it layed a theoretical foundation for analysis. Furthermore, by reviewing the literature, gaps in the current research were identified and helped to position this study in relation to it (Saunders, Lewis, & Thornhill, 2015).

Among the different topics reviewed, the common denominator for literature was a clear connection to *projects*. In the field of project-driven organisation, project challenges, project success/failure and poor cost performance of projects were the main research topics. In addition, context and its influence on increasing the in-depth understanding of projects were important.

As an abductive approach was used, literature was continuously revisited during the study. By using an iterative approach, new data insights or new literature topics found interesting to the study were further reviewed. The electronic database used for the academic literature was *Web of Science: Core Collection.* It was chosen in order to find peer-reviewed published content according to publicity standards with easy access. Moreover, the search tool KTHB Primo, provided by the KTH Royal Institute of Technology was used to gain access to published books.

Moving beyond academic literature, scientific and technology reports and news within the industry were an important contribution to increasing our understanding of the industry-related problem, which was considered interesting to compare with academic literature.

3.3 Data Collection

One favourable aspect of case study research is the possibility of using multiple sources for data collection. Having multiple sources of data can enable better results as richer understandings and triangulation is possible (Yin, 2009). As the study covers complex topics and contains rich context, multiple data collection methods have a clear contribution. The different methods that have been used will be described further below.

3.3.1 Interviews

Interviews are essential to incorporate as a data collection method in case study research in order to capture the context and human behaviours. By conducting interviews, different insights and perspectives on complex phenomena can be discovered (Yin, 2009), which is why this method is suitable for the conducted study.

All interviews in the first phase were conducted through video calls due to the situation of Covid-19 and with one person at a time. All interviewed employees received an email before the interview explaining the initial problem formulation so that they could prepare for the discussion. During the interviews, one interviewer took a more prominent role and the other took notes so that the interviewee could focus more on one person. As the purpose of the interview was to orient ourselves within the problem formulation and organisational context, the interviews were unstructured, focusing more on discussing the topics formulated by the supervisor and partly on our findings in the literature. After the interview, the notes were summarized in a table to get a structured overview of the information. In table 1 below, the activities of data collection during the first phase of interviews are outlined.

Table 1 : Summary of conducted first phase interviews

Interview	Role	Type	Length	Date
1	Head of Business Control	Unstructured interview	45 min	20220125
2	Business Controller	Unstructured interview	55 min	20220127
3	Head of Production support	Unstructured interview	50 min	20220128
4	Head of Project Organisation	Unstructured interview	40 min	20220128
5	Distribution optimising and Researcher	Unstructured interview	40 min	20220131
6	Investment analyst	Unstructured interview	40 min	20220131
7	Head of R&D and Researcher	Project formulation discussion	50 min	20220201
8	Production facility Manager	Unstructured interview	45 min	20220207
9	Project Manager	Unstructured interview	55 min	20220207
10	Head of Purchase	Unstructured interview	55 min	20220207
11	Project Manager	Unstructured interview	60 min	20220208
12	Asset Manager	Unstructured interview	55 min	20220208
13	Asset Manager	Unstructured interview	55 min	20220208
14	Asset Manager	Unstructured interview	55 min	20220209
15	Asset Manager	Unstructured interview	60 min	20220210
16	Head of Business Development	Project formulation discussion	70 min	20220210
17	Asset Manager	Unstructured interview	55 min	20220214
18	Project Controller	Unstructured interview	55 min	20220214

The main study began with collecting quantitative data on all projects conducted over the last ten years. The data were analysed in order to lay a foundation for the selection of projects. Together with the data analysis, several meetings seen in table 1 were held with managers and project controllers in order to select projects to be investigated in-depth.

The projects for further study were chosen from a sample of projects from the last 15 years. These projects were sorted on budget size since large and complex projects were of interest. The definition of a large project was set at 50 million SEK as this is the internal definition of when the board has to approve investments. Projects that had not yet been commissioned were eliminated in order to enable an evaluation of time and budget, therefore all selected projects had already been commissioned or completely finalised. Some projects that were chosen during the first screening had to be eliminated due to security regulations and are therefore not included in the final project selection. Ultimately, nine projects were chosen as our large projects according to budget size and categorised and classified according to internal standards (see section 4.3 *Description of Projects*).

When projects had been selected and documentary research had been conducted, a second round of interviews was held with the project managers of the selected projects seen in table 2.

Table 2: Summary of meetings and conducted interviews during the main study

Interview	Role(s)	Type	Length	Date
1	Project Controller, Project Controller	Teams meeting to extract data on projects	55 min	20220223
2	Head of Production support, Head of Business Development, Head of Production	Group discussion to select projects	45 min	20220224
3	Project Controller, Project Controller	Teams Meeting to select projects	50 min	20220228
4	Project Controller, Project Controller	Teams Meeting to select projects	40 min	20220304
5	Project Controller, Project Controller	Meeting on project data	75 min	20220315
6	Project Manager (project #5)	In-depth interview	60 min	20220330
7	Project Manager (project #4)	In-depth interview	60 min	20220404
8	Project Manager (project #8)	In-depth interview	60 min	20220405
9	Project Manager (project #6)	In-depth interview	60 min	20220407
10	Project Manager (project #3)	In-depth interview	60 min	20220408
12	Supervisor	Discussion	60 min	20220408
11	Project Manager (project #9)	In-depth interview	60 min	20220408
13	Project Manager (project #2)	In-depth interview	60 min	20220408

14	Project Manager (project #1)	In-depth interview	60 min	20220412
15	Project Manager (project #7)	In-depth interview	60 min	20220419

3.3.2 Documents

Document research was an important contribution to data collection during the entire research process. As the research target was projects within the organisation, access to internal organisational documents was granted. The documents were both related to the organisation's structure and processes but also project-specific.

First, documents regarding the organisation and its internal structure and processes were collected to increase the understanding of the organisation. Some project-specific documentation was also collected at this point to screen the layout and content of it, laying the foundation for the main study. This data helped to later understand relevant internal language present in other documents and interviews.

Moreover, a large data set of historical projects were collected to enable a selective sample. As individual projects were researched during the main study, specific documents regarding estimated and actual budgeted costs were collected to enable a deep and exploring analysis of the project's financial outcome. This was complemented by final reports, weekly meeting reports and experience reports to explore the individual project challenges and related solutions and failures. All documents are listed below in tables 3 and 4 .

Table 3: Internal documents retrieved from case company

Document Name	Content of Document	Pages	Name in Thesis (reference)
Projekthandbok	Process description for projects	47	Internal Document 1
Instruktion för beslutsprocessen	Instruction for decision making (investments)	24	Internal Document 2

Table 4: Internal documents retrieved for each project

Project #	Content of Document	Type
1	Investment presentation TG1, Investment presentation TG2, Lessons Learned	PPT, DOC
2	Final Reports, Lessons Learned	PPT, DOC
3	Investment presentation TG1, Investment presentation TG2, Cost Report, Lessons Learned	PPT, DOC, XLSL
4	Investment presentation TG2, Cost Report, Final Report,	PPT, DOC, XLSL
5	Investment presentation TG1, Investment presentation TG2, Cost Report, Lessons Learned	PPT, DOC, XLSL
6	Investment presentation TG1, Investment presentation TG2, Final Report, Lessons Learned	PPT, DOC
7	Investment presentation TG1, Investment presentation TG2, Cost Report, Project Plan, Status Report	PPT, DOC, XLSL
8	Investment presentation TG1, Investment presentation TG2, Final Report	PPT, DOC
9	Investment presentation TG1, Investment presentation TG2, Final Report, Lessons Learned	PPT, DOC

3.4 Data Analysis

Below is a description of how both the qualitative and quantitative data have been analysed. In addition, both the quality and ethical considerations are discussed in accordance.

3.4.1 Qualitative Data

Thematic analysis has been applied to analyse the qualitative data from the first phase of interviews as it is a generic and common approach. This approach is suitable when searching for themes within large and varied data sets as it provides a systematic approach which generates rich descriptions.. The thematic analysis is a flexible stand-alone technique as it is not linked to any philosophical or theoretical-methodological approach. The themes can either be derived from literature or occur during the coding, thus appropriate when using an abductive approach (Saunders, Lewis, & Thornhill, 2015, pp.579). As the thematic analysis approach is flexible there is no strict set of procedures needed to be conducted to ensure the correct method, instead focus can be on creating a rigorous analysis. However, the guidelines described by Saunders, Lewis, & Thornhill (2015) were applied. The guidelines include familiarising with data, coding the data, searching for themes and evaluating themes against the theory.

To familiarise with the data, one of the researchers took notes during the entire interview, and directly afterwards the notes were controlled by both researchers to ensure *credibility and then a transcript* *summary was prepared, including key takeaways*. To analyse the data, the thematic coding procedure was conducted. The codes used were data-driven, both derived by us through analysing the data and in-vivo codes.

As this research consists of a multiple case study each individual case is important to analyse in-depth. But within the rather narrow setting also being important, a comparative analysis to identify cross-case similarities or differences between the projects is important to conduct (Eisenhardt et al., 2018). The data collected during the main study was extensive and varied, consisting of many internal documents and interviews. In order to comprehend and analyse the data, the Data Display and Analysis approach by Miles et al. (2014) was applied. The process for analysis in the Data Display and Analysis approach consists of the following concurrent processes: *Data condensation; data display* and *drawing and verifying conclusions*.

Data condensation focuses on simplifying and summarising the collected data in order to condense the data (Saunders, Lewis, & Thornhill, 2015, pp. 614). This process was performed iteratively during the data collection, and was especially important when synthesising all documents. Each individual researcher used the most appropriate method for each document and interview, such as transcript and document summaries and coding of data. When both researchers had processed each information source, the condensed data were compared and a final version was developed.

The data display is important as it helps to recognise patterns and relationships. As it enables a deeper interpretation and analysis of data, to draw and verify better conclusions (Saunders, Lewis, & Thornhill, 2015, pp. 615). Data were displayed by matrices and by a framework derived from literature. The matrices did to some extent quantify the qualitative data for further analysis together with other quantitatively collected data.

3.4.2 Quantitative Data

The qualitative data was important to analyse in order to evaluate project performance objectively. As the quantitative data was not prioritised as the main collection methodology, Microsoft Excel was used as a tool to perform simple analytics. The data was thoroughly checked for any errors before being used in any analysis which according to Saunders, Lewis, and Thornhill (2015, pp.498) enhances the reliability of the analysis. Two types of data were collected; descriptive data on variables and continuous data on performance.

The descriptive data was used to analyse which budgetary items were exposed to cost increases and the frequency of each variable. The variables were selected based on the original budget item, and to some extent categorised as a group to ensure that each final variable was unambiguous and discrete (Saunders, Lewis, & Thornhill, 2015, pp. 500). The continuous data were used to measure project performance on time and cost as these variables could take any value.

3.5 Enhancing Rigour in Research

It is important to establish the quality of research conducted in the thesis in order for the results to be reliable. Common measurements to ensure quality in qualitative research are reliability and validity, however, these measurements have received criticism as they are based on positivist assumptions, which qualitative research generally is not, hence other measurements might be more appropriate when conducting qualitative research. In the case of a more interpretivist research philosophy Lincoln and Guba (1985) developed new measurements; dependability, credibility and transferability (Saunders, Lewis and Thornhill, 2015, pp. 205). This thesis has a philosophical standpoint between pure interpretivism and positivism, which is why a mix of different measurements has been used in order to ensure a rigorous study.

