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Large government investment projects

The influence of exogenous economic determinants on cost performance for large government investment projects in Norway

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Engineering & ICT
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Abstract

Since the early 2000s, the state project model has appraised large governmental investments in Norway to ensure more successful projects and satisfying cost performance. Furtherly, the Concept research programme is in charge of doing follow-up research on the projects, and aims to enhance the knowledge of managing large government investment projects. The national and international literature has tended to focus on analysing the effect endogenous variables have on the cost performance, whereas exogenous determinants have been neglected.

The main purpose of this report is to evaluate what exogenous economic variables affect the cost performance of large government investment projects in Norway. Furtherly, the report seeks to indicate which exogenous economic determinants are most influential on the projects, and if they are related to the cost performance to the extent expected compared to other factors.

The report is quantitatively based, utilising simple linear regression to indicate the relation between exogenous economic variables and the projects' cost performance. The analyses are done on a sample of 90 Norwegian projects. In addition, a literature review is undertaken. The main purpose of the literature review is to provide an overview of the field of large-scale projects, and lay the basis for what exogenous variables are deemed interesting to analyse.

The findings in this report suggest that exogenous economic determinants do play an essential role in cost performance for large government investment projects in Norway. However, skewness of focus in the literature may have undermined their value. Further on, utilising an HP filter, it is found that the business cycles are a significant determinant of cost performance. Specifically, higher positive deviations from GDP lead to higher increases in cost overrun. The other determinants were not found to be statistically significant in driving cost overrun, but are deemed important towards cost performance. Further research with a more extensive set of projects is regarded as valuable to enhance the knowledge of what effect exogenous economic variables have on large government investment projects.

Sammendrag

Siden tidlig på 2000-tallet, så har store statlige investeringsprosjekter i Norge blitt vurdert gjennom statens prosjektmodell for å sikre suksessfulle prosjekter og tilfredsstillende kostnadsutfall. Forskningsprogrammet Concept har hatt ansvaret for å drive følgeforskning på disse prosjektene, og har som mål å forbedre kunnskapen hva gjelder å styre store statlige prosjekter. Litteraturen både nasjonalt og internasjonalt har tendensert til å analysere effekten endogene variabler har på kostnadsutfall, mens eksogene variabler stort sett har blitt neglisjert.

Hovedhensikten med denne rapporten er å evaluere hvilke eksogene økonomiske variabler som har en effekt på kostnadsutfallene til store statlige investeringsprosjekter i Norge. Videre, så søker rapporten å indikere hvilke eksogene økonomiske determinanter som påvirker prosjektene mest, og om de er relatert til kostnadsutfall i den grad man forventer i forhold til andre faktorer.

Rapporten er basert på kvantitative analyser ved å utnytte simpel lineær regresjon som metode for å indikere relasjonen mellom eksogene økonomiske variabler og kostnadsutfall for prosjektene. Analysene er utført på et sett med 90 norske prosjekter. I tillegg er det utført et litteraturstudium. Hovedhensikten med litteraturstudiet er å gi et overblikk over store prosjekter som felt, og legge grunnlaget for hvilke eksogene variabler som er ansett som interessante å analysere.

Funnene i denne rapporten viser at eksogene økonomiske variabler spiller en viktig rolle for kostnadsutfall i store statlige prosjekter i Norge. Men, det skjeve fokuset i litteraturen kan ha undergravet verdien av disse. Videre, ved å utnytte et HP-filter, så er det funnet at konjunkturer er en signifikant determinant til kostnadsutfall. Nærmere bestemt, desto større positive avvik fra BNP Fastlands-Norge, desto større blir kostnadsoverskridelsene. De andre determinantene ble ikke funnet statistisk signifikante mot å eskalere kostnadsoverskridelser, men er likeledes ansett som viktige for kostnadsutfall. Videre forskning med et større datasett er sett på som verdifullt for å forbedre kunnskapen av effekten eksogene økonomiske har på store statlige investeringer.

Preface

This master thesis marks the end of my five-year journey as a student at the Norwegian University of Science and Technology in the programme of Engineering & ICT. Further, this report concludes the work undertaken in TPK4920 Project and Quality Management, which accounts for 30 ECTS.

Large government investment projects became a growing interest of mine during the last couple of years. Accordingly, getting the chance to look further into the topic has indeed been very interesting. It has been a challenging, but likewise an encouraging task to dig deeper into the field of large-scale projects. Noentheless, it has been worthwhile as I genuinely believe the research in the field is of great benefit to society.

First and foremost, I would like to thank my supervisor Nils Olsson. The feedback, help and enjoyable meetings throughout the working period have been of much value to the report. Thanks should also go to the Concept research programme for letting me access and analyse the projects within Trailbase. I am also thankful to Christian Hjeltnes at the Norwegian Agency for Public and Financial Management (DFØ) for providing good input to the report. At last, a special thanks go to my friends and family. My dad, who also works at DFØ, for kindly listening to my problems and being a good discussion partner. My mom who helped me proofread and edit. And finally, my friends for their much appreciated emotional support throughout the semester.

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Sigurd Spildrejorde

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Abbreviations and vocabulary

CCI	Construction cost index for road construction (Byggekostnadsindeks for veganlegg) – Measures the price development in the input factors for construction and maintenance of roads. Mainly used to regulate construction contracts.
Concept	The research programme that does follow-up research for large governmental investments in Norway.
Cost frame	(Kostnadsramme) – The total amount of funding initially is set aside for the completion of the project.
CPI-ATE	Consumer price index adjusted for tax changes and excluding energy products – A measurement for the underlying core inflation in Norway.
GDP	Gross domestic product – A measurement used for defining the total economic activity within a defined territory.
HP-Filter	Hodrick Prescott-filter – A method of data-smoothing used to analyse business cycles.
I-44	Import-weighted krone exchange rate – The exchange rate index based on a weighted average of the exchange rates of the 44 countries most important to Norway in terms of import value.
SSB	Statistics Norway (Statistisk sentralbyrå) – The official national statistical institute of Norway. Main provider of official statistics in Norway.

Steering frame	(Styringsramme) – The cost frame equal to the maximum amount to be used by the ministry or agency in charge.
ToD	Time of Formal Decision to Build – The point in time when it is formally decided to proceed and implement a project.
Trailbase	The database that obtains data for all projects that are, and have been, undergoing the Norwegian state project model.
QA1	Quality assurance 1 – The first quality assurance for a project undergoing the Norwegian state project model. Undertaken by an external part
QA2	Quality assurance 2 – The second quality assurance for a project undergoing the Norwegian state project model. Undertaken by an external part.

1 Introduction

1.1 Large government investment projects in Norway

During the 1980s and the greater part of the 1990s, a number of large government investment projects in Norway experienced final costs exceeding initial estimated costs (Berg et al., 1999; Odeck et al., 2015). To deal with the unfavourable cost overruns and the related management issues, The Ministry of Finance found it necessary to standardise both planning procedures and estimation methodologies for these types of projects (Berg et al., 1999). Accordingly, they introduced a scheme that included external quality assurances in the decision phase for all large government investment projects obtaining a cost frame of 500 million NOK. At first, the scheme was introduced with the sole purpose of having external quality assurances to handle the cost- and management problems within the projects. However, the now-named Norwegian state project model was in 2005 extended also to ensure valuable concept choices and realisation of utility for the projects (Samset & Volden, 2013). The overall target for the state project model is to ensure more successful projects, reduced costs for the state of Norway and obtain more value for the money spent (Torp et al., 2006). As of 2022, all government investment projects with an estimated budget above NOK 1 billion, or for digitalisation projects NOK 300 million, need to undergo the state project model (Finansdepartementet, 2019). Beneath is a visualisation showing the different aspects of the model.

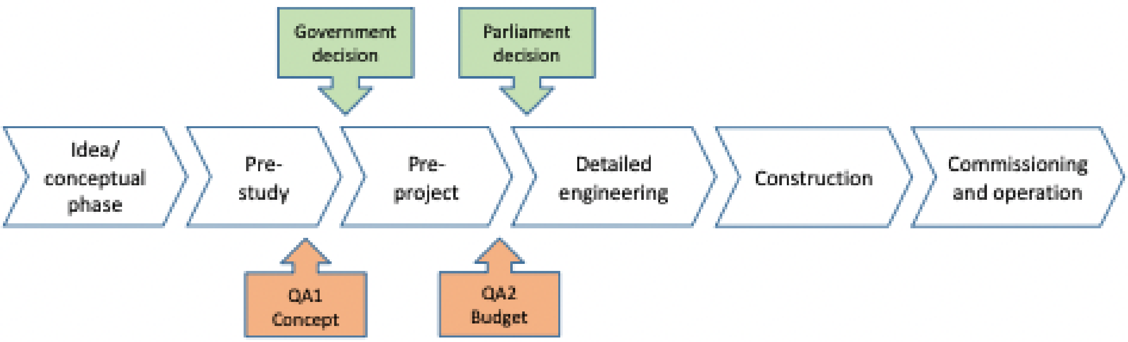


Figure 1.1 - The Norwegian state project model (Samset et al., 2016).