Data triangulation has been accomplished by having multiple sources of data such as two rounds of interviews, documentary research and quantitative data. In addition, Member checks of each case have been done. These activities contribute to enhancing the research credibility (Shah and Corley, 2006).

To ensure reliability, both researchers have analysed all data sources independently. Moreover, the research design and process have been described meticulously in order to help other researchers to replicate the methodology (Saunders, Lewis and Thornhill, 2015, pp. 203). These actions, together with ethical considerations described in 3.5.4 also align the study with Lincoln and Guba's measurement dependability (Shah and Corley, 2006).

Lastly, a detailed and rich description of the context, cases and research design allows other researchers to interpret the level of transferability (Saunders, Lewis and Thornhill, 2015, pp. 206).

3.6 Ethical Considerations

Ethical principles are important to promote good ethical practice to ensure no harm will be made. Ethical principles to ensure this is described by Saunders, Lewis and Thornhill (2015): avoidance of harm, privacy, voluntary participation, informed consent, and confidentiality. These have been applied when respondents are involved, further described below. In addition, the responsibility for the analysis, compliance of data and safety for researchers are important ethical principles to deal with.

Before each interview, the respondents were informed of the topic, their expected contribution and how that information would be utilised. The respondents were invited to participate, but not obligated to do so. Regarding data collection, consent was given prior to the interview. Privacy was ensured as all data were anonymised before being presented and treated as confidential throughout the report.

4 Context Description

This chapter describes the settings for the cases, based on primary data retrieved from the case company during the empirical study. The chapter begins with an overall description of the project management organisation, followed by a description of the project investment process. Lastly, the selection of projects for the multiple case study is motivated and each case is described in detail.

4.1 The Case Company Context

The setting of the multiple case study is the Swedish company Stockholm Exergi. The company operates in the Stockholm area and provides both heating, cooling and electricity to residents, hospitals, and businesses around the city. The company is highly dependent on its large energy infrastructure assets such as CHP plants, boilers and especially their distribution network with heat pumps. In 2021, 8309 GWh of heat was sold, 979 GWh electricity, and 321 GWh of cooling (Stockholm Exergi, 2022a). Stockholm Exergi has high climate ambitions and in 2021, 98 percent of generated energy came from renewable or recycled sources. And their goal is to have a climate-positive business already by 2025 (ibid). Stockholm Exergi aims to contribute to the sustainable transition by incorporating digital solutions, contributing to a more circular economy and the electrification of society by providing local production of electricity when needed (Stockholm Exergi, 2022b). The local production of electricity also offers important services to society when the transmission capacity is limited in Stockholm, especially on cold winter days when the demand for electricity is high (Stockholm Exergi, 2022a)

4.1.1 The Project Management Organisation

The company runs projects regularly and therefore has developed a project management organisation (PMO). The ability to conduct projects has an impact on quality, cost and revenues for the company which is why good project management is highly important.The PMO has responsibility for the project management of each project which also includes ensuring project quality and efficiency as well as offering resources to the organisation. The company describes a project as a "temporary investment to create a unique product or service" (Internal Document 1).

The investment board (IB) is responsible for managing the total portfolio of projects by prioritising the allocation of resources, evaluating Key Performance Indicators (KPI) and acting as a claimant toward investment- and decisions-processes (Internal Document 2). They have the responsibility to either reject or promote projects and priorities between investments (Internal Document 1). The board consists of key managers and company executives.

Investments (or projects) are divided into four overarching investment categories; legislation, maintenance, productivity and growth, and classified as *simple, complex* or *strategic*. The different types are described below (Internal Document 2) in figures 4 and 5.

Legislation	Enforced by new legal or environmental requirements.
Maintenance	Investments to extend lifespan, enhance accessibility or reduce future operation and maintenance costs on existing assets. Including change of parts to maintain the performance of assets.
Productivity	Investments for enhancing productivity in existing assets or new production capacity that will replace old capacity.
Growth	Investments for building new capacity or connecting new customers on existing networks.

Figure 4: Investment categories (modified from Stockholm Exergi 2021)

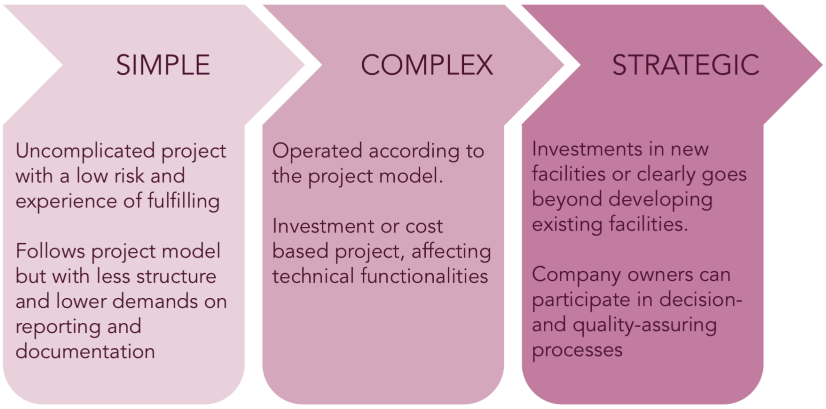

Figure 5: Investment classification (modified from Stockholm Exergi 2021)

Individual projects have several important stakeholders to ensure that the project succeeds. First, there is a PMO representative responsible for the portfolio to optimise resources and personnel and conduct overall coordinating and supporting work. The project owner is the commissioner of the project, who holds decisive views and ensures project benefits and costs. The project manager takes the active leading position to deliver the project during the different process phases. The project manager is supported by a technical project manager whose objective is to ensure technical standards and quality and a project controller to ensure time and cost are within budget (Internal Document 1). In addition, the project Steering Committee and the Reference Group assist the project and are described in detail in the appendix, together with a description of the general technical requirements and procurement process (see section 9.2 *PMO in detail*).

4.2.2 The Project Investment Process

The project process within the organisation is standardised to clarify decision making, change management, project leadership and project documentation. The project process starts with the initiation of the project, then the planning of the project, followed by implementation and lastly finalisation of the project. All these phases are continuously monitored and controlled (Internal document 1).

The project process at Stockholm Exergi can be divided into four phases: Initiate, Plan, Execute, Terminate, well-aligned with the Project Management Institute's PMBOK® Guide (ANSI standard). Between the phases, the process consists of five toll gates (TG0-TG4) to decide whether the projects should continue or not. The process for projects seen in figure 6 is described in detail below according to Internal document 1.

Figure 6: Project process and toll gates for investment decision (modified from Stockholm Exergi 2021)

Initiate Project and TG0

The initiation of the project takes place before TG0. The objective of the initiation process is to capture ideas and needs, priorities and develop a project description. At TG0 it is decided if the project should be started and an initial project description should underlie the TG0 decision. The project should be aligned with business development and budget with identified business risks.

Pilot Study and TG1

The start of the project begins with a pilot study which underlies the following TG1 decision. The objective of the pilot study is to develop a project plan and analyse the ability to realise the project. The pilot study is approved when conducted according to standards, which include identifying technical risks and developing a risk abatement plan and a purchasing strategy.

Pre-projecting and TG2

If a TG1 decision is made the pre-projecting starts which are followed by a TG2 decision. The planning phase between TG0 and TG2 is comprehensive and should result in clear goals, scope and requirements as well as an analysis and documentation of required operations, resources, budget and risks. The project's overall benefits and contributions to strategic business objectives are evaluated.

The TG2 decision decides if the project should be implemented or rejected based on the proposed budget and risks, thus this toll gate is the formal investment decision.

Implementation of Project and TG3

In between TG2 and TG3 the project is carried out according to the project plan. Durgin this implementation phase, large scope changes can occur. For scope changes that will impact time or cost objectives, a new decision is taken by the investment board on whether it should be neglected or incorporated. If the scope change is necessary, the budget and time schedule are changed to incorporate the change in cost and/or time. At this stage, the budget can also decrease if some budget items are predicted to be lower than estimated. The phase is finalised when the operations have been tested and approved. From a TG3 decision and onwards. Stockholm Exergi is responsible for the operations of the asset.

Termination of Project and TG4/TG5

The finalisation of the project starts after the TG3 decision is made, the project should then be more or less fully implemented and delivered to the operations and maintenance team. The TG4 decision is taken to close the project after final submissions are approved. The project is then achieved according to standard procedure. The objective of TG5 is to ensure that the project reaches the efficiency standards demanded at TG2.

4.3 Description of Projects

A short description of each selected project is summarised below in table 5. In the appendix (9.3 *Detailed Project Description*) all projects are described in detail based on the project-specific documents and the interviews with each project manager. The projects are in descending order based on their budgeted cost at the time of investment decision. As large-scale projects are the subject of research in this thesis, all projects were classified as either strategic or complex according to internal standards. In addition, no projects conducted out for legal reasons were chosen in this sample as they have a much smaller budget and are therefore not considered large-scale.

Table 5: Selected projects

Project	Start - Finish	Classification	Category	Location	Description
1	2009-2018	Strategic	Productivity	City	Construction and commission of a brownfield CHP plant.
2	2006-2015	Strategic	Productivity	North	Construction and commission of a brownfield waste fired CHP plant.
3	2015-2022	Strategic	Productivity	South	Replacement of two old boilers (45 years old) with a single one to ensure cheap and efficient waste incineration to ensure capacity in the network.
4	2016-2021	Strategic	Growth	North	Building a new waste sorting facility in close connection to an existing plant.
5	2015-2020	Complex	Maintenance	South	Replace old boilers with a new hot water boiler, the old ones had exceeded their technical life span.
6	2016-2022	Strategic	Maintenance	North	Distribution. Replace old and increase culvert size to minimise leakage, ensure future heating demands and lower production costs.
7	2014-2018	Complex	Maintenance	City	Lifetime extension of hot oil boilers and conversion to fossil-free operation.
8	2017-2021	Complex	Growth	South	A pump station with double pumps for increasing heat capacity to meet current and future demands.
9	2009-2017	Complex	Productivity	South	Adding new capacity to district cooling by converting an existing heat pump for district cooling production during summer time.

5 Project Analysis

This chapter outlines the findings from the empirical study. First, the projects are evaluated according to the Iron Triangle; cost, time and quality. Following, the main contributing factors explaining project performance are outlined in addition to other factors found to have a significant impact.

5.1 Project Performance

5.1.1 Cost Performance

The cost performance of the nine selected projects varies from -0.83 percent to 41.09 percent. The average cost difference is therefore an increase of 10.33 percent compared to the latest approved budget and 12.91 percent if compared to the original budget estimated at the investment decision. Three out of nine projects meet the cost objectives when measured against the latest approved budget, but only two projects perform within the budget compared to the investment decision. It is important to highlight that some projects have had separate finalisation projects. These projects are separate investments, but critical to ensure the full functionality of the original scope. These are difficult to find and therefore not included in the cost performance. Accordingly, cost increases would have been higher if finalisation projects were included.

Risk and contingency are included in all projects as a separate budget item to allow for risks and unknown costs. The amount of risk is calculated by first developing a list of possible risks, then addressing a cost to each risk which then is multiplied by the possibility of occurrence. Contingency is to cover all unknown costs and there is no standardised way to evaluate this. Project #1 and #2 were the only projects without risk and only contingency allowed. Comparing the amount of risk with the economic size of the project shows that more expensive projects do not receive a larger amount of risk and contingency. Older projects were not allowed to budget extra for risks which have now changed in recent years. For all projects, the money as risk and contingency was 100 percent utilised in all projects except project #5, however, that project was lucky to have some extra money intended for inflation which was not needed in the end. Instead, this was utilised to cover extra costs. Having risks and contingencies as budget items hence lowers the impact on cost increases that occur. Without this buffer, cost increases would have been higher for all projects.

All projects and their corresponding cost performance are shown in table 7, with corresponding colour keys in table 6. The projects are in descending order based on their budgeted costs at the time of investment decision.

Table 6: Colour key to cost performance

Colour	Cost Difference Colour Key
Green	No cost increase, or cost decrease
Yellow	1% < Cost increase ≤ 5%
Orange	5% < Cost increase ≤ 10%
Red	10% < Cost increase

Table 7: Cost performance of the selected projects

Project No.	Start year - Finish year	Risk and Contingency [percent]	Finalisation Project(s)	TG1 - Actual [percent]	TG2 - Actual [percent]	Current budget - Actual [percent]
1	2009-2018	4.8	Yes	38.92	32.61	32.61
2	2006-2015	7.3	Yes	N/A	17.52	12.16
3	2015-2022	9	No	4.43	-2.43	-0.83
4	2016-2021	10	No	N/A	9.38	0.63
5	2015-2020	8	No	3.94	-4.27	-4.27
6	2016-2022	13	No	8.05	0.93	2.41
7	2014-2018	12	No	75.15	5.48	5.48
8	2017-2021	7	No	N/A	9.43	3.70
9	2009-2017	7	No	N/A	47.50	41.09

5.1.2 Time Performance

The project life cycle from TG0 to TG4 and termination of the project was on average 6 years and 6 months with a range from 4 years to 9 years. Delays on total project lifetime were on average 413 days, with a range from only a month's delay to several years. The time from the investment decision and beginning of the execution until the first test for commissioning (TG3) was delayed for all projects between 23 days up to 413 days, with an average of 140 days. However, 4 out of 9 projects reported that production could start according to the original time schedule despite the delays.

In table 8, each project's lifetime duration and overall delays are presented. The right column with colouring shows whether the project could start with the intended operation despite any project delays (green) or if the delays also delayed operations (orange).

Table 8: Time performance of the selected projects

Project No	Total project duration [days]	Total delay TG0 to TG4 [percent]	Delayed start of commissioning
1	3282	19.59	(orange)
2	3471	16.71	(orange)
3	2692	3.38	(green)
4	2131	10.00	(green)
5	1884	6.16	(orange)
6	2199	33.20	(green)
7	1437	6.96	(orange)
8	1550	1.55	(green)
9	2784	45.87	(orange)

A majority of projects have prioritised time over costs, which in some cases mean that costs have been allowed to increase in order to avoid delays. In some projects, time has been critical since delays could impact the overall business and in other projects time is prioritised so that benefits could be retrieved as soon as possible. Because the company is influenced by seasonal aspects, a delay could heavily impact profitability. Daily operations are critical to an energy company because of two reasons. First, their operations are providing important services to society such as heat and electricity, and secondly, they rely on their daily operations to ensure revenue and thus profitability.

5.1.3 Quality Performance

The quality performance of the projects is difficult to easily present and comprehend because quality is a more complex and often more subjective aspect than both cost and time. However, the aspect of quality was discussed with all project managers during the interviews and their answers are summarized in table 9 below.

Table 9: Illustrative quotes of quality performance of the selected projects

Project No	Project Manager quote
1	“It has worked great, a really high-performing facility”
2	“Good quality today after adjustments”
3	“Good, recently had a stop for a week, but fantastic performance compared to the history of other facilities”
4	“A success, thanks to the team! Clear goal picture early on … all contractors, suppliers and consultants did the little extra”
5	“Precisely able to show what we required, on the margin for some loads. And a tendency to have a problem with ash”
6	“No quality deficiencies yet”
7	“Sufficient quality, but not completely satisfied with some technical choices today”
8	“The quality exceeds the expectations as the pump station is running at overcapacity right now”
9	“The company was not pleased then and there”

The majority of projects have, as seen in table 9, reached the targets and some have even exceeded the expectations regarding quality and overall performance. Some have been adjusted after the project has been finished in order to either reach the set targets or enhance the performance further, examples are projects #1 and #2. For all projects, quality is a measure that should also stand over time, as all project end-products are planned to be used for many years to come. Another aspect is that quality deficiencies might not even be detectable yet, this is especially the case for project #6.

As mentioned above, the projects have often prioritised the aspect of time and this could also be a reason why adjustments may be done after the project is finished, it might be advantageous to start commissioning if possible and ensure or enhance the quality later.

5.2 Explanations for Project Performance

In order to understand why projects have been subject to both good and more commonly, poor performance regarding cost, time and quality, explaining factors have been identified. Figure 7 shows for each project which factor has had either a positive (green) or negative (red) impact on performance. Bold lines represent a strong impact of the factor on project performance. Influence is seen as strong if they have been mentioned by the project manager as highly influential and are clearly described in the project-specific documents. The colour of each project indicates the overall project performance, with the majority of the weight on cost performance.

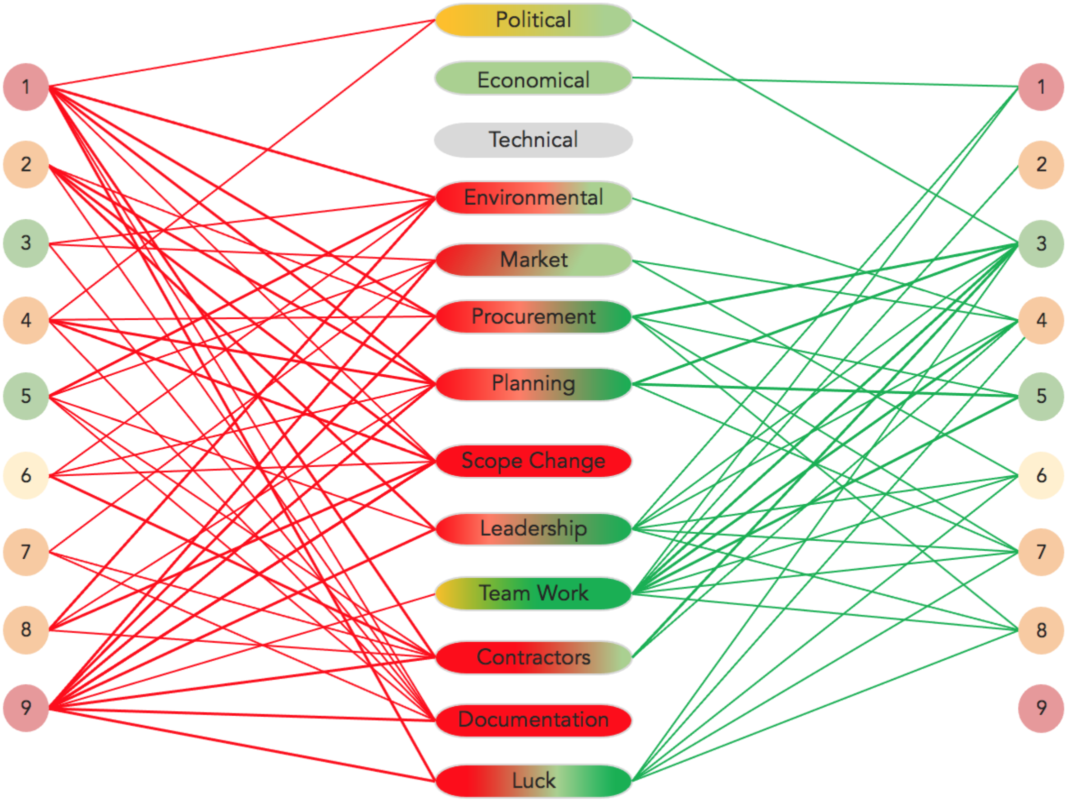

Figure 7: Project performance and its explaining factors

Across the majority of the cases, *procurement, planning, contractors, teamwork* and *documentation* were found to have a large impact on project performance. Other explanations that have had a large impact on some but not all projects are: *political, environmental context, scope change, leadership, documentation* and *luck*. The explanations that have impacted project performance have been further analysed below. Of the remaining factors listed in the figure, *market* is included in the above-mentioned factors as there is no clear boundary between it and procurement. The other not mentioned factors are excluded based on their low impact on project performance in these nine cases.

Planning and Procurement

Conducting rigorous planning and procurement are critical for project success in this context where all work is outsourced. When key elements are missed by insufficient knowledge or time it causes weak contracts, opening up for cost and time increases during the project implementation. This was the case for project #2 where incomplete contracts caused major cost overruns. Technical requirements and designs were not finished at the time of procurement for project #2 and the internal purchasing division became involved too late in the process. The same applied to project #9, where the procurement and detailed construction of project #9 were frozen until after the investment decision. As a consequence, there were not any technical solutions done when quotes from contractors were requested. The winning contractors were not qualified enough but fell through due to an inadequate evaluation and vague requirements. Choosing correct boundaries between different contracts is key to ensure strong quotes but also to manage risk most efficiently. Insufficient planning is also a major driver for time increase as time schedules might be unrealistic or incomplete at the beginning of project execution, as seen in project #8.

During the first phase interviews, procurement was the most commonly found theme mentioned as problematic. Besides having time and competence, it's important to attract many contractors to create a competitive price environment for buyers. By having a clear scope definition, design and requirements it is easier to eliminate less qualified contractors early in the process to ensure good quality of the work. A clear example of this is project #3 where the feasibility study was conducted over several years and was very comprehensive, opening up for creative and smart solutions and decreasing project risks. The feasibility study created well-defined contracts and to quote the project manager: "*the methods, structure and tools used during the procurement were really good"*.

Leadership and Teams

One very important skill are to have knowledge both within engineering and modelling but also to understand the reality and lead contractors. If strong leadership is available on site to motivate and lead the contracted workers it can turn the project around. When there is a lack of leadership, problems arise more often which causes cost and especially time increases. There is no guarantee that internal leadership within contracting companies is sufficient and aligned with the project goal. A low presence of leaders on-site also complicates communication between different parties, this is especially mentioned for project #9 and project #2 as something that impacted the project performance negatively. On the opposite, project #3 decided to have a high attendance at site to manage contractors, which was very helpful as some contractors had trouble managing their own sub-contractors.

Team building, both internally within the project group and externally towards contractors is an important success factor. Several projects had designated kick-offs to ensure unity among all participants which enhanced the final project outcome. Many contractors are only responsible for a specific part of the project, and establishing a common sense of the project outcome can increase cohesion, engagement, motivation and help establish good communication. For project #4, the project team describes the project as *"a success, mainly because of the group"*. There was a team-building activity at the beginning of the project which contributed positively in creating a high level of collaboration and communication within the project. In addition, the project manager for project #4 explains that there was "*full disclosure between all parties*" which led to fewer disputes during project implementation.