As the visualisation shows, a project must undergo two phases before the choice of concept eventually is evaluated externally. The pre-study prior to Quality Assurance 1 (QA1) relates to the construction of a conceptual appraisal that is the basis for the upcoming quality assurance created under the responsibility of the agency or ministry in charge of the project (Samset et al., 2016). QA1 is performed upon the completion of the pre-study and is meant to ensure that the most valuable concept among the alternatives is chosen. Here, *valuable* is an umbrella designation referring to the tactical and strategic successfulness where the aspects of effect- and societal goals along with purpose- and allocation efficiency is evaluated (Samset & Volden, 2013). If the government decides to proceed with one of the concepts found in the conceptual appraisal, the project enters the pre-project phase before it eventually is being externally evaluated a second time in Quality Assurance 2 (QA2). This quality assurance is equivalent to the original scheme introduced in 2000 (Torp et al., 2006). While QA1 specifically looks to choose the most optimal concept, QA2 is meant to ensure operational success by focusing on realistic budgets and enduring that the project delivery is done in a time -and cost effective manner (Samset et al., 2016). In general, the quality assurers will, in QA2, introduce their recommendations on the project's overall strategy along with cost estimates comparable to those initially provided by the ministry or agency in charge (Odeck et al., 2015). The two key cost estimates are the ones denoted P50 and P85. In short, the P50 estimate marks the 50 per cent probability that the final cost will be within this figure, while P85 refers to the 85 per cent probability regarding the same matter (Samset & Volden, 2013). P85 is often referred to as the cost frame and represents the total amount of funding that is theoretically available to spend on the given project. Furthermore, P50 is commonly called the steering frame and represents the threshold to be disposed of by the ministry or agency in charge (Meunier & Welde, 2017; Samset & Volden, 2013). Generally, if considering a portfolio of projects that has been undergoing the Norwegian state project model, it is then to be assumed that 85% of the projects have total costs within the cost frame, while 50% of the projects have total costs within the steering frame (Welde, 2017).

The research programme Concept, based at the Norwegian university of science and technology (NTNU), is embodied by the Ministry of Finance to do follow-up research for large government investment projects in Norway covered by the state project model (Bukkestein et al., 2020). The main goal of the research programme is to ensure better use of resources, optimal choosing of concepts and obtain overall success for large government investment projects (Solheim et al., 2010). In addition, the Concept research programme plays an essential role in getting empirical data about large government investment projects, sharing its knowledge in the domain with actors in business and management as well as developing new understandings within the field of managing large government investment projects (Torp et al., 2006). Since the embodiment of the Concept research programme, several studies have approached the case of cost performance within large government investment projects by evaluating empirical data for a larger set of projects. Studies including Samset and Volden (2013), Welde (2017) and Welde et al. (2019) all quantitatively evaluate the cost performance by comparing final costs to the key cost estimates, namely the steering frame and the cost frame. These studies are important to assess to what degree cost -and steering frames and uncertainty estimates have been realistic, and accordingly, where the main potential for improvement lies of managing large government investment projects (Welde et al., 2019).

1.2 The actaulity of exogenous determinants

The literature on cost deviations for large infrastructure projects has focused mainly on endogenous motives, especially project characteristics, and partially neglected exogenous reasons and their potential relation to cost performance (Catalão et al., 2019). Other than Dahl et al. (2017) and Oglend et al. (2016), that studied the effect business cycles had on the accuracy of project costs for Norwegian development projects in the petroleum industry, there seems to have been little empirical research on the specific topic of exogenous determinants' effect on cost performance in Norway. It is acknowledged that determinants related to the market situation are of importance regarding cost overruns as most QA2 reports generally identify the market as the primary driver for uncertainty (Welde, 2017). Berntsen and Sunde (2004) did, in the very first Concept report, discuss the handling of market uncertainty and brought up suggestions on how to handle this when calculating a project's cost estimates. Nonetheless, Welde et al. (2019) argue that there has been a lack of capability in learning from past experiences and projects, as the uncertainty analyses seemingly have not been improving over the years. Along with previous research, which has primarily been looking into the relationship between project characteristics and cost performance, there lies importance in evaluating the relation between exogenous determinants and cost performance to obtain further knowledge about what set of determinants drives cost overrun in large government investment projects.

1.3 Research questions and purpose of report

This report seeks to extend the knowledge of what specific determinants that relate to cost performance, particularly cost overrun, for large government investment projects in Norway by analysing at exogenous economic determinants. Considering the number of resources that goes into developing these types of projects, there is underlying importance in obtaining as much knowledge as possible to optimise their cost performance. Within the field of large-scale projects, studies enhancing empirical analyses have been biased towards endogenous determinants, although exogenous determinants have proven significantly important for the cost performance of large-scale projects and public projects (Catalão, 2019; Catalão et al., 2019; Dahl et al., 2017; Oglend et al., 2016). The report aims to bring extended knowledge within the field to strengthen further the decision basis for the estimation and calculation of cost -and steering frames for large government investment projects. The results in the report are meant to enlighten the impact exogenous determinants have on large-scale projects, and broaden the perception of what drives cost performance in these projects. To accomplish the aims of this report, the following research questions are to be answered:

- Which exogenous economic variables do seem to impact the cost performance in large government investment projects in Norway?

- To what extent can exogenous economic variables explain cost performance in large government investment projects in Norway?

- Do exogenous economic variables contribute to cost performance to the extent expected compared to endogenous factors based on literature findings and the results?

To answer the research questions, the report will include a literature review and quantitative analyses of large government investment projects having available cost frames and having undergone QA2 per March 2022. All the project data is extracted from Trailbase, the database which contains data for most large government investment projects in Norway. Throughout the report, the research questions will be addressed before being answered distinctly in relation to the conclusion and discussion of the report.

2 Literature review method

The primary purpose of a literature review is to summarise a set of relevant sources to get an overview of the specific topic of interest to the research (Knopf, 2006). The review would often present what is already known and what is not necessarily known concerning the subject in focus (Denney & Tewksbury, 2013). For this particular review, a range of different sources aimed for different purposes has been used to get the most satisfactory overview of the domain of large-scale projects. The review's main focus has been to get a good grasp of the range of studies that particularly assessed cost performance and its possible explanations by analysing large-scale projects quantitatively. In addition, other studies that do not follow this approach have also been included to shed light on possible explanations or inferences which were not prominent within the quantitative studies. Further on, the search for relevant literature and findings has been conducted in two specific ways. First, the literature review was undertaken with inspiration from the practices done for systematic reviews by Denyer and Tranfield (2009). Second, the search for relevant literature has also been done by exploring the papers and reports published by the Concept Research Programme. The literature within this program was deemed especially interesting towards the actuality of research aimed at Norwegian projects. It is to be noted that although the literature review has been inspired by the characteristics of a systematic review, it should not be regarded as likely comprehensive.

2.1 Systematic literature review

As mentioned, the literature review conducted in this report has taken inspiration from some of the steps and ideas originating from a systematic review. This method of research is used to obtain theory by gathering and analysing a large number of studies, such that the consistency and results of the review are increased (Akobeng, 2005). There are two main reasons for choosing the specific approach with a basis on the research of Denyer and Tranfield (2009). First, they use the methodology of systematic review as a tool specifically aimed to be used by scholars, policymakers, and practitioners within the domain of management and organisation studies. Second, the general characteristics of systematic reviews are viewed advantageously for grasping the literature of interest for this report. In particular, it is aimed to locate existing studies and analyses to the extent that robust conclusions can be made from the content in the existing literature. These assets are deemed prominent regardless of the review not being a complete and comprehensive classic systematic review. The method was undertaken in two different stages, the planning stage and the development stage. Accordingly, both stages will both be thoroughly explained below.

2.1.1 The planning stage

The planning stage refers to the point in the literature review where the concurrent needs for the review are stated, a protocol is developed, and the strategy, which includes the list of keywords and combinations used, is defined (Denicol et al., 2020). However, the rigid protocol of systematic reviews poses a problem at this stage in the review, for the domain of management in particular, as the terminology is somewhat divergent compared to other fields of research. In other words, different terminologies and conceptualisations explain and refer to the same phenomenon or meaning (Denicol et al., 2020). Hence, keywords and their most nearby synonyms had to be chosen with care to obtain the most desirable range of relevant studies. The set of keywords was divided into three main categories, where keywords from two of the different categories were used for each search. More specifically, the category that included the synonyms to "cost performance" was both searched with the category including "large-scale project" and the last category. The latter included a set of words aiming to extract the studies explicitly having cost performance determinants in focus. Beneath is a visualisation over the set of terms combined in the search procedure.