Contractors

Another main contributing factor to why projects have a poor performance is the contractors. It is essential to ensure that contractors have the right competence and engagement to ensure that projects are delivered on time and within budget. Projects that to a large extent have used contractors with already established framework agreements or good knowledge about the industry have performed better. Framework agreements are specifically mentioned as favourable in projects #6, and #8, where these contractors performed really well during project execution. Besides the ability to attract good contractors, there is always a risk of faulty deliveries for process equipment which impact both cost and time negatively. An example of this is project #9 where suppliers were unable to deliver critical parts on time and to the required quality which in the end caused major cost and time overruns.

When project execution begins at the site, the project manager is no longer in control of time. Instead, contractors are responsible to ensure that the agreed time schedule is maintained. Lacking control of the time schedule impacts projects negatively if delays occur. Both contractors and subcontractors are generally lingering to provide an updated forecast of the time schedule. Difficulties regarding contractors keeping up with the time schedule are mentioned in project #6, this was mainly due to a dispute about the division of stages, which also relates to unclear requirements in contracts.

As the actual work performed during the project implementation is outsourced, it is common to move a lot of risks to the contractor. In turn, this leads to higher prices on quotes as contractors need to hedge for risks. In addition, vague descriptions of technical requirements and scope open up for additional work and alterations from the contractors' side. To dispute, the cost of additional work demands high competence and time from the buyer. While these risks can be hedged to some extent by contracting penalties, it is also a time consuming, expensive and difficult legal process to proceed with. One way to move beyond these difficulties was performed in project #3 where any risk and ambiguity were moved from large contracts to keep them *"clear of any uncertainties"*. Instead, smaller contracts with local contractors were used for risky ventures as the buyer (case company) then has more power to control and impact the outcome if anything goes wrong.

Political

Whether political factors such as optimism bias and strategic misrepresentation are present in the projects is hard to evaluate. The interviews have shown that project managers believe that estimations of cost are as close to reality as possible. One argument to why optimism bias and strategic misrepresentation have not occurred is that *"project managers put pride in delivering projects close to the initial budget estimated at investment decisions"* mentioned by project manager #3. If the initial budget was low due to too optimistic estimation or based on strategic misrepresentation, project managers would not be able to meet this budget in the end, putting them in a poor position. Moreover, the initial estimated budget set at an earlier stage (TG1) is usually prepared by another team than the later assigned project manager. The project manager then revised the budget before the official investment decision to make it more accurate with new estimations and sharp quotes. Again, project managers said that they do not wish to differ much from the first estimate, which lowers the chances of them creating political factors.

From the nine cases, several manifest that specific parts of the project budget have been estimated conservatively, usually due to insufficient time to conduct a thorough procurement. An example of this was in project #8 where some parts were overestimated in the budget which helped to cover several other cost increases and thus kept the project close to initial cost objectives. A conservative estimation which reduces overall poor cost performance is the opposite of any optimism bias as it rather indicates pessimist bias.

However, the decision-makers are mentioned to have a different view on risk and cost compared to the project managers. They show a culture that believes that projects are expensive, and are unwilling to accept high risks. In some projects, project managers feel the pressure to even lower budgets or reduce risk in order to meet acceptance by the investment board, which was the case in project #1. Such risk and cost averse culture can lead to cost escalation.

Context

The specific environmental context of conducting large-scale infrastructure projects within a large city was mentioned as a negatively impacting factor already during the first phase interviews. The specific contextual features of **Stockholm** City increase the complexity of just in time procedures and logistics. It is also a limited space around construction sites and rarely any greenfields to build upon. Instead, old facilities are often totally demolished and new infrastructure is built within old shells or at the same designated places. For the cases with specifically difficult circumstances, this has had a major impact. One example is project #5 where the site was very limited in space which obstructed the contractors. The environmental context caused major time delays during the test of the boiler as there was limited space to perform work and the limited space also impacted the operation of the boiler. The small building which now houses a too large boiler has also led to increased yearly maintenance cost as the emissions from the boiler are precisely within the accepted range, causing a lot of soot.

In addition to the difficult environmental context, the technical context of the projects also impacts project performance. New unique technical solutions are more difficult to plan as there are few references from past experiences. Project #1 is described by the manager as *"unique, grotesquely big* *and difficult"* and project #9 mentions the novelty of the projects as a major driving factor for poor cost and time performance, however, project #4 which also was a new technical solution managed to perform well despite this.

Scope change

It was found that scope changes can explain cost escalations to some extent as they have occurred in several projects. The two primary reasons for large scope increases are either poor pre-engineering, missing essential parts or new unforeseen business opportunities, the last mentioned is the reason for the scope change in project #4. Large scope changes lead to revised budgets which in turn minimise the actual effect of cost increases. Project #2 experienced scope changes for two main reasons. Firstly, there was a change of consultants contracted to deliver engineering, procurement, construction and management (EPCM) services between TG 1 and TG 2. About 6 months were lost during the transition period between the consultants which in turn led to an incomplete design before the investment decision in TG 2. Secondly, there was no possibility to delay the investment decision as the multiple stakeholders involved needed the project to meet time objectives despite the incomplete design, hence causing a large scope change later.

Documentation

Project documentation is mentioned to have a negative impact on seven of the projects. The process of documentation essentially impacts the time performance negatively as the process often is time-consuming. Even if the documentation internally at Stockholm Exergi is for some projects described as an issue it is also dependent on documentation from contractors, a process which should be established in contracts in order to cause as little disturbance as possible. The documentation process is also the main explanation for why projects are delayed between TG 3 and TG 4. Projects are not closed predominantly because the documentation is not in order. For project #9, the largest issue was the documentation. The documentation department was not involved at the start, the processes and requirements were not developed and what should be documented went from mouth to mouth. Documentation was at the beginning done by the company themselves but then transferred to an external party which caused some delays. Changing requirements led to additional time delays due to incorrect information and difficulties with compilation in the end.

Luck

Sheer luck, either good or bad, can have a large impact on project performance. Of these selected nine projects, at least half of them explicitly mentioned different types of luck impacting the outcome.
Some projects, such as project #1, project #6 and project #9 mentioned that cost increases would have probably been much higher if contractors had been aware of all alterations and additional work that

they performed. The projects were lucky that contracting companies were unaware of all the additional costs they could have charged for. Another type of luck impacting project #8 was external stakeholders cancelling their business due to bad weather. This enabled the project to gain four weeks of additional time to keep performing civil and construction work.

Some projects were conducted during the Covid-19 pandemic in Europe. Foreign contractors usually work two weeks on-site and then go home for a week which became impossible due to the global situation. In addition, at the beginning of the pandemic, Sweden had rather “weak” precautions compared with the rest of Europe, making contracting workers feel unsafe in Sweden. As countries closed down, the workers' urge to go home became an additional factor. Both project #3 and project #4 were conducted during this time period and were initially afraid of the negative consequences if contractors were to leave. However, Stockholm Exergi had established contracts with penalties towards the contracting companies if there were any delays. The economic impact of the pandemic was therefore only affecting the contracting companies and their subcontractors. Luckily, contractors managed to motivate their workers to stay in Sweden and complete their work before going home.

An example of bad luck occurred in two projects, project #1 and project #9 where the contractors chosen turned out to be dishonest and lying regarding costs and deliveries which caused escalating costs and time delays as new contractors had to be assigned to the project.

6 Discussion

The following discussion below consists of two parts. First, the results from the thesis are discussed in relation to literature and possible future research. Secondly, implications for practice are highlighted.

6.1 Implications for Literature

6.1.1 Similarities and Differences to Other Large-Scale Infrastructure

In this thesis, the focus has been on energy infrastructure, in particular, infrastructure within the combined heat and power sector. The majority of literature regarding large-scale project performance has so far mostly focused on transport infrastructure (e.g., Flyvbjerg, Skamris and Buhl, 2003; Odeck, 2004; Lundberg, 2011; Love et al., 2016). It is important to acknowledge similarities and differences when comparing and generalising different results.

One difference is situated around the size of the projects, measured as money invested, and the number of stakeholders behind. Other infrastructure projects are usually financed with taxpayers' money and to some extent bigger in terms of cost. Some studies define megaprojects in the range of 500 million - 1 billion USD (Love et al., 2021; Denicol et al., 2020; Flyvbjerg et al., 2012) compared to the smaller projects in this thesis which have a range of 5 million - 20 million USD. Electricity and heat-generating infrastructure are usually operated as incorporated companies, partly or wholly owned by a municipality. Similar to transport infrastructure, energy infrastructure investments provide vital services to the community, but are supposed to be financed by revenues from daily operations and not public means.

Looking at project characteristics, there are major similarities between transport and energy infrastructure. The projects are characterised by high complexity, with many contractors and activities ongoing simultaneously and often difficult site conditions (Islam et al., 2019). However, while other infrastructure might be more influenced by political and socio-economical instabilities due to public funding (Cantarelli, Molin, Flyvbjerg, 2010), it might be that energy infrastructure is more influenced by problems with technical solutions and deliveries of components to build the main processes. Cost deviations during the implementation phase have been shown repeatedly in research is attributed to changes in order, bad and unforeseen weather conditions, unforeseen ground conditions and labour shortages (Love et al., 2021) which is similar to these nine cases. For the pre-construction phase, Love et al. (2021) argue that the scope change and macro-economic factors are the main driver of costs during the long planning and procurement process. In this thesis, scope change is one common reason, but macro-economic factors are not. In addition, scope changes are not only driven by stakeholder needs and demands for transport infrastructure (Love et al., 2021), rather it have been the consequence of poor planning and design.

6.1.2 The Iron Triangle - Implications on Time, Cost and Quality

The cost increase of 12.9 percent from estimated cost at investment decision compared to actual costs is similar to what several other authors have found when investigating transport infrastructure. To give examples, Odeck (2004) found an average cost increase of 7.9 percent in Norwegian road infrastructure, Catalão, Cruz and Sarmento (2019) found a cost increase of 17.8 percent in Portugal and Lundberg et al. (2011) found 11.1 percent cost increase on average for Swedish transport infrastructure. Other researchers, such as Flyvbjerg and Skamris (1997) looking at Danish transport infrastructure and Flyvbjerg et al (2003) looking at transport infrastructure with geographical variation have found much larger cost increases, which this thesis cannot match. In the sample on energy infrastructure derived by Sovacool et al (2014) thermal power plant projects had a cost increase of 13 percent, which is very similar to this study. However, the entire sample on energy infrastructure gave an average of 66 percent cost increase, significantly higher than the results from this study.

Looking at the range of cost deviations in previous studies, the range found in this study is much more narrow than in earlier studies. To compare, Flyvbjerg (2003) found cost increases of 50-100 percent to be common and Odeck (2004) had a range of project cost deviations from -59 percent to 183 percent. Of course, the sample of projects in this study is much smaller and too small to draw any significant conclusions regarding range. Out of the nine projects, only two experienced cost decreases, both very small which is similar to what Flyvbjerg et al. concluded in 2003 that "*cost underestimations are much more common (..) and larger than cost overestimations"*. Similar, looking at energy infrastructure, Sovacool et al. (2014) found in their sample that three out of four projects experienced cost increases.