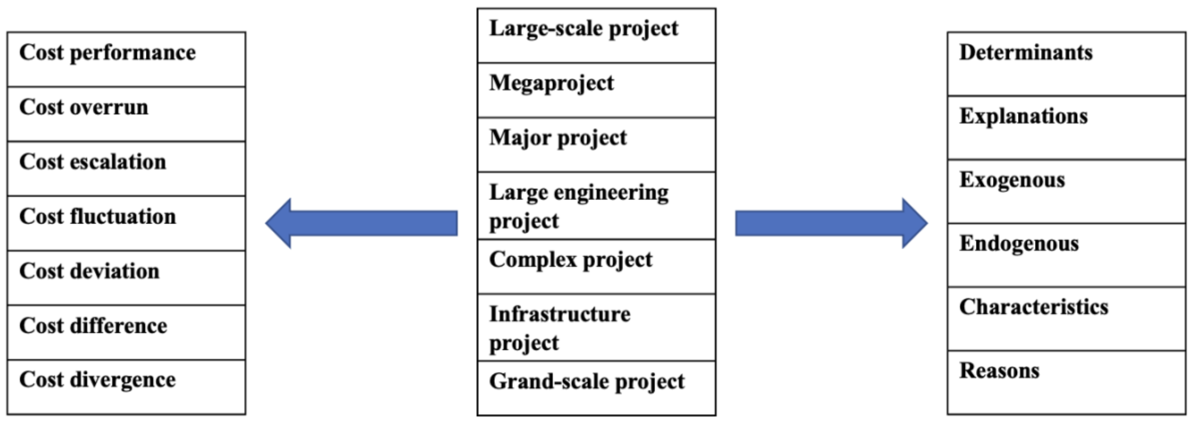


Figure 2.1 - Lists of search terms and search combinations

In addition to deciding what terms, and combination of terms, to be included in the search, it was necessary to form a strategy for both the exclusion and inclusion criteria. Capka (2004) argued that there lies importance in differentiating large-scale projects to the extent that they are to be viewed as a unique type of projects rather than a larger version of more standard projects. In a similar fashion to the literature, which is elaborated on in chapter 3.1.1, the criteria will mainly revolve around the size of the projects being analysed in the studies. Primarily, only the studies researching projects that were approximately the same size as the ones in Trailbase, NOK 500 mill and above, were included in the review. However, studies that could point towards distinct findings for a set of larger projects, although also including findings for smaller ones, were also regarded and potentially included. Further, studies that explored slightly smaller projects but had findings or explanations deemed interesting for the research of large-scale projects were also included to add some depth to the range of possible inferences to cost performance. In addition, and lastly, studies that promoted explanations and findings not found among the studies with more empirical-based analyses were also included to shed light on the range of explanations for cost performance. The studies that had an empirical approach towards the analyses of their projects are listed in Table 3.2 along with the respective project data and main determinants.

2.1.2 The development stage

The systematic search was carried out utilising two of the largest online academic databases, namely Web of Science and Scopus, in line with what was done by Denicol et al. (2020). The search was conducted by the two distinct combinations of search terms, where the results were combined and analysed as a whole. The search analysis was undertaken in line with the following steps.

1. In compliance with the described aims for the literature review pointed out in the planning stage, the search was conducted by utilising Web of Science and Scopus as academic search engines.
2. The first search string, that included the terms in the categories related to "megaproject" and "cost performance", resulted in 65 hits on Web of Science and 347 for Scopus. The second string, which included the terms in the categories related to "megaproject" and "determinants", returned 10,034 for Web of Science and 1,855 for Scopus. In total, the number of papers found then ended up being 12,291.

3. The large number of reports found in the initial search was much too large to analyse manually, and further exclusion criteria needed to be included in the search. At first, it was decided only to include papers verified as an article. In other words, papers that belonged to either of the groups of reports, books, proceedings papers or conference papers were excluded. This exclusion criterion ended up cutting the results to 10,260 articles.
4. The large number of articles called for additional measures to reduce the number to an analysable amount. Hence, it was decided to remove the search strings that included the terms “large engineering project” and “infrastructure project”. These terms were considered the vaguest out of the project-related terms. They brought up problems as a decent portion of the studies that used these terms studied projects considerably below the wanted size benchmark. Applying this exclusion criterion brought the number of articles down to 9,839.
5. A concurrent problem of this stage of the search was the substantially large number of articles being returned from the strings containing the combination of terms related to “determinants”. 9,646 of the articles stemmed from these search strings. Accordingly, it was decided to target abstracts only, to compress the number of results. The main idea behind this choice was that articles having the potential to be interesting for the review would most likely include the combination of the project-related terms and the “determinants”-related terms already in the abstract. With this specific targeting, the number of articles returned was reduced to 866.
6. Finally, two core inclusion terms were set before inspecting the articles manually. The articles needed to be either in Norwegian or English and had to be obtainable for free. These criteria narrowed the results down to 234. By excluding duplicates, the number of articles ended up being 139. These would furtherly be analysed manually.
7. All the articles were analysed by first assessing the abstract and conclusion. Further, the articles were excluded if they did not include projects of sufficient size, did not obtain any focus on cost performance for the projects, or could not provide any valuable insight into the determinants related to cost performance. Included in the resulting articles were quantitative studies, which in total explored 26 different sets of projects. These are summarised in Table 3.2.

2.1.3 Short evaluation of the systematic review

The criteria chosen for both inclusion and exclusion of the articles do bring limitations to the search and methodology itself. Adams et al. (2017) argue that excluding other types of writings than articles, such as books, is common practice despite the disadvantage of missing out on possible useful information. Denicol et al. (2020) explain that although key literature in the project management domain was first developed in books, a lot of these are referenced and used as theoretical support in many articles surrounding the same field. Accordingly, although influential books are excluded from the review, their core ideas and important findings should still be indirectly evident in the articles included.

Another problem of the review is the separation of the two main search paths. That is, there lies some instability in dividing the overall search into two different core searches. The thought behind this way of dividing the search was to grasp a more considerable portion of the literature. An alternative could have been to use all the three different pools of terms in one combination. This would likely have returned a set of more precise results. However, the trade-off would have been to miss out on potentially relevant articles. Since the criteria were not strict to its core, the method that would generate the most articles was chosen, although seemingly more exhaustive to analyse in the long run. Further on, the exclusion of search terms within the process of the development stage will have the possibility of discarding relevant articles. Nonetheless, this was seen as a necessity to compress the search results. This was done by choosing to exclude the vaguest and least specific terms to reduce the results without damaging the quality and relevancy of the returned articles.

Finally, it was also deemed necessary to take advantage of snowballing to increase the relevancy further and supplement the number of articles. Snowballing refers to the method of reviewing the reference list and citations of relevant papers to identify new papers that may as well be relevant to the topic in focus (Badampudi et al., 2015). There was one main reason why it was found plausible to utilise this method along with the review. A reasonable number of the papers found in the search were literature reviews, like for instance Cavalieri et al. (2019), Denicol et al. (2020) and Aljohani et al. (2017). Hence, snowballing these types of articles was seen as an effective way to grasp an overview and obtain a good range of articles, especially when gathering studies with a quantitative focus. Nonetheless, the snowballing also led to a partial objection to some of the exclusion and inclusion criteria. For instance, some conference papers were included because of this method. However, the inclusion of these papers was restricted to describe and getting an overview of the whole literature and possible interesting research approaches. The use of snowballing also led to some books being brought into the resulting review. Nonetheless, these were explicitly utilised only when domain theory, distinct phenomena or methods were to be explained.

2.2 Targeted document -and report review

To get a holistic picture of the research on large government investment projects in Norway, it was deemed necessary to search through reports and other writings published by the Concept Research Programme. As mentioned in the introduction, Concept is responsible for the follow-up research on large government investment projects in Norway. Hence, much of the research that has been done within this domain in Norway is to be found in their articles. The content within the reports published by Concept is diverse but maintains a common aim to improve the knowledge around large government investment projects in Norway. Consequently, the search analysis had two parallel goals. First, to identify themes, areas of focus or gaps in the literature, it was important to include studies that could help provide an overview of the research done nationally. Second and naturally, studies that quantitively explored cost performance within a portfolio of projects were also included. The search itself was done manually with a primary focus on the 66 reports, per April 2022, that are included in the Concept official Report Series. In addition, relevant literature was added from reports included in Concept's working reports. The theory and knowledge obtained from this separated part of the literature review will be merged with the findings from the systematic review when presented in the following chapter.

3 Theory

3.1 A short overview of the literature

3.1.1 Large-scale projects – A definition

Within the literature, the definition of large-scale projects, popularly called megaprojects, could seem to be rather ambiguous or vague. However, the necessity in defining these types of projects is in the importance of being able to differentiate them from other smaller projects. The arguably most common way to ensure a definition for large-scale projects is to distinguish them by their size, or rather their initial cost. Flyvbjerg (2017), for instance, suggests that a large-scale project should be defined as a project costing at least USD 1 billion, impacting millions of people, being processed over several years and involving multiple stakeholders. Locatelli et al. (2014), on the other hand, propose that the threshold for a project to be large-scale should only be that the initial cost is EUR 500 million. On a more country-specific note, Hu et al. (2015) argue that defining large-scale projects just by their initial cost estimate is a simple approach that only is reliable for more developed countries, and proposes that a project should equal 0,01% of the GDP in the initial country to be regarded large-scale. This is much in line with the arguments of Mišić and Radujković (2015), which state that smaller and medium countries with low GDP in Europe should have projects being defined as large-scale if their size is between EUR 250 – 300 million. As of late, it has also been suggested to define large-scale projects not only in reference to their cost but rather as a composition of characteristics that can promote their inherent convolution (Pitsis et al., 2018). Additionally, hydropower projects tend to relate size to other factors such as dam height and production of megawatts (Ansar et al., 2014; Awojobi & Jenkins, 2016; Bacon & Besant-Jones, 1998; Braeckman et al., 2019). Despite their differences, all the presented definitions aim to determine where the differentiation between standard projects and large-scale projects goes. The most important is the acknowledgement that large-scale projects differentiate from other projects to the extent that they are to be regarded as a unique kind of projects and not a more expensive version of other smaller and more standard projects (Capka, 2004; Greiman, 2013).

3.1.2 Definition of cost performance and measuring baseline

Cost deviation can either be positive or negative and refer to the deviance of the final cost when compared to the initial cost estimate (Catalão et al., 2019). Additionally, cost performance, or cost overrun, may be measured in absolute or relative terms. Absolute terms refer to actual costs minus initial cost estimate whereas relative terms refer to actual total cost in percentage deviation of the estimated cost (Cantarelli, Molin, et al., 2012; Flyvbjerg et al., 2018). Within the literature, there are different thoughts on both how to measure cost performance within a set of projects effectively, and what the various methods of calculations are best suited to measure.

Flyvbjerg et al. (2018), for instance, argue that the baseline which one chooses to measure cost performance from highly relates to what one wants to measure. Here, baseline refers to the point in time where the initial cost estimate is taken from. Additionally, they state that estimated costs typically are established at different points in time, where the cost estimate becomes more accurate the closer in time a project is to an initial investment. A common way to deal with the issue of unreliability in the time chosen for the initial cost estimate has been to define what is called the ToD, Time of Formal Decision to build. The Time of Formal Decision to build refers to the time of which the decision-makers within the project decided to formally initiate and implement the project (Flyvbjerg, Bruzelius, et al., 2003). At this moment, the decision-makers are assumed to have enough available data to make an informed decision regarding the proceeding of the project (Cantarelli, Molin, et al., 2012). The primary source of criticism towards choosing the ToD as the consistent baseline in cost performance calculations has been Love and Ahiaga-Dagbui (2018). They claim that determining the price of a project is dependent on a series of negotiations between possible and related contractors and the public sector. Hence, using the ToD as a baseline rather than the time of contracting, which is their suggestion, would promote inflated cost overruns as the estimate at this time is argued not to reflect the complete picture. Flyvbjerg et al. (2018), however, directly counterargue with the claim that the two baselines refer to two different aims of the cost performance measurement. Along with Cantarelli et al. (2013) and Cantarelli et al. (2010), they suggest that the the ToD baseline should be used when wanting to examine the accuracy of the information the decision-makers had obtainable, while the time of contracting should be used when wanting to measure the performance of the contractors.

3.1.3 Categorising of the literature

Within the literature on large-scale transportation infrastructure projects, the problem of unsatisfiable cost performance is recognised, but the explanations and causes for the related issues are ambiguous (Cantarelli et al., 2013). As in other fields of subjects, there are many ways to categorise and divide theory into smaller bulks to perceive the topic better. Cantarelli et al. (2013) claim that most studies within large-scale transportation infrastructure projects are empirical. In other words, studies that for the most part use data from observation or experience based on real projects. Furtherly, they differentiate the studies within their literature research between two main sources of focus:

- Broad focus – Studies addressing the project performance in general.
- Narrow focus – Studies that specifically look at cost overrun or cost performance.

Studies with a broader focus are, in general, more focused on how the actions of the players within a project affect the general project performance. On the other hand, studies that fall under the division of the narrow focus are more tuned into which characteristics one should be aware of when estimating and judging the cost of a project before initiation. In terms of categorising causes and explanations for cost performance in large-scale projects, Flyvbjerg, Bruzelius, et al. (2003) propose a categorisation that includes four different categories of explanations with corresponding causes.

- Technical explanations.
- Economical explanations.
- Psychological explanations.
- Political explanations.

Oglend et al. (2016) explain that technical explanations to cost overrun refers to the thought that imperfect methods and data are the main causes behind proclaimed bad luck and forecasting -and estimating errors. Flyvbjerg et al. (2002) argued that studies explaining cost performance with a focus on forecasting errors did not do so empirically because the number of project cases up until that time had been too small to allow the data to be tested statistically. An example of such technical explanations is managerial incompetence, referring to random errors or mistakes made by the project management being a significant cause of cost overruns (Love et al., 2005; Morris & Hough, 1987; Olawale & Sun, 2010). Odeck (2004) reports that project complexity as a technical explanation plays a vital role towards cost performance. Scope creep, which refers to changes in the scope of a project, is mentioned as important by both Gil and Lundrigan (2012) and Love et al. (2011). These factors are indeed important sources of uncertainty and could bring the possibility of misleading forecasts (Flyvbjerg et al., 2002).

Regarding economic explanations, there has been a rather distinct focus on the case of deliberate underestimation among the agents in charge of estimating project costs (Oglend et al., 2016). Welde (2017) explains that in some cases, in a pressured market situation, the only way for the entrepreneurs to gain profits is to pursue resource-heavy change orders after having won a contract which may have been deliberately underestimated. Jørgensen (2014) found that selection bias, which is said to be the case where the contract situation makes it beneficial for the providers to underestimate the costs, is the main reason why ICT projects become more expensive than planned. Flyvbjerg et al. (2002) argue that for many stakeholders within a project, such as engineers and construction firms, the incentive to underestimate project costs is present and rationally based because the likelihood of obtaining the project, and therefore revenues and profits, would increase by lowering the presented estimated cost. Consequently, the economic self-interest theory and the public interest theory are the most prominent theories within the economic explanations for cost overrun (Oglend et al., 2016). In this case, the latter theory refers to the issue of project promoters and forecasters intentionally underestimating cost estimates such that officials of the public furtherly can communicate a lower total usage of the public's money and thereby gain more interest in the project (Flyvbjerg et al., 2002; Wachs, 1990).

Psychological explanations revolve around the theory that cost overrun is caused by optimism bias and faulty decision-making within the mind of the forecasters (Oglend et al., 2016). Flyvbjerg is arguably the most potent promoter of the importance of psychological explanations regarding cost overrun or cost underestimation. Flyvbjerg et al. (2018) argue, with a basis in behavioural sciences, that the root cause of cost overrun is human bias. They state that although scope changes, complexity, geology, and business cycles are to be viewed as causes of cost overrun, overconfidence bias, strategic misrepresentation and planning fallacy are to be considered as root causes for the problem of unfavourable cost performance. In addition, the so-called prospect theory presented by Kahneman and Tversky (2013), which assumes that forecasters directly or indirectly make decisions based on possible gains rather than possible losses, is considered important among psychological explanations for cost performance (Flyvbjerg et al., 2018; Oglend et al., 2016).

The political explanations towards cost overrun are similar to the economic explanations in that cost overrun is thought to be the result of intentionally underestimating a project, but here based on political reasoning rather than economic (Oglend et al., 2016). Cantarelli et al. (2013) state that political explanations towards cost performance are within the literature generally agreed upon to be the main explanation for cost overrun. They proclaim that cost estimates are deliberately underestimated to increase the probability of acceptance for the project. Additionally, they argue that agency theory is considered the most interesting among the political explanations because of three main reasons. Expressly, agency theory assumes that people act guilelessly purely based on their distinct self-interest (Noreen, 1988). First, because of its specificness and the direct possibility of addressing cost overrun. Second, it has already been proven to have indicated relevance in an initial attempt to address cost overrun based on this theory. Third and last, the theory includes politics, economics and sociology, which presumably makes the theory complete in its definition. Wachs (1990) argues that although projects are presented to the public as unbiased scientific procedures, they are often substantially subjective with an inherent purpose to support a political set of actions already being made. As such, there is a profound and severe ethical problem related to forecasting large public projects (Wachs, 1982). The tactical use of straight-out lying to get projects started is to be viewed as highly relevant to the explanation of costs in transportation infrastructure projects that are systematically underestimated (Flyvbjerg et al., 2002).

3.1.4 How the literature has been approached

There are different approaches regarding how the literature within the field of large-scale projects has been conducted. Welde (2017) explains that the identification of causes concerning cost performance has been based on everything from document studies, interviews and statistical analyses to expert evaluations or pure guessing. It is furtherly argued that since the economic, social, organisational, and context-specific parts of projects have been based on qualitative methods, the casual relationships can be adjudged as vaguer compared to analyses based on quantitative methods. Both De Jong et al. (2013) and Welde (2017) raised the question of why substantially few studies have utilised quantitative methods to study casual relationships. Cantarelli et al. (2013), in opposition to the indications of Welde (2017), argue that most studies on large-scale transportation studies have been conducted as empirical studies. Specifically, they claim that a more significant part of the studies in the literature uses data from observation and experience from real projects to evaluate cost performance. In addition to statistical analyses of large databases and questionnaires with relevant stakeholders, case study analysis has also been conducted as a part of the large-scale project research field (Locatelli, Mikic, et al., 2017). As perceivable, there is no consensus on how the literature should be approached and what has been the most frequent of the approaches. Naturally, there still lies plausibility in giving some examples of the different methods of research.