An important note is that all these projects have been conducted in Sweden, specifically in Stockholm. Flyvbjerg et al (2003) determined that *"geography matters for cost escalations"* and while these findings and their actual significance have been questioned by other authors, this study shows similarities with the 167 Swedish infrastructure projects investigated by Lundberg et al (2011). It could be that Sweden experiences smaller cost increases than some other countries.

Similar to the findings by Sovacool et al (2014) time performance is in a dependent relationship with cost performance. Sovacool et al. found that 64 percent of all projects had time increases, whereas only 10 percent of thermal power plants. In this study, all projects experienced delays compared to the original time schedule. However, almost half of the project could still be put into daily operations as planned while some final works were still ongoing. As seasonal variations in demand are important for heating companies, this could be an explanation for why many projects focus on keeping the original time schedule and being commissioned on time, despite the added costs that come with it.

The impact of different points of reference is also important to discuss when comparing the magnitude of cost performance. Love et al (2015) mean that using initial budgets leads to overinflated values, as more formal processes of planning develop better estimations later on. This trend is observed here where different points of reference show different magnitudes of cost escalations. However, informal decisions can be based on these early estimations, and they should not be neglected as they impact the perception of project performance. Moreover, in this specific company context, budgets are revised several times with the project steering committee during the project implementation. If projects are only measured against this latest approved budget, it will have a deceiving effect on how projects really are performing. This is especially important as profitability and benefits usually are estimated and compared to the budget at the formal investment decision before any changes.

6.1.3 The Current Debate on Explanations for Project Performance

In this section, factors that contribute to explaining why large-scale projects experience poor project performance is discussed in relation to earlier findings from the literature. To summarise, the debate is currently situated around two approaches for explaining deviations in cost performance of other large-scale infrastructure. The project management perspective, suggesting underlying errors and decisions by management drive deviations. Contrasting, is the behavioural perspective which suggests that the Planning Fallacy provides the best explanation. This thesis found evidence that the project management perspective serves a better explanatory framework for why projects fail than the behavioural perspective. Moreover, within the project management view, there are several factors that impact project performance to a different extent, meaning that the complexity of that perspective makes it hard to find one single factor to blame in order to find the best solution to curb it. This research continues to put emphasis on the complexity and dynamics of design, planning and procurement process and its impact on project performance similar to Love et al. (2015). All factors found in the literature are discussed below in relation to the result of this study.

Behavioural Explanations

Political and psychological explanations relate to the behaviour of humans. The Planning Fallacy, which includes both optimism bias and strategic misrepresentation is advocated by some authors to be the best explanation for why projects experience cost overruns (Cantarelli et al., 2012; Flyvbjerg et al., 2018). In this research, evidence of political behaviour has not been found to any large extent. Instead of finding evidence that costs are almost always underestimated, it was found that costs were sometimes rather conservative. In addition, as project managers wish to perform well in regards to cost objectives, there is an incentive to not underestimate costs in the beginning as it then becomes impossible to keep this budget later on. It must be said, however, that human bias is difficult to prove using common research methods such as interviews. Interviewees can be either afraid of speaking the truth, or not even aware of their bias which both impact the result.

One reason why there has not been much evidence of the Planning Fallacy could be that there are teams rather than individuals that prepare any cost and time estimations, minimising the influence of one individual's bias (Love et al., 2021). Another reason might be that the characteristics of energy infrastructure differ from other large-scale infrastructure. For instance, each project is financed by internal means, while other infrastructure is often financed by public means. It is therefore not the same amount of competition between different projects in this context. Projects are usually initiated when there is a new business opportunity or a critical refurbishment or replacement of an old asset. Competition mostly arises within a project among different technical solutions, not between replacement projects or new business opportunities. It is still the same project team that is conducting the project independent of the technical solution decided.

Project Management Explanations

As this study only analysed a small sample, it is not easy to draw any significant conclusion on whether project size or type had any impact on project performance. It can be said that for these projects, size did not matter, as both the smallest and largest project had the highest percentage cost increase. Odeck (2004) and Lundberg et al. (2011) argue that smaller projects experience higher cost overruns, as opposed to Flyvbjerg et al (2004) and Singh (2009) who showed that a larger project is subjected to larger increases. Based on the results of this study, it is still open to assessing the impact of project size on cost performance. However, if measured in absolute terms, the two most complex projects, which also were the largest by size, experienced the main cost increase. Love et al. (2015) suggested that it is complexity, rather than size that impacts cost overruns which is similar to the results in this study. A major driver of complexity seen in these nine projects was uniqueness. Some projects were “one of a kind” projects which contributed to very high complexity as there were many levels of unknowns. Moreover, variation in cost increases across project types can be explained by differences in the amount of utility work and site conditions which usually are hard to predict (Love et al., 2015).

Across all projects, no economical factors such as price increases or macroeconomic factors were said to have had any major impact on the project’s performance. However, what was mentioned by many project leaders is that the current state of the economy is harder to predict than it has been up until recently. With the urgency of climate change, a pandemic and a war in Europe, prices of products, basic materials and labour are harder to predict than ever. Despite not being a critical factor explaining project performance in this study, it should not be seen as any evidence that it cannot occur in other or future settings. Similar to Xia et al . (2017), it was found that the long bidding process increases the risks of price changes on materials and equipment. Likewise, if few suppliers were available, the low market competition also contributed to increased prices. This is similar to what Pham et al (2020) found on cost increases in transmission line projects, as many components and processes usually need very specialised competence.

As for technical explanations, they have been rejected as contributing factors by several authors in earlier research (Cantarelli, Flyvbjerg and Molin, 2010; Grubler, 2010). In this study, insufficient forecasting techniques were neither mentioned by project managers nor documents as a constraint to good project performance. Therefore, it is agreed with the literature that technical explanations can be ruled out as an explanation. Similar to what Grubler (2010) found when looking into the French nuclear Pressurised Water Reactor program, new environmental constraints, safety requirements and higher availability of technical solutions inevitably increase costs at the bottom line.

The pre-engineering and procurement process was a major contributor to why projects performed differently. Understanding what can be done in-house and how to allocate remaining risks on contractors demands knowledge (Denicol et al., 2020). When the scope changes either through insufficient design and pre-engineering or based on changed business cases it has a large impact on established contracts. Similar to Chang (2002) it was found that insufficient design, requirements and scope all contribute to an inadequate basis for procurement, inevitably leading to time and cost increases.

To minimise the effects of poor procurement Love et al. (2015) suggest a shared risk-reward model between project owner and contractor. Similar to this, when projects had large contracts with contractors already familiar with the case company, the outcome was better. Contractors with already established framework agreements or long experience working together had a stronger incentive to perform according to objectives contracted as that opened up for future business opportunities.

When the effects of poor procurement can’t be minimised, fines and penalties can assure progress for the buyer. Of these nine cases, almost all of them put a lot of energy on legal discussions regarding the costs of alterations and additional work that the contractors demanded. In most cases, disputing these extra costs helped to reduce additional extra costs but it demands knowledge and is time-consuming. Some projects had to change contractors mid-way through project execution as not even fines and penalties were enough to ensure reasonable cost and time. In contrast to Szentes and Eriksson (2016), it is therefore argued that fines and penalties *are needed* to ensure that contractors keep their promises.

However, as mentioned by Szentes and Eriksson, it might cause unnecessary conflicts and agreements to unreasonable objectives. Therefore, fines and penalties should be incorporated with this in mind, and only used to minimise risk for dishonest contractors. Fines and penalties should not be seen as a means to move risk from the buyer to the contractor. Similar to this Love et al. (2021) mention the tendency of governments to place too much expectations on contractors while including too much risk at a fixed price in the presence of information asymmetry. Having this strategy only opens up the possibility for cost and time deviations even more.

It should not be forgotten that this research does not include the perspective of the contractors. It, therefore, becomes easy to blame the ones not being able to defend themselves. While the contractors in this particular research are one contributing factor to poor performance, they also perform well. Several projects have had good relationships and well-defined contracts to support them. Dealing with contractors and their subcontractors, and not possessing the competence in-house is a common feature when conducting large-scale infrastructure projects. Moreover, energy infrastructure might be even more prone to have issues with contractors as the projects usually consist of many different elements such as civil-, construction-, electrical-, automation-, processes-work etc which all need different contractors. Transport and other infrastructure might have fewer but larger contracts, as they don't have as many technical components.

Good and sufficient leadership in combination with a competent and well-established team were a major factor influencing performance in this study. Similar to Catalão, Cruz and Sarmento (2019) this study also highlights that good relationships between project parties are essential. In some of the projects, team-building has been a higher priority and is seen as a success factor in the end. A mutual goal and feeling of togetherness have impacted and improved the results. In addition, this study found that weak management on-site often causes problems which also relates to Catalão, Cruz and Sarmento (2019) who highlight that knowing when to act on the first signs of poor performance is key to a well-performing project. If management on site is weak, acting on these first signs becomes difficult because managers might not be present to detect these signs. In relation to Pham et al. (2020) who argue that incompetence regarding management could impact project performance, this study found that skills within engineering and modelling are important but leadership skills might be equally critical. This study found that relying on external leadership within contracting parties is not enough, especially if clear project targets are not set, the responsibility, therefore, falls on the buying company to ensure sufficient leadership.

The complexity of the projects studied is the aspect which has influenced the risk and uncertainty of projects most, which is also one of the most predominant factors mentioned in the literature (Denicol, Davies and Krystallis, 2020). Further on, the case company has methods in place to assess risks during planning which is often to the project's advantage according to Siematycki (2009), who also argues that expertise in risk management and structured, state-of-the-art methods are favourable. But structured methods might not be sufficient since risks are often disorderly. When assessing risks with a probability of it and a cost of their impact to determine the total budgeted risk, the reality is overlocked. The reality of risks is more binary. If realised, they are realised completely, and not only to a percentage of the cost which was mentioned by various project managers during this study. To conclude, risk management is a complex matter in itself and as mentioned by Siematycki (2009) often constrained by time and cost.

The aspect of luck is seen as important in this study, some projects have experienced that pure luck has been a success factor. They have not planned for something to happen the way it did but lucky circumstances influenced the outcome in a good way. Other projects have instead experienced sheer bad luck which influenced their performance poorly, with problems arising with cost, time and quality. However, luck is not a factor mentioned by literature on large-scale project performance, maybe because the aspect of luck is almost impossible to influence and often arises unexpectedly. Though, luck often presents itself to the prepared mind and project managers should therefore be prepared to take advantage of lucky circumstances and handle the unlucky ones.

The environmental context has been highlighted in this study, mostly through the geographical settings of some projects. This has in some cases been a cause of arising problems during execution and in relation to literature (Odeck, 2004; Flyvbjerg 2003; Lundberg et al, 2011) the geographics could be an explanation to cost overruns. However, as Ika, Love and Pinto (2020) argue, a universal solution to these environmental issues neglects the context, which, for the aspect of this study, is also important to mention. Since all 9 projects are unique the explaining factors found should not be considered without their context but rather be put into context.

6.1.4 Future Research

The area of large-scale infrastructure project performance and the current debate in the literature is an evolving subject. However, the current literature is mostly focused on transport infrastructure and could evolve and expand to include other types of infrastructure to a larger extent. The aim of this study was to explore energy infrastructure, in particular, an area which has been studied previously but not to a large extent. This study examined one company in particular but for future research, a comparison to other energy companies, both within and outside Sweden, could possibly provide additional insights, especially since the Stockholm context is mentioned as a constraint and an influential factor in this study.