Questionnaires offer a possibility to get objective means by collecting information based on the knowledge, beliefs, behaviour and attitude of people (Boynton & Greenhalgh, 2004). A portion of the studies in the domain of large-scale projects is questionnaire-based. Cheng (2014) conducted a questionnaire based on expert opinions to identify and provide a ranking for the most prominent factors towards cost overrun in construction projects in Taiwan. Zhao et al. (2017) sought exploratory cost drivers for building development costs in New Zealand by combining a literature review, pilot interviews and a resulting questionnaire. Durdyev et al. (2017) pursued a similar approach when researching contributing determinants to cost overrun for construction projects in Cambodia. Most questionnaire-based studies seek to find a large number of possible cost drivers for the type of projects they are researching by gathering opinions from relevant actors in the industry. Lack of skilled workers, poor estimation techniques, and inefficient cost control measures are found to be pertinent to cost performance (Cheng, 2014; Durdyev et al., 2017; Zhao et al., 2017)

Case study analysis is a methodology often used to thoroughly understand the behaviour and workings of one particular project (Yin, 2018). Case study research, in for example construction, has been criticised for the generalisation of results when sample sizes are small and for obtaining information from untrustworthy participants (Lopez del Puerto & Shane, 2014). However, its use may provide important notions to the literature if performed correctly (Eisenhardt, 1989). Greiman (2013) concluded that skilled workers were important to enhance the emergent risks unique to megaprojects when she conducted a case study of the Big Dig, a large road project. Lopez del Puerto and Shane (2014) studied two large-scale highway projects in the USA and Mexico, emphasising the importance of public outreach. Locatelli, Mariani, et al. (2017) used the Italian high-speed railways to demonstrate that corruption is a highly relevant factor in megaproject cost performance. Although there is a reasonable amount of case studies interpreted in the literature on large-scale projects, they inherit the main limitation of emphasising theory building rather than theory testing, which is more extensively undertaken by studies with a more quantitative and statistical approach (Locatelli, Mikic, et al., 2017).

There have been notable studies that perform statistical analysis of databases containing large-scale projects (Locatelli, Mikic, et al., 2017). In particular, this report has had a distinct focus and goal to extract these studies out of the literature. Flyvbjerg et al. (2004) elaborated on the causes of cost overrun for a set of 258 projects and performed statistical analyses, such as the t-test, along with simple linear regression to research what determinants influenced cost performance for the projects the most. Odeck (2004), Catalão et al. (2019) and Awojobi and Jenkins (2016), among many others, have utilised multiple regression analysis to create models that, in the best way possible, could explain cost overrun within the set of projects that were evaluated. The goal for this type of statistical analysis is rather often to maximise the explanation power of the model, the determination coefficient R^2, which explains how well the estimated model explains the variation in the data set, is important (Welde, 2017). Further on, within the pool of the statistically-based studies, it is not uncommon to focus on a particular type of project (Locatelli, Mikic, et al., 2017). For example, Braeckman et al. (2019) and Ansar et al. (2014) focus on hydropower dams. Sovacool et al. (2014), on their side, conducted analyses distinctively towards large electricity projects, while Terrill (2016) and Lee (2008), to name two out of many, turned their focus toward transportation projects. On the more experimental edge of the statistical analysis approach of research, there are the likes of Locatelli, Mikic, et al. (2017), which among other methods, applied machine learning techniques to investigate the relation between large-scale characteristics and project performance.

3.1.5 Notes on comparing findings between different regions

Since cost estimates will vary between the sets of data explored in the literature based on, for instance, the type of government, different decision-making methods, and state of the countries in which the projects have been situated, it is difficult to interpret the comparison of projects between markets, hence sectors and countries (Love & Ahiaga-Dagbui, 2018). Factors like project management development, cultural differences and political influence may also be of such variation between countries that the cost performance for large-scale projects cannot be compared on the same premise (Mišić & Radujković, 2015). Within the literature, it seems to have been a relatively large discussion whether the comparison of projects and, more specifically, the cost performance of these projects between countries and sectors is a plausible way to go about the findings within the domain. Welde (2017) also points to the difficulties of comparing large-scale projects between countries. In line with Love and Ahiaga-Dagbui (2018), it is mentioned that differences in estimation methods are a point of concern due to the lack of consistency in declaring what estimation methods that have been used in studies focusing on cost overrun. Furtherly, although the consensus of best practice in the literature is to make a deterministic basic estimate with additional stochastic uncertainty analysis, it is argued to be uncertain whether this practice is undertaken. Samset et al. (2016) investigated the practices for cost estimation of large-scale government investment projects in six different countries and found that only two of them applied the best practice of estimation methodology by using stochastic estimation, while the rest made use of varying mark-up factors. Among 12 estimation methods identified in a literature review, Barakchi et al. (2017) also concluded that the most frequent method used in studies was not compliant with the best practice.

Welde (2017) elaborates on the consistency of which cost estimate different studies compare to the final cost. It has already been mentioned that the time of formal decision to build (ToD) is a well renowned and widely used baseline for measuring cost performance (Cantarelli, Molin, et al., 2012; Flyvbjerg et al., 2018). This is a reasonable baseline to make measurements from as changes in the estimate after this point in time tend to be relatively seamless, while changes in the budget up until this point in time rarely can be changed without a more considerable formal decision (Welde, 2017). However, the main matter of concern pointed out by Welde (2017) is at which point in time the actual formal decision to build is taken. It is argued that within the literature, it is broad agreement that the uncertainty within the cost estimates is reduced the longer the project has undergone. The question which is asked is to what extent the point in time where the formal decision is made, and the information retrieved at this time, is similar between sectors and countries. For instance, between two countries, the formal decision to proceed with a project could be made on two very different bases of information. In Norway, a consequence of the state project model is that the project needs a high degree of maturity before the government can make the ToD, which may reduce the risk of cost overruns (Samset et al., 2016; Volden & Samset, 2017; Welde, 2017). Consequently, in a country where the formal decision to proceed is made at an earlier point in the project phase, the risk of cost overrun, presumably most visible on a portfolio level, may be more prominent compared to Norwegian projects.

3.2 Endogenous vs exogenous variables

There are several different interpretations regarding endogenous and exogenous determinants throughout different domains. In macro-economic modelling, endogenous determinants are determined by the model, while exogenous determinants are considered outside the model (Fisher, 1953). Whereas exogenous determinants traditionally are referred to as variables that are beyond the control of an organisation, endogenous variables are adjustable to the extent that the organisation itself can control their values or effects (Isik et al., 2010). Despite the different interpretations, the core thought of exogenous and endogenous variables is that they relate to the set of factors which is to be considered in a decision-making scenario, where exogenous variables relate to those variables external to the decision system, whereas endogenous refer to the ones within (Torraco, 2003).

From a large-scale project management research perspective, the focus of studies has mainly been pointed toward the endogenous determinants rather than the exogenous ones (Catalão, 2019; Catalão et al., 2019). For government projects in particular, one can differentiate between endogenous determinants being different project characteristics, and exogenous determinants relating to the context of, for instance, economic, political and governance factors (Catalão et al., 2019). Table 3.1 beneath is meant to give a perception of some of the differences in the variables that are reported in the literature.

Endogenous	Exogenous
Project size	Annual inflation
Length of implementation	GDP growth
Type of project	Wages in specific sector
Type of ownership	Employment in specific sector
Year of implementation	Amount of national investment in sector
Number of contracts	Election year
Years between the ToD and execution of project	Government stability
Geographical location	

Table 3.1 - Examples of endogenous and exogenous determinants

3.3 Endogenous variables

As explained in the previous sub-chapter, the literature on large-scale projects has mainly focused on endogenous variables as explanatory determinants rather than exogenous variables. This chapter aims to provide an overview of some of the more prominent endogenous determinants that have been studied in the literature. Each determinant will be elaborated on in its own sub-chapter. As mentioned, a summary of the studies that quantitatively provided and pursued findings towards cost performance will be listed along with their most prominent factors in Table 3.2.

3.3.1 Geographical location

Within the literature, different aspects are being explored regarding the geographical location being used as a determinant of cost performance. As will be elaborated in the following section, comparing projects between different countries, regions, larger areas of context, or continents are common practices within the domain. This also goes for different regions within countries, such as municipalities and counties. Furtherly, there have also been studies regarding the differentiation in cost performance for large-scale projects implemented within large cities and outside. Consequently, these comparisons may have the potential to indicate how well an area of interest may or may not perform in contrast to other areas. Despite the arguments in 3.1.5 that comparisons between areas can be troublesome, there are still a number of studies that willingly approach with this task in their studies.

Flyvbjerg et al. (2004) divided their 258 projects into three categories, Europe, North America, and other geographical areas, respectively. Without pointing out the number of projects in each category, North American fixed links -and road projects were found less prone to cost overrun as their implementation phase was significantly shorter than the others'. Using the same set of projects, Flyvbjerg, Skamris Holm, et al. (2003) and Flyvbjerg et al. (2002) found that geography significantly affects cost performance. Specifically, the rail projects within the group of other geographical areas, which consisted of 10 developing countries and Japan, were more exposed to cost overruns than those in North America and Europe, having an average cost overrun of 64% compared to 34,2% and 40,8%. Subsequently, projects in less developed countries suffer more extensive cost overruns than those in more developed countries (Flyvbjerg et al., 2002; Flyvbjerg, Skamris Holm, et al., 2003; Flyvbjerg et al., 2004). However, when comparing Slovenian projects to projects from Norway, Sweden, the USA, Denmark, and Great Britain, considered economically developed countries, Makovšek et al. (2012) did not find that cost overrun was consistently worse for projects in Slovenia, which obtained cost overrun of 30 -and 19 per cent for two different samples of 36 projects in total. Utilising a similar approach, Cantarelli, Flyvbjerg, et al. (2012) found that within a set of 78 Dutch transportation projects, the average cost overrun for 26 rail projects was significantly lower, with average cost overrun of 10,6%, compared to rail projects worldwide with an overage cost overrun of 37,7%. However, the same comparisons made for the road, -bridge, -and tunnel projects were not found to be significantly different.

Ansar et al. (2014) analysed a total of 245 dam projects situated all over the world. With a combination of more straightforward statistical tests, parametric and non-parametric, along with slightly more advanced multivariate regression models, they observed that the 40 projects situated in North America had a substantially lower cost overrun, with a mean of 11%, compared to the dams built elsewhere, that had an average cost overrun of 104%.

Further, it is argued that this phenomenon complies with the theory of anchoring in psychology. In short, the theory regards that decisions based on familiar cases may be biased downwards due to an unrealistic big trust in the belief that projects situated outside a specific area will experience the same success as those located within (Tversky & Kahneman, 1974). Interestingly, although the difference was not found significant, three out of four dams had a North American firm advising the engineering. Braeckman et al. (2019) observed the same for a meta-data set existing of hydropower dam data from Ansar et al. (2014), Awojobi and Jenkins (2016), and Bacon and Besant-Jones (1998) and Le Moigne (1985). The finding that the location to not significantly matter towards cost overrun in the hydropower industry could be explained by the industry being largely globalised and cross-continent corporations being reasonably common (Kirchherr et al., 2017). This, although more regionally based than country-based, opposes previous findings that suggest the governance within a country is correlated with hydropower project performance (Plummer, 2014). However, a continental-based analysis could presumably be too broad and contain too much deviation in governance between countries classified in the same region to catch what previous literature has found on a country-level basis (Braeckman et al., 2019).

Cantarelli, Flyvbjerg, et al. (2012) analysed if there were any differences in cost performance for projects situated in different regions in the Netherlands. Simple statistics showed that projects implemented in the two most populated regions in the Netherlands also suffered the highest average cost overrun with 23% and 33% respectively. The findings are in line with what Welde (2017) found when analysing a set of 78 Norwegian projects. Utilising a student t-test, it was proved with statistical significance that projects implemented in cities have a higher average cost overrun than those situated outside. Næss et al. (2006), on the other hand, could not find any statistical evidence that cost forecasts were underestimated in metropolitan areas compared to non-metropolitan areas for the 70 projects they analysed.

3.3.2 Project size

In trying to understand the explanatory determinants for cost performance, quite a few studies have explored if the inherent size of a project could be one of these. Welde et al. (2019) explain that the approaches and basis of research in the literature when regarding project size have been revolving around asking one of either two following questions.

- Are projects that have higher total costs more often underestimated?
- Are projects with higher cost estimates more often underestimated?

Additionally, it is suggested that the most interesting to look at would be a third definition regarding if the so-called inherent size of a project is relatable to cost performance. Moreover, it is argued that the literature rather often only has studied one of the prior two definitions, seemingly without pointing out which one, but interpreted the analyses as if it was the inherent size they were analysing. The following sections will show some of the literature that has reported results on project size and, to the best extent possible, report on what definition of project size is used.

Bacon and Besant-Jones (1998) explored the estimation of cost and schedules for 135 power generation projects situated in developing countries. Among 18 significant variables in a multiple regression found to be drivers towards cost escalation, 5 of them were related to size, estimated cost being one of them. However, the regression model formed only explained roughly half of the perceived deviation between estimated and final costs. The estimated construction costs were on average 21 per cent lower than what the actual costs were. In line with Bacon and Besant-Jones (1998), Braeckman et al. (2019) partly defined size by capacity in megawatts and dam height and found that increases in size to be related to a rise in cost overrun. The same findings were obtained for Ansar et al. (2014) when they discovered that both installed capacity and dam wall height had significant relationships toward cost overrun. However, in opposition to Bacon and Besant-Jones (1998), neither the value of estimated costs nor actual costs had a significant negative impact on the cost performance.

Flyvbjerg et al. (2004) argue that forecasted costs should be the standard measurement of size, as opposed to the usage of the actual costs. The explanation is two-headed. First, it is argued that cost deviation is statistically spuriously associated with actual total costs, which the forecasted costs are not. Second, the decision variable, namely the decision of whether to proceed with a project or not, is based on the forecasted costs, not the actual costs. Furtherly they were able to obtain numbers on the percentage deviation between total costs and estimated costs for 131 transportation projects. Dividing the projects into different sub-groups without mentioning the number of projects in each group, it was found that larger projects obtained a higher percentage of cost overrun than smaller projects for the bridge -and tunnel projects. Rui et al. (2017) concluded the same for their oil and gas projects and argued that large projects obtained inherently more uncertainty. Flyvbjerg et al. (2004) found no statistical significance when applying the same analysis for the road -and rail projects and all project types together.

In opposition to the majority of previous research, the study of Odeck (2004) suggests that smaller projects suffer a larger percentage of cost overrun than projects that are bigger in size. This was found using sequential regression analysis, evaluating 20 different variables, where only the significant variables were included in the resulting model. Although the findings suggested that smaller projects were significantly more prone to cost overruns, there are some remarks to notice. First, the number of small projects was substantially higher than the larger ones. That is, only 11 projects out of 620 had an estimated cost of above NOK 350 million. In addition, out of the 20 possible indicators going into the evaluation, 17 of them were discarded. The estimated model ended up only being able to explain 21% of the variation in the data set. However, the findings are in line with Cantarelli, van Wee, et al. (2012) arguing that the problem of cost overrun is most critical for the smaller projects in their sample.

In line with Odeck (2004), Samset and Volden (2013) found that there was a larger frequency of cost overrun for the smaller projects compared to the larger ones when analysing 40 Norwegian projects having been through QA2 with available cost frames and total costs. With an extended set of data built upon the ones Samset and Volden (2013) analysed, Welde (2017) and Welde et al. (2019) performed similar analyses to explore cost drivers for cost performance. Welde (2017), with a total number of 78 projects, could not find the same correlation between deviation from the cost frame and project size as Samset and Volden (2013) did. There were tendencies toward larger cost overruns for the largest projects. However, the number of projects above NOK 2 billion was found too small to make any conclusions. Welde et al. (2019) did two distinct analyses in to determine if project size did matter towards cost overrun for their total of 83 projects with obtainable cost frame. When defining project size as projects with high total costs, they found a positive relation toward cost overrun. However, when project size was defined based on estimated costs, there was no relation to be found. Much like Flyvbjerg et al. (2004), and based on Halkjelsvik and Jørgensen (2018), they argue that projects that end up having high total costs naturally also end up obtaining cost overruns due to the statistical and direct mathematical relation between cost overrun and total costs. Additionally, it is remarked that the larger projects within the set may be inherently different from the smaller ones based on factors such as complexity in the execution and that size based on costs may not be comprehensive enough to grasp this.

3.3.3 Project type

There are different types of projects that may be referenced as megaprojects. Some examples are Ansar et al. (2014) analysing hydropower dams, Bacon and Besant-Jones (1998) exploring hydroelectric -and thermal power plants, Dahl et al. (2017) looking at petroleum projects, and Odeck et al. (2015) researching road projects. Accordingly, there have been scholars differentiating their analyses on project type to perceive whether there exist differences in cost performance and determinants between the types.

Ansar et al. (2016) argue that road and rail projects have lower mean cost overruns than dam projects and nuclear power plants based on comparisons to the analyses of dams in Ansar et al. (2014) and nuclear power plants in Schlissel and Biewald (2008). Sovacool et al. (2014) analyses' of different power generation projects proved that hydroelectric dams suffered the largest cost overruns. Bacon and Besant-Jones (1998) found that cost performance deviated much between the different types of power plant projects. Here, thermal projects had an average cost underestimation of 6 per cent, whereas hydropower projects averaged a 27 per cent underestimation. Furtherly, it was concluded that regression analyses should be divided on project type if wanting to reduce variability in cost performance.

Cantarelli, van Wee, et al. (2012) found that Dutch rail projects performed better compared to the road and fixed link projects, whereas road projects were the most prone to cost overrun. Further, these results are claimed to oppose findings in the literature, where rail projects are commonly found to be the worst. However, Welde (2017) indicated that the Norwegian road projects obtained a larger cost performance uncertainty than other project types such as construction -and rail projects.

3.4 Exogenous variables – An economic approach

Exogenous variables may affect the estimates and outcome of projects but cannot be controlled by the project forecasters or owner (Welde et al., 2018). This sub-chapter is set to give an overview of the relationship between exogenous economic variables, project estimates and cost performance. First, it is provided with a short background on how macroeconomics and economic macro variables affect large-scale projects, the implications of their importance and how they are concerned in project estimating in Norway. Second, a brief look will be pointed toward the theory of business cycles. At last, relevant studies in the literature that have researched the potential relationship between exogenous economic variables and the cost performance of projects will be in focus.

3.4.1 The importance of considering economic variables

Macroeconomics is a field of study where the overall aggregate performance of the entire economy is in focus (Barro, 1997). The main objective and core thought is to analyse what determinants that drive the main trends in the economy. This refers to the total output of goods and services, inflation, and unemployment, but also wage rate, interest rate, and the exchange rate, which all, to a different extent, can give a picture of the economy as a whole (Barro, 1997; Blanchard & Sheen, 2013; Snowdon & Vane, 2005). There lies vast importance for government policymakers to understand the factors that determine both the long-run growth and the short-run fluctuations in the economy to implement and ensure a stable and predictable economy, as satisfactory macroeconomics is of crucial importance for a country (Snowdon & Vane, 2005). Unstable economies, including widespread corruption, have been one of the main challenges towards developing sustainable and long-lasting successful large-scale projects in developing countries (Brookes & Locatelli, 2015; Tabassi et al., 2016). Supplementarily, it is likely as important for project forecasters to understand the underlying dynamics in the economy and know have to act on them accordingly to apply the best estimates possible (Catalão et al., 2019). For example, to robustly estimate construction costs, the forecasters need extensive knowledge of the labour and product markets (Snyman, 2007).