For future research, the energy sector in general should be a prioritised sector of study. Mainly because the sustainable transitions, including decarbonization of industrial sectors, require large investments in energy infrastructure across the globe in the years to come. An understanding and best practicees on project performance in this setting would therefore serve a larger purpose, beyond individual companies' profitability and return on investments.

6.2 Implications for Practice

6.2.1 How to Measure Project Performance

The nine projects that have been the foundation for this study are all measured against time, cost and quality. Quality is measured in terms of the functionality or efficiency of the constructed parts. In all projects, time has been promoted as the most important variable, which is partly different from Ghyoot and Kerzner (1983) implicating that time and cost come secondary to quality. While the quality is important, it is easily forgotten when the project has been finalised. Energy infrastructure of this kind is usually meant to last over several decades and will be needing continuous maintenance of varying degrees. The cost of maintenance is not always seen as project success or failure since it is no longer a project.

Moreover, Pollack, Helm and Adler (2018) argue that while time, cost and quality are important for project success, they should be seen as short term goals since they do not include long term benefits. Atkinson (1999) takes the critique of the Iron Triangle one step further as he stresses the importance to realise that time- and cost objectives are based upon estimations or best guesses which is why too much weight should not be put on the Iron Triangle. In light of this, this thesis can agree with the critique of the iron triangle. For example, project #1 is by far the project that escalated cost the most, measured in absolute terms, but it is also seen as a success today as it is generating substantial value for daily operations. Based on this, the Iron Triangle might not be sufficient to measure real project success. According to Sue et al., (2019) it is important to develop an understanding of emerging risks and challenges that impacts project success and what competencies are required to overcome them to ensure project success in the future.

DeCotiis and Dyer (1977) identified five dimensions to measure project success: (1) Business Performance of the end product; (2) Technical performance of the end product; (3) Efficiency of the project operations; (4) Personal growth of project team; (5) Technical innovativeness. Including one or more measures similar to these might generate a more accurate and holistic picture of project performance to the organisation. In addition, as the company is playing an important role in decarbonising the heating sector and the city of Stockholm, the level of the environmental impact of each project could also be included as a measure of success.

6.2.2 Planning and Procurement

From the discussion above, implications can also be made to practice. It cannot be said too much that putting enough time and knowledge into the planning and procurement processes is important to ensure desired project performance. Good planning is characterised by on-site planning and not just 3D modelling. Moreover doing a feasibility study with contractors will help to create good contracts and ensure capable contractors. Choosing contractors with established framework agreements is favourable as they have more incentives to perform a good job. When the future seems to be less predictable, having well-established relationships with contractors can help to ensure project performance.

6.2.3 Knowledge Transfer Between Projects

Despite that many of the projects have a unique character, they do have enough similarities so that knowledge from one project could be transferred successfully to another project. Seizing the opportunity of this knowledge, both understanding and having the competence to apply it in another context have a positive impact on project performance. An example of this is project #1 which produced extensive material regarding what to do and not to do in future projects. The project manager of project #8 mentions that this material was very useful in that project, despite being two very different technical solutions and contexts. DeCotiis and Dyer (1977) (referred to by Kerzner and Ghyoot, 1983) observed that while project managers might know that projects are successful, they do not know what leads up to that success and thus they do not learn from the experience.

Overall, all project managers agree there is a lack of knowledge transfer between projects. One reason is a lack of engagement and time. Planning one project is partly stressful and it is easy to forget about other projects and their knowledge as you only focus on moving your own project forward. Another reason is that information regarding project experience, such as “lessons learned” reports are difficult to come across. Especially for consultants not granted access to internal archival systems. Even with access, internal documents are difficult to find and sometimes also difficult to interpret. Moreover, while documents are hard to access, raw data on project cost and time performance is unreliable. When data is unreliable and projects sometimes have separated finalisation projects it becomes hard to measure project performance on an aggregated company level. The same applies to which budget the project is compared to. If the organisation constantly keeps allowing changes in the budget and then measures project performance against this changed number the performance will naturally look good. Sometimes it can be justified to do this comparison, for example, if there has been an additional scope which will allow for a larger benefit of the project. However, sometimes budgets are changed because of poor planning, poor procurement or another factor that could have been avoided with better practices. Neglecting this by comparing to changed budgets only may lead to lower learning of mistakes and ultimately more expensive projects and lower profitability.

Today, the PMO offers some common presentations of lessons learned from recently conducted projects and encourages project managers to discuss experiences. This method does not seem sufficient to ensure that knowledge is transferred. Documents should be easier to access and more clearly structured, to ensure a smooth process. A recent project developed a structured plan on how to transfer knowledge back to the organisation which helps to guide the project managers and ensure quality work. Also, a more quantitative analysis of a larger set of projects could be conducted if all data was validated before. This type of analysis could give insights into whether specific project types or sizes impact project performance.

6.2.4 Leadership, Teams and Human Capital

Conducting large-scale infrastructure investment as a customer puts a lot of pressure on leadership capabilities and teambuilding. Simple measurements, such as kick-offs with external contractors help to create a better sense of the entire project objective to ensure unity. Having motivated workers that are more focused on creating a unit, such as a power plant, rather than just a small part of it increases collaboration and engagement. In addition, weak leadership, both from the internal organisation but also between contracted companies and their subcontractors is important to ensure transparency regarding time schedule and additional costs. Being a good leader during these situations also includes being a leader on-site, despite it being time-consuming. When several parties are working simultaneously, communication and unity are key.

To ensure future project performance, high competence within all different areas of engineering is important. Without a high performing human capital, it is impossible to construct well-defined scope, clear requirements and designs to ensure a good foundation during procurement. Performing engineering and design partly on-site can enhance knowledge, lower costs and facilitate contractors on quotes. Having contractors with knowledge of the company, or the specific industry is favourable to minimise risks and poor cost and time management.

7 Conclusion

The purpose of this thesis was to explore the performance of large-scale energy infrastructure projects and answer the research question *"What factors influence the performance of large-scale energy infrastructure projects?"*. The results showed that insufficient planning and procurement, weak leadership and ill-performing contractors explain to a large extent why projects have had poor performance. On the other hand, having a strong team together with clear and well-distributed objectives among all parties can help projects perform according to plan. Furthermore, projects are complex undertakings that rarely depend on one single factor in order to succeed or fail. It was also found that a complex project environment, scope change, insufficient documentation processes and luck are large contributing factors that help to explain project performance.

Looking at these results, there are both similarities and differences to current literature. The main explanations for why projects experience varying performance have some similarities with the internal project management perspective (Love et al., 2015; Love et al., 2021). However, no single silver bullet is likely to be found within this perspective as projects are unique in all dimensions. Contrary to what the other side of the debate holds as the main explanatory factor, the Planning Fallacy (Cantarelli et al., 2012, Flyvbjerg 2018), this has not been found to have a large impact on the project performance of these nine cases. Whether it is because of the specific context of these energy infrastructure projects, the specific case company, the difficulty in assessing human bias or another reason is left open for questioning. Instead of finding a single silver bullet, these nine cases show that many factors interact to explain project performance. Having a balanced approach when understanding the underlying reasons for project performance opens up project managers' possibilities to enhance their knowledge and strategies on how to avoid them.

One important explanatory factor for project performance which was mostly overlooked in earlier literature on large-scale energy infrastructure is the importance of good contractors. It is hard to say if contractors have been overlooked by earlier literature as it is closely connected with the planning and procurement, as well as the impact of luck. Infrastructure projects are in general owned by companies acting as a client toward all external capabilities needed to actually realise the project. As all competence and equipment are outsourced to contractors and their subcontractors, they naturally have a large impact on project performance.

Furthermore, it is important to remember that while many projects might not perform as initially estimated, some also do. Therefore, analysing the varying performance helps to enhance knowledge on *what went right,* which should be equally important as to *what went wrong.* Investors, project teams and companies must remember that decisions are based on estimates, not 100 percent certainty.

Simultaneously, the world is becoming more complex and uncertain. As large-scale infrastructure projects are risky ventures, estimations of costs and probability of known and unknown risks create an illusion of certainty. The desire to “understand, reduce and respond” (Maylor and Turner, 2017, p.1076) is common within project management practice which promotes reducing uncertainty and risk, rather than embracing it and equipping project managers with the tools needed to make the right decisions.

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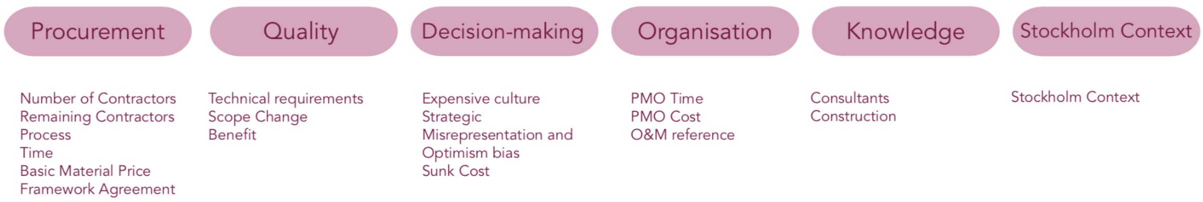
9 Appendix

9.1 First Phase Interviews

The findings from the 18 interviews conducted were 21 factors which influence the projects and their performance. The identified factors impacting project performance were grouped when appropriate into the following overarching themes; Quality, Procurement, Organisation, Decision-making, Knowledge and Stockholm Context. Themes with underlying factors are summarised in the figure below.



To further explain the meaning of each factor, the table above is a summary of the interviewees' explanations. Each factor was identified by at least one interviewee, numerd in the right column.

Factor	Theme	Explanation	Interviewee
Number of Contractors	Procurement	Number of contractors impact ability to negotiate a competitive price, important to open up for new relationships	1, 2, 10, 11
Remaining Contractors	Procurement	A sufficient number of companies must remain through the process to balance competition and workload	11
Process	Procurement	Project must be packed and bundled into suitable offers to the market to ensure a correct estimation of the budget	11, 14
Time	Procurement	Insufficient time in the procurement process increase poor estimations	10, 11, 14, 18
Basic Material Price	Procurement	The volatility of basic material prices affect cost performance due to long planning stage of projects	11, 8

Framework Agreement	Procurement	Framework agreements do not always match prices and are thus insufficient to estimate budgets	9
Technical requirements	Quality	High technical requirement above industry standard to meet high flexibility objectives and reduce future maintenance. Trade-off between cost now (in project) or future (maintenance). Preferences of high quality drive cost performance, incorporated too late the project process	1, 5, 9, 11, 12, 14, 17, 18
Scope Change	Quality	Contributes to cost increase Scope changes usually result in changes of budget	2, 9, 10
Benefit	Quality	The projects usually perform according to KPIs and have a positive benefit	2, 6
Expensive culture	Decision-makin g	Comprehension that early estimates should sustain, making "everything is expensive" a truth	1, 6, 8
Strategic Misrepresentation and Optimism bias	Decision-makin g	Pressure on PL to minimise cost and risk from IB, creating a optimistic budget proposal	6, 14
Sunk Cost	Decision-makin g	Few projects are turned down between at TG2 compared to TG1, as projects usually are "too far gone"	1, 8
PMO Time	Organisation	Large and administrative PMO, creates a slow process	5, 12, 17
PMO Cost	Organisation	Larger budget item and create projects of line operations	9, 17, 18
O&M reference	Organisation	Low engagement of operations and maintenance reference groups impact performance. Have not enough time	9, 17, 18 17
Consultants	Knowledge	Risk of lower engagement and knowledge transfer	2, 9, 13, 18
Construction	Knowledge	Civil engineering is the hardest part to estimate costs of. A lack of knowledge can explain why construction is hard to estimate	1, 8, 9, 11, 12, 15

Stockholm Context	Stockholm Context	Conducting projects in Stockholm creates difficulties with space, timing, ongoing production and traffic	5, 11, 14

The main conclusion to be drawn from the first round of interviews is that there is a varying comprehension regarding project performance. While some argue that projects do perform well in terms of selected KPIs, quality and benefits, some believe that there are projects who do not meet economical objectives and time objectives. There is a higher rejection rate before TG1 than later on in the project process and projects seem to usually be *"too far gone"* (Interviewee 1) when cost escalates.