To cope with large cost overruns for government projects, several countries have introduced quality assurance schemes that, among other concepts, include guidelines regarding essential variables to be monitored (Samset et al., 2016). The activity of monitoring variables considered to have inherent systematic uncertainty is an important part of the forecasting process to ensure reliable cost estimates and successful cost performance for large government investment projects in Norway (Berntsen & Sunde, 2004). Two of the factors that are to be considered when estimating project cost are the following.

- Currency uncertainty
- Market uncertainty in the construction industry

The currency uncertainty factor is included mainly due to its dominancy among the factors of uncertainty in military projects, whereas the market uncertainty in the construction industry is included because the development in this respective market is the most prominent uncertainty for most of the road projects in Norway (Berntsen & Sunde, 2004). Given the prerequisite within the economic theory that the actors seek to optimise their own welfare, it is reasonable to assume that a project owner seeks to maximise the value of the project while a contractor aims to maximise its own profits (Englund et al., 2013). The dynamics between the project owner and the contractor play into the market uncertainty (Lo et al., 2007). A pressured contractor market would likely generate low competition for the contract and lead to higher prices for the project, whereas if there is low activity in the market, the contractors would have a more substantial need to gain contracts that may lead to higher competition and a lowering in prices (Welde et al., 2018). Berntsen and Sunde (2004), concerning the market uncertainty, proposed an equation reflecting the underlying uncertainty in the market based on the years between the ToD and the first contract initiation

$$Market\ uncertainty = \pm 6\% * \sqrt{N}.$$

In addition, they are recommending that the yearly indicative standard deviation should be set to 6 per cent. In later years, it has been settled to use more advanced and resourceful methods to calculate the uncertainty analysis, that in return, have proven to be useful (Welde et al., 2019).

3.4.2 Business cycles and related indications

The phenomenon where the economy in modern markets recurrently fluctuates between upturns and downturns of variating degrees is defined as business cycles (Bodie et al., 2014). Already back in the early 1900s, Burns and Mitchell (1946) described business cycles as fluctuations in the economic activity of nations, where business enterprises are predominant and specifically consist of expansions followed by recessions merging into the next cycle, creating a recurrent but not periodic sequence. Zarnowitz (1992) argues that economic activity should be measured with reliable and comprehensive measures such as employment, real income, and real expenditures. When evaluating business cycles, it is generally measured and analysed by looking at the deviations between the current GDP and long-lasting trends for GDP. In particular, business cycles are differentiated between expansions and recessions, where expansions occur when the GDP level is above the trend level, and recessions occur when the GDP level is beneath (Johansen & Eika, 2000). Below is a visualisation of a calculated GDP trend line and the business cycles between 1970-2022 in Norway. Here, the trendline is equal to the zero-level, while the graph itself shows the yearly deviations. Exactly how the visualisation has been extracted will be discussed further in chapter 4.5.

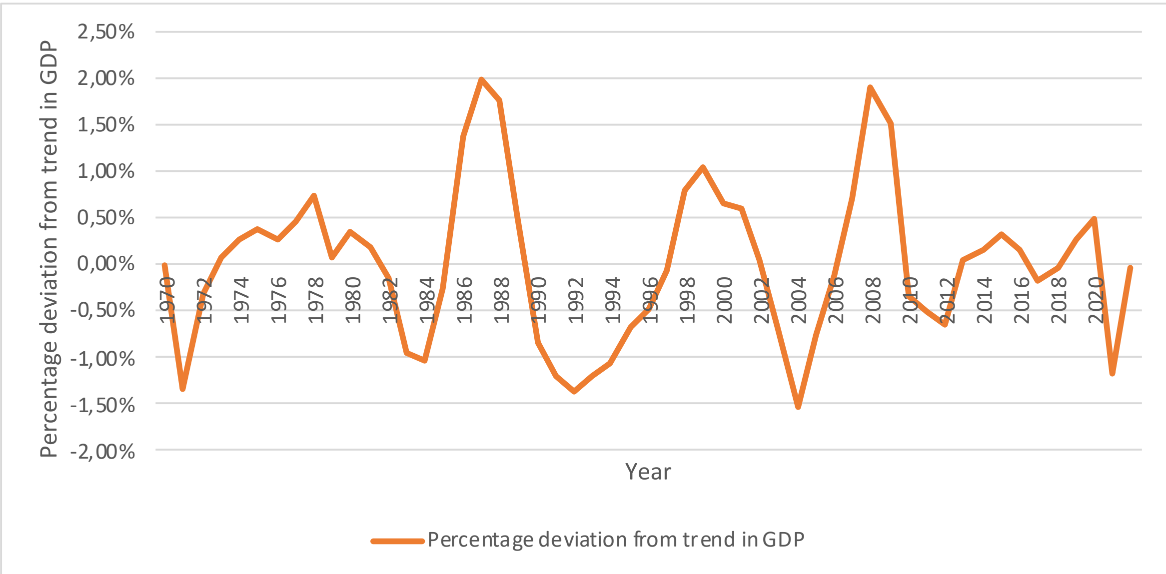


Figure 3.1 - Percentage deviation from trend in GDP Mainland Norway

In particular, the figure shows a clear deviation between the short-term fluctuations and the trendline for some distinct areas. For example, there is an apparent business cycle downturn between 2008 and 2011, while an upturn between 2004 and 2008 may also be seen. It is out of the scope of the report to extensively elaborate on different theories of what drives GDP and business cycles, including all influences, causes and results of the varying GDP growth and trend. The most important takeaway from the cyclical behaviour of business cycles, in this case, is how they could possibly affect cost performance for large government investment projects. However, examples of exogenous macro variables that may affect large-scale projects are those largely influenced by the business cycles, such as the rate of employment, the Consumer Price Index and Gross Domestic Product (Welde et al., 2018).

3.4.3 Literature on economic factors

For the construction industry, there have been proven several consequences in relation to upswings in the business cycle due to a higher demand for building projects in general (Hillebrandt, 2000). The list below shows a selection of these consequences, presented in Snyman (1989) and Bon (1998).

- Labour rates, building materials and plant prices tend to accelerate.
- Discounts on building material prices, from suppliers to contractors, are reduced.
- Labour productivity declines as a result of a shortage of skilled employees.
- Contractors grab the opportunity to increase their profit margins to maximise current profits or make up for previous losses.

Snyman (2007) argues that all the cyclical factors presented above are prominent in the sharp rise of tender prices during a growth phase of the business cycle. Furtherly, the study concludes that during expansions, the projects usually experience cost-increasing scenarios in relation to the tightened supply of labour and material. Consequences opposite to those related to expansions would apply during recessions. In short, it is argued that productivity would likely improve, competition would intensify, and tender prices would rise less quickly.

Welde (2017) and Welde et al. (2019) also argue that for large government projects in general, one tends to experience lower productivity and higher margins for different products during an expansion, while during a recession, the experience has in periods been the opposite, namely that market prices has gone significantly down. Welde et al. (2019) explain, much in line with the arguments of Bon (1998) and Snyman (1989) about the lack of skilled employees, that a pressured market will result in higher costs for the contractor -and supplier services. In Africa, Rui et al. (2017) point out that the lack of qualified staff is a significant factor to cost overruns. Dahl et al. (2017) exemplify the problem and argue that projects may have to employ contractors that not necessarily would have been chosen if the market was in a downturn. Welde et al. (2019) state that although uncertainties in the market are to be included when doing the initial estimations for large government projects, it is argued to be difficult to fully foresee both a rise in commodity prices and a lack of capacity within both the contractor -and supplier market. In other words, it is claimed there exist projects where market uncertainties have been a main concern but still experience even higher prices than estimated for. A remark is in example given to the construction cost index for road construction (CCI) that is used to calculate the input factors for projects in the infrastructure sector. The index includes hourly rates for workers and material prices but not the prices in the market directly. Pickrell (1992) pointed out that the price of construction services had risen quicker than the broader indices measuring prices in the economy at the time of the study. Berntsen and Sunde (2004) explain that historically, the difference in the CCI and the actual market development have been of such volume that it should be regarded as a systematic uncertainty when being addressed during the development of new projects. Despite the recommendation, based on deviations still seen today, it could look like one still has not been able to favourably adjust the estimates accordingly (Welde et al., 2019).

Concerning the pressure in the market, Welde et al. (2019) point out that in the years before the financial crisis, the government initiated especially many large-scale projects. Additionally, it is argued that since the state of Norway is considered an important client for infrastructure projects in Mainland Norway, initiating a vast number of projects when the economy is seemingly at a high could have a huge influence on the capacity in the market, and followingly be unfavourable if wanting to avoid cost overruns. This phenomenon, that large-scale investments could potentially affect the market situation in specific sectors, has been explicitly studied in Englund et al. (2013). Here, it is pointed out that the market situation can be influenced in mainly two different ways.