Procurement is the most commonly found theme, as it compromises six factors. The procurement stages of the project which occurs before TG2 and the official decision stage is complicated and time demanding. Besides having time and competence, it's important to attract many contractors to create a competitive price environment. Moreover, as the project process for large scale projects is naturally long, the volatile basic material prices have both a direct impact but also indirect through predetermined framework agreement.

Furthermore, **organisation** impacts project performance with several factors. First, the large size of the PMO has created a slow and administrative project process which drives costs. Secondly, low reference group engagement impacts the process and budget negatively.

Decision-making is also mentioned to affect project performance, but only mentioned by a few participants. This theme shows influences of a culture that believes that projects become more expensive than estimated, which inturn has generated misrepresentation by project managers as high costs and risk are not accepted by top management.

While **knowledge** is a rather narrow theme, there is a high frequency of answers that points in the same direction that there might be knowledge gaps within certain areas such as civil works that is hard to estimate based on the interviewees perception.

Lastly, the specific contextual features of **Stockholm** City is mentioned as a factor that impacts project performance. Building complex and large scale infrastructure in a large city, increases complexity of just in time procedures and logistics. It is also a limited space around construction sites and rarely any greenfield to build upon. Instead, old facilities are often totally demolished and new infrastructure is built within old shells or at the same designated places.

9.2 PMO in Detail

Project Steering Committee

The Steering Committee consists of the project owner and other relevant stakeholders and is responsible for controlling the project from start to finish, follow up on project status and objectives, ensure resources and make decisions regarding deviations beyond the mandate of the project manager. It is important that the Steering Committee is small in order to generate a fast decision process (Internal Document 1).

Reference Group

The reference group consists of specialists acting as an advisory to the project team in either technical questions or other important questions. It is appointed based on the project team's prerequisite and demands assigned by the Steering Committee or the project manager (Internal Document 1).

General Technical Requirements

The general technical requirements (GTR) set the desired standard on assets and underlying components. These play a vital role for the operation and maintenance team to enhance quality and flexibility while reducing future costs on maintenance. The technical project manager is responsible to ensure that the project is aligned with the GTR (Internal Document 1).

Procurement

The purchasing process is based on either quotes or framework agreements. Which method, or combination used is based on Total Cost of Ownership, the market, time plan and risks for each project. Procurements are conducted according to the strategy decided upon in the planning-phase of the project (Internal Document 1). Approved contractors are registered for future inquiries. New contractors must be controlled before being approved (Internal Document 1).

9.3 Detailed Project Description

Project 1

Project #1 is the largest project in the portfolio considering the budget size and experienced cost increases and these delays did however not affect the start of commissioning too much. The project manager describes the project as *"unique, grotesquely big and difficult"*. The project was changed almost entirely between tollgate 1 and 2 and which, looking back, was a good decision at the time. The contractors would not have been able to deliver what was initially required. The project team was well-functioning, together they had to solve a lot of upcoming problems which became easier because of an overall good atmosphere within the team. A lot of specialists on process were assigned which the project really needed. The coordination was complicated, mainly due to the project size and its complex nature.

However, it is difficult to find construction expertise, meaning contractors that possess knowledge on how to build CHP plants and are used to work in similar settings. The construction contractors are described as the most difficult to coordinate and it was a challenge to engage them to work together with the other teams on site. The contractor who won the procurement for construction was in hindsight too small to carry such a large project. The procurement of the project was built on collaboration contracts with current accounts, which influenced the costs negatively. The project manager describes the current accounts as risky and something they regret choosing today, a set price would have been more cost efficient. The electricity contractor was also an issue, they realised that their part of the project heavily influenced the schedule and took advantage of this when their subcontractors could not deliver to the initial price, which was set too low according to them. Therefore, another contractor was assigned for these parts to solve the issues. The project was in general mostly driven according to the time schedule, which was too optimistic for some parts, this required provisional solutions at times so that delays would be avoided. The project's final product would have a lot of value for the company and the steering committee took many decisions with time in mind to be able to start commissioning according to plan. This affected the budget negatively in general.

The main external factors influencing the project were the limited amount of space at the site. This also contributed to an increased need for coordination regarding the planning of traffic and space needed for construction equipment. The geographical placement also brought issues since the environment around the site always had to be considered during project implementation. The project was not accepted to include any extra risk or uncertainty in the tollgate 2 budget. The project team experienced that pressure where put on them to instead lower the budget, without having the final delivery in mind. In addition, no pre-investments were allowed before the tollgate 2 decision, which could have possibly saved some costs during project implementation.

Even though the costs exceeded the budget, the quality of the plant is exceptional. Which is mentioned not only by the project manager, but by others in the company as well. The plant's performance and quality is above expectations. After the project finalisation, there have been adjustments done to the plant to increase performance further and in general there is a consensus in the company that they are very satisfied with the investment, even though it became way more expensive

Project 2

Project #2 is the second largest project in the portfolio and perceived large cost and time increase. One major reason for the increase between tollgate 2 and the revised budget (current budget) was a scope change. The scope change occurred for two main reasons. Firstly, there was a change of consultants contracted to deliver engineering, procurement, construction and management (EPCM) services between tollgate 1 and tollgate 2. About 6 months were lost during the transition period between the consultants which in turn led to an incomplete design before the investment decision in toll gate 2. Secondly, there was no possibility to delay the investment decision as the multiple stakeholders involved needed the project to meet time objectives despite the incomplete design, hence causing a large scope change later.

The project team performance was twofold. Firstly, the EPCM consultants were placed in Denmark which caused weak management on site, however they possessed great knowledge regarding technical solutions. The internal PMO was initially weak, had too few resources and a change of leadership. However, during the project implementation there internal PMO had to take lead on site. The team had a strong focus on problem solving, good knowledge and high level of attendance at site in order to manage problems. The stakeholders and project steering committee were always supporting and focused on making fast decisions.

The procurement was divided into several smaller packages, however, the procurement process still had incomplete contracts which caused major cost overruns. There were several reasons for the incomplete procurement but predominantly the reasons were focused around the incomplete scope, substandard engineering and design with no complete technical requirements at the time of procurement. The internal purchasing division was incorporated too late in the process. "*When contracts have not correct quantiles, time schedule or scope definitions it leads to major claims and delays"*.

In addition to the cost increase, the original time schedule was delayed. A small delay occurred at the end of the implementation, again driven by weak management of contractors and inability to freeze design. However, the large delay occurred during the start of the cold commissioning. The major reasons for delay in this stage was due to poor coordination between EPCM consultants and the comissiong team, critical design changes, the discovery of unbought scopes and some faulty design of components. During the last phase of testing the plant, there were only minor delays despite some technical issues and Christmas holidays.

The external context with good infrastructure in the area made it easy to bring in oversized deliveries. There was sufficient space for prefabrication, storage and other preparatory use. However, this project consisted of building a new plant, which was supposed to work in series with an already existing plant. This technical feature was needed in order to reach desired capacity, but it created a complex interface which increased time and cost.

Project 3

Much knowledge, good communication and a engaged project team were characteristics of the project team for project #3. Moreover, the team was *"open-minded and not much hierarchical"* which led to fast decisions. Albeit the strong project team, the resources were partly scarce as members had other tasks outside of the project. The project manager also had the opportunity to create his most desired team, as the project manager was experienced and had worked within the organisation for a long time. Having the opportunity to *"build a team that you believe will succeed"* is favourable to enhance project performance.

Early in the planning process, people with different technical responsibilities were asked to contribute with their knowledge. The pilot-study was conducted over several years and was very comprehensive which decreased projects risks by opening up for creative and smart solutions. The generous pilot-study also also had a positive effect on the procurement process. Some smaller parts of the project were not planned to the same extent due to unclear scope and lack of competence. During the most intensive planning phase, resources were again scarce, inducing stress. After a discussion with contractors, one agreed on conducting a complete feasibility study of the project. Both parties incurred cost due to this, but it was favourable for the contractor to nurture business relationships for future opportunities.The feasibility study led to a well defined contract, lower risks and a more on-point cost estimation.

The procurement process focused on developing clear boundaries between contracts and a balance between risk and responsibility. To summarise "*the methods, structure and tools used during the procurement were really good"*. Risk and any ambiguity was moved from large contracts to keep them "clear". Instead, smaller contracts with local contractors were used for risky ventures as the buyer (case company) then has more power to control and impact the outcome if anything goes wrong. Despite a tight time schedule the inquiries were not delayed. With more resources, more specific and earlier requests for the construction part could have been done. The number of quotes from contractors for this project was just enough, but having a few more would have increased competition. The main reason for the low number of quotes was the complex site of the project.

Since the least qualified contractors were eliminated already in the procurement process, the contractors chosen for the large contracts had a high competence and performed very good work. The project team chose to have a high level of attendance at site which helps managing contractors, ensuring a high efficiency and that rules were obeyed. One contractor had difficulties leading their own sub-contractors, which should be even more clearly required in the contract. A common "kick-off" with contractors and their management would have been preferred to ensure entirety and objectives.

Due to the chosen contracts, the Covid-19 pandemic and following macro economic effects did not impact the project in any major way. Instead, this became a problem for the contractors who both were affected by price increases and labour difficulties. Another contextual factor is the project site. While there was enough room for equipment and transport, replacing a boiler within an existing building is very difficult due to the small space. Risks and following costs related to demolition and restoration within a building were underestimated. Despite the small building, the overall quality and benefits of the boiler ended up above expectations.

Project 4

Project #4 experienced changes to the initial scope after the investment decision in toll gate 2 was made, the reason for these were identified business opportunities from the suggested new additional solution. This scope change required a larger budget which was revised and increased after toll gate 2.

In general, the project had a high functioning project team with good collaboration and communication. This also involved the contractors who together with the project team participated in a team building activity at the start of the project. The project team had overall a good knowledge and high competence which encouraged a high level of trust both within the project team and from the steering commitée. The project managers explained that there was *"full disclosure between all parties"* which contributed to less disputes. The steering commitée were highly engaged in the project and the many stakeholders contributed to make the project more fun and engaging. The management of contractors worked really well and contractors were in general both highly engaged and competent. However, the contractors should have clarified the work ethics more to their subcontractors. The project organisation consisted of few people from the case company itself but the project manager mentions this as favourable since no individual wishes or desires were taken into account during planning. However, multiple people were involved in the decision making on site but no one really wanted to claim responsibility for the decision.

The planning phase was owned by the project team which made a rather bold project plan. This resulted in some parts of the project being inadequately planned during stressful times which affected the time schedule later during implementation. The planning involved quite a lot of 3D modelling which in perspective could have been complemented with more reality checks of the project site. The planning on site by the contractors could have been better and resulted in time delays, particularly regarding the final adjustments. However, since partial inspections were made adjustments could be made more directly which saved time in the final phases.

Multiple parallel procurements were conducted for project #4 which enhanced competition amongst contractors. In general, the turnkey contracts affected the project positively, however some parts which were not turnkey contributed to difficulties regarding division between different areas. The resources to ensure a good procurement were not sufficient and because some parts were not fully projected when the procurement was made the initial budget was set too low for these particular parts.

The contractors did a good job in motivating their workers to stay on site when the covid-19 pandemic struck, this could have had a large negative impact on the project otherwise but was handled really well. The project was commissioned on schedule but the project finalisation was delayed due to optimistic planning of the closing stage. In general the project manager describes the project as *"a success, mainly because of the group"*.

Project 5

The project team conducting project #5 consisted of individuals which were highly engaged with very good cooperation and knowledge. The only thing missing was some *"team building activity, dinner or kick off for all project managers".* There was full transparency on how the project was performing during the entire implementation. Some, however limited, rotation of project members have occurred which temporarily has caused knowledge gaps which were time consuming. The management of contractors was partly weak, which led to mistakes, in turn affecting both budget and time negatively. In addition, Some contractors changed internal management constantly which made cooperation difficult. Moreover, contractors had a hard time to develop new time schedules when delays had occurred. Apart from weak management, time delays were mainly driven by low quality on the contracted deliveries of the boiler and brick and mortar work.

The project management had a plan early in the process, which contributed to the overall good project performance. Some parts should have been projected earlier and done together with contractors to incorporate their knowledge. Smaller scope changes did occur, however no change in budget was needed as the budget had enough room for these changes. The delivery method chosen was ABA99 (functional contract) and not a turnkey contract, which was a *"successful decision"*.The main problems with the procurement process was the inconsistency between predetermined framework agreements and aqual prices on quotes, a low number of quotes from contractors implying low competition and not sufficient time to perform a thorough procurement. The cost of electrical engineering was overestimated.

The reference group was too big in some areas and was lacking competence in some. Within these areas, there were low quality of meetings. However, the project steering group was very supportive which increased the team spirit and ensured fast decisions and processes. The operation and maintenance was incorporated early in the project which led to enhancements. The deployment was budgeted and thus did not lead to increasing costs.The project team was dissolved too soon, which delays and makes documentation more difficult. Furthermore, while consultants had good knowledge and competence, they lacked time to execute the documentation which delayed that process even further.

The environmental context of the project impacted performance. The site was very limited in space which obstructed the contractors. The project was initially built within an existing building, which affected time delays as the space was limited. The context of a small building which now houses a too large boiler has led to increased yearly maintenance cost as the emissions from the boiler are precisely within accepted range, causing a lot of soot.

Project 6

Project #6 has not yet passed tollgate 4 because there are still some parts remaining due to some unsolved issues with other parties and final inspections. However, the project is not handled by the project organisation any longer and the final parts are handed over to the distribution unit. There were some scope changes during the project, which affected both time and budget negatively but these were seen as necessary. Some changes were preparations for an upcoming large project and were therefore budgeted on that project's behalf.

The project organisation in project #6 changed during the project implementation and the interviewed and current project manager was not assigned until after tollgate 2. He was therefore not responsible for the planning and projecting of the project leading up to the final investment decision. The handover of the project could have been better according to the project manager who explains that this resulted in some coordination and planning issues along the way. However, the collaboration within the project team was good and fast decisions could be made when needed. The project team was rather small considering it was a large project and mainly consisted of consultants but had good support from an engaged project steering committee. The project manager and his team had good knowledge of the technical aspects which was helpful during implementation. The project manager says that a larger project organisation with divided responsibilities for different project parts could have been preferred.

In general, the collaboration with the contractors worked well, but some issues regarding multiple site managers and difficulties to keep to the schedule. The largest issue was a dispute with one of the contractors that was mainly due to an unclear division of stages. This was one of the issues with the procurement but insufficient requirements and some important parts were completely missing quotes during planning. Another issue mentioned was that many contracts were missing quantities during the procurement and the contractors had to calculate these themselves. There are mentions that the budget could have been set way too low in the initial stages but the project managers explains that the risks and uncertainties were the ones calculated way too low. Uncertainties should be set higher for a project like this on every budget item.

Some external factors influenced the project, traffic disruptions due to another large project conducted close by. Material prices also went up and most of the material was procured in euro, and the project managers do not recall that there was any insurance regarding currencies. Even though the project experienced some time delays, tollgate 3 was only delayed by 1-2 months and the project was commissioned before the winter season which was critical. The final product lived up to the required quality and when finished the project manager describes the outcome as successful. No deficiencies have been reported regarding the quality yet but these are difficult to discover in just a few years.

Project 7

Project #7 consisted of a large re-investment in four old boilers to secure peak load production and enhance safety at site. Initially, the scope was thought to be around changing low voltage switchgear and controlling the unit. After the pre-investment decision in TG1, a more thorough planning and pre-engineering was conducted. During pre-engineering it was found that more electrical gear needed to be replaced in order to match new regulations and existing systems at the centralised controlling unit. In addition, the scope increased to include conversion of the fossil fuel fired boilers to become bio-fueled in order to meet new environmental regulations.

Of the two main contracts procured, one performed well with no complaints even below estimated budget. The project team possessed much knowledge which helped to shape the contracts, however, during this time, the market competition was rather low. The other contractor chose a subcontractor initially that was already in a large conflict regarding penalties and cost with another project. Luckily, this project managed to require the contractor to use another subcontractor. Despite this, the subcontractor was somewhat troublesome to manage at site and incurred costs. During the beginning of the implementation, contamination was found at the site which delayed work several weeks. Luckily, project #1 was conducted at the same time as project #7 was delayed and had the same contractors as project #7. During the initial delay, where no work was allowed at project #7, contractors could work at project #1 instead which helps to keep the cost of delay down to a minimum. However, as the time schedule was critical to keep, extra costs had to be incurred to oblige workers to perform extra shifts and weekend work.

The project team was good and the project manager was assigned to the project during the entire project lifespan. At the end of the projects, contractors charged extra costs for alterations and additional work. Since the project team was rather intact and possessed high knowledge within the areas of work being contracted, a lot of the cost could be disputed which minimised any cost increases. Overall the project had good cooperation with the organisation. The steering committee was very supportive and responsive. The work with the reference group was to some extent less smooth as their time spent in the project was limited and they usually had many opinions on how things should be performed. As a result of lacking time, these *"wishes"* usually came in late in the project, making it hard to add them.

Project 8

Project #8 is one sub-project to a larger program. During the investment decision there was a change of scope between two of the sub-projects in the program were project #8 was assigned adjacent civil work which initially was planned in another sub-project. The change of scope did affect the overall project performance and metrics but they were still executed within its original sub-project.

The project team had a good cooperation and knowledge, which helped to achieve creative solutions when problems occured. As the sub-projects were interconnected and sometimes conducted simultaneously at the same site, the leadership between the project managers was somewhat fluid in order to enhance efficiency and utilise knowledge to a maximum. The overall work with the project steering committee worked well, however there was an imbalance of competence towards some disciplines which was a better match to other sub-projects within the program. All decisions should be established with the steering committee which sometimes is time consuming and decreases the flexibility and creativity of the project manager. In this case the project manager sometimes thought that *"forgiven rather than permitted"* was better in order to ensure project performance.

Procurement and bundling of project sub-parts was challenging in order to find the optimal boundaries between contracts. The comprehensive work during this phase created an initial well estimated budget and timeplan with enough space for changes. The civil work that initially was outside of the scope however had multiple missing parts in the budget and some were too optimistic. This was partly compensated with a good procurement and conervative budget for Power Supply. In hindsight, the complexity of the project's environment was underestimated which also was the main driver for cost and time increase. In general, the contractors who had established framework agreements conducted a very good job during the execution of the project. Having established framework agreements with contractors already familiar with the company's procedures and demands enhances efficiency during the project execution and quality.

The overall time schedule was delayed several times, and was not initially in scope. Firstly, the time plan estimated for civil work was unrealistically estimated, but approved by the main contractor. Their subcontractors were however not able to keep it. The reason for the tight time schedule was to not interfere with external stakeholders conducting business close to the project. In addition, the second reason for time delays was that the contractors for the civil work delivered faulty work, which needed to be fixed. Lastly, the municipality did not allow any work during the springtime in order to not disturb wildlife. The delays could to some extent be managed by some sheer luck and by rearrangements in contract, over time work and overlapping work which instead increased costs. Regarding the delivery of faulty work, persistence and a high level of knowledge within the project team minimised cost increases from alterations and additional work.

Project 9

Project #9 is the smallest project considering budget size in the portfolio, and experienced both time and cost increases and quality related issues. In general the project had a well-functioning project team which the clearly defined responsibilities of the sub-project managers contributed to. However, the construction knowledge was inadequate which affected the project negatively. The communication between different parties could however be better if all parties were more on-site. The collaboration with the steering committee was inadequate and time-consuming because of resource deficiency and geographical location. The steering committee was changed after tollgate 2 and they had therefore not been part of the planning at all, but they have been supportive when the project encountered problems. Project #9 was run like a regular project but it might have been better to see it as a development project because such a project requires more time and has a higher level of risk. During a development project, the organisation has to be more on-site during implementation which could also have been favourable for the project in the end.

The procurement and detailed construction of project #9 was frozen until after the investment decision. This in turn affected the procurement process, there were not any technical solutions done when contractors were asked. The contractors who won the procurement were not good enough and fell through due to an inadequate evaluation and vague requirements. All the above-mentioned reasons led to insufficient procurement in general. Even if the procurement would have been better it would, according to the project manager, have been difficult to find competent and good contractors for this project since the technicalities of the project were advanced and new at the time.

Project #9 faced many technical problems along the way, suppliers of critical parts could not deliver on time and to the required quality which in the end required these parts to be exchanged altogether. This of course affected the time and the budget negatively. But the project experienced time delays in all parts, even before the investment decision which in the end delayed the commissioning. The time delays in the early stages caused a tight and stressed schedule. The project was controlled by its schedule and the project manager explains that *"we took the costs that came with an optimization of time"*.

External factors influencing the project performance evolved to a large extent around the company and project process. The tollgate process was quite new at the time and not completely defined during project #9. The largest issue with the project process was, however, the documentation. The documentation department was not involved at the start, the processes and requirements were not developed and what should be documented went from mouth to mouth. Documentation was at the beginning done by the company themselves but then transferred to an external party which caused some delays. Changing requirements led to time delays due to incorrect information and difficulties with compilation in the end. Project #9 did not deliver on cost, time, or quality. After project finalisation, there have been many technical issues and *"children's diseases"* regarding the final product.