- The government investments may affect the competition in the markets in the sectors where the investments are taking place.
- Government purchasing of goods may lead to competition-related problems in the market where the purchases are made.

The first instance relates to the effect the government investment projects may have on a market already pointed out by Welde et al. (2019). Englund et al. (2013) point out that the latter relates to the exploitation of the governmental buying power in combination with the possibility the government may have towards demanding the suppliers to finish the projects in focus, seeing that these often are of high priority and value. In other words, initiating a high value of projects at the same time may negatively influence the cost performance of the respective projects in several ways (Englund et al., 2013; Welde et al., 2019).

Dahl et al. (2017) studied 277 large petroleum development projects set out on the Norwegian continental shelf by 39 private companies. Following the core thought that a problematic supplier market and lack of capacity and expertise among employees yield difficulties in managing projects, they investigated particularly the effect reoccurring business cycles had on the cost performance for large petroleum projects. Among the projects, they could document that oil price developments had a statistically significant relationship with cost overruns. Both Dahl et al. (2017) and Oglend et al. (2016) found that changes in the number of employees, defined as the relative change in employees on the Norwegian continental shelf between the current year and the year of the time of the decision to build (ToD), had a significant positive relationship with cost overruns for oil and gas projects. Further on, Dahl et al. (2017) argued that the findings support the hypothesis regarding business cycles affecting cost overrun, seeing that project costs were seen to increase more during times of expansion in the economy. As a concluding mark, and similar to what has been stated about expansions from before, it is also claimed that a tight labour market both affects higher margins as a consequence of higher wages and followingly higher project costs, but also has the effect of reducing productivity by having the average competence in the working stock being reduced, which effectively reduces the capacity to follow up and control the projects.

Makovšek et al. (2012) did a study investigating the claim that less developed countries experience significantly larger cost overruns than more developed countries (Flyvbjerg et al., 2002; Flyvbjerg, Skamris Holm, et al., 2003; Flyvbjerg et al., 2004). In pursuing this research goal, they found among other factors, that prices of construction services and products were problems relating to cost overruns. During the period in which the study has gathered project data, the volume of general construction per year also increased threefold compared to the period of 1970 to 1994. For the 36 projects, a sample of 20 of them, which were the only projects with obtainable total project costs, it was found with statistical significance that construction costs had the greatest impact on worsening the cost performance. Furtherly, it was concluded that there is no evidence to show that projects in Slovenia, here defined as a less-developed country, have projects performing systematically worse than the sample of

Flyvbjerg, Skamris Holm, et al. (2003). In addition, it is argued that the low mean systematic cost overrun among the projects, despite what is considered unfavourable circumstances such as a tight market situation, limitations in historical data, experience, and resources in general, could possibly be explained by the political favourability of road infrastructure in Slovenia compared to other transportation expansions. At last, it is also remarked that economies, especially those that experience frequent changes and market fluctuations, should be considerably aware of these factors when analysing and estimating cost performance.

Ansar et al. (2014) included several exogenous variables in the search to find the variables that could be related to the cost performance for their 245 dam projects. The following were some of these.

- GDP of the country where the dam project was implemented.
- The average actual cost growth rate in the country for the implementation period.
- Long-term inflation rate.
- The actual average exchange rate between the ToD and project finish year.

Using a multivariate regression model including 21 variables, it was identified that the long-term inflation rate within a country is significantly related to the worsening of cost performance. In this case, the long-term inflation rate is referred to as the calculated fitted line of a linear model to the log of the prolonged time series of the GDP deflator index. This is regarded as a common practice in many countries when wanting to analyse long-term inflation rates (Ma, 2010). The fitted line is followingly interpreted as the annual average growth rate. Since it takes many years of eventual deviations in the inflation to change this growth rate, it is considered a reliable predictor in the short-run (Ansar et al., 2014). Ansar et al. (2014) argue that countries with considerably high long-term inflation rates have a larger chance of suffering cost overruns for their dam projects than countries with lower-growing trends in their inflation rates. Bacon and Besant-Jones (1998) found the same relation for their hydropower projects.

Pickrell (1992) remarked that cost forecasters should ensure not to neglect the effects of unanticipated inflations. Furtherly, the study indicated that unanticipated escalation in inflation and therefore prices of construction costs, largely contributed to cost increases for the projects. However, the findings suggested that the forecasters underestimated the rate of price inflation only in one of the projects, whereas the other projects experienced a higher rate of inflation than anticipated during construction entirely due to project delays. Ansar et al. (2014) claimed that large dam projects were severely prone to experience unanticipated inflation and proved that forecasters, on average, expected the average inflation rate to be 2,5 per cent but ended up being 18,9 per cent. Since the early 2000s, Norway has used inflation targeting as its monetary policy (Røisland & Sveen, 2005). This policy is characterised by having an announced inflation target within the respective monetary union and allows for a high degree of transparency and accountability (Svensson, 2010). Inflation targeting as a monetary policy has the power to lessen the effects of shocks in the aggregate demand and hence stabilise prices (Bernanke et al., 2018)

Catalão et al. (2019) have been much at the forefront of investigating the importance of exogenous determinants towards cost performance in transport projects. With 1091 Portuguese government projects, they specifically aimed to quantitatively study exogenous economic, political, and governmental – determinants that could relate to cost performance. Using different regression methodologies, they found among several exogenous determinants that both inflation and economic growth were relevant factors for the worsening of the cost performance of the projects. The latter is argued to fit into the phenomenon that governments in control of more money than historically usual tend to slack off control mechanisms related to spending and followingly increase the probability of cost overruns (Siemiatycki, 2009). Catalão (2019), Catalão et al. (2019), and Pinheiro Catalão et al. (2019) all found that the financial crisis led to fewer cost deviations, arguing that since the government had less money on their hand, the increase in spending control ensured this. In compliance with the indications from Welde et al. (2019) and Englund et al. (2013), Catalão et al. (2019) also found that having a greater public investment as a percentage of GDP was related to obtaining higher deviations in the cost performance. The latter result is in accordance with the findings of Pinheiro Catalão et al. (2019), which found the same to be true for the 4305 local infrastructure projects they studied. Further, it is pointed out that there lies fundamental importance within knowing the economic dynamics when investigating and initiating an infrastructure project.

3.5 Summary of studies on project data

This chapter presents some of the studies in the literature that have provided statistical results on cost performance for large-scale projects. The studies that provided findings regarding determinants significantly related to cost performance are listed with these. The determinants are divided into two columns, *exogenous* and *endogenous*, respectively. For the most part, the studies analysed what would be regarded as large-scale projects or megaprojects. However, despite not necessarily analysing large-scale projects, some studies are included due to their interesting perceptions and findings. Since the table mainly is meant to function as a way to get an overview of the different studies and not as a comprehensive list of comparisons, the *average cost per project* column is not recalculated to fixed prices. The list is ordered alphabetically on the authors' names.

Study	Average cost per project	Type of projects	Number of projects	Average cost overrun	Exogenous determinants	Endogenous determinants
(Ansar et al., 2014)	$1441 million USD	Dams	245	96 %	-Long-term inflation rate	-Size -Implementation length
(Ansar et al., 2016)	$684 million USD	Road and rails	95	30,60 %	N/A	-Project type
(Awojobi & Jenkins, 2015, 2016)	$1036 million USD	Hydropower dams	58	27 %	N/A	N/A
(Bacon & Besant-Jones, 1998; Bacon et al., 1996))	Between $3,2-$1782 million USD	Power generation	135	21 %	-Local inflation	-Project type -Size
(Blanc-Brude et al., 2006; Blanc-Brude et al., 2009)	20 mill euro -> 300 mill euro	Transportation	227	24 %	N/A	-Ownership
(Braeckman et al., 2019)	$979 million USD	Hydropower dams	184	43 %	N/A	-Size
(Callegari et al., 2018; Sovacool et al., 2014)	$2045 million USD	Power plants and transmission	401	66,30 %	N/A	-Project type
(Cantarelli, Flyvbjerg, et al., 2012; Cantarelli, Molin, et al., 2012; Cantarelli, van Wee, et al., 2012)	147 million Euros	Transportation	78	16,50 %	N/A	-Project type -Location -Size -Implementation length
(Catalão et al., 2019)	2.6 million Euros	Transportation	1091	11,54 %	-Right-wing government -2008 EU regulatory framework -Inflation -Economic growth -Greater public investment in of % GDP	-Size
(Catalão, 2019; Pinheiro Catalão et al., 2019)	N/A	Infrastructure projects	4305	19 %	-Greater public investment in of % GDP -Financial crisis -Election periods	N/A

Study	Average cost per project	Type of projects	Number of projects	Average cost overrun	Exogenous determinants	Endogenous determinants
(Creedy et al., 2010)	Above $1 million AUD	Transportation	231	16 %	-Uncertainty	-Changes in project design -Changes in scope
(Flyvbjerg et al., 2002; Flyvbjerg, Skamris Holm, et al., 2003; Flyvbjerg et al., 2004)	$349 million USD	Transportation	258	28 %	N/A	-Ownership -Size -Location -Implementation length
(Dahl et al., 2017)	41 000MNOK - 200 000MNOK	Petroleum	277	N/A	-Employment surprise -Policy implications -Oil price	-Size -Implementation length
(Lee, 2008)	$271 million USD	Road, Rail, Airport, Port	161	27,45 %	N/A	-Scope changes
(Love et al., 2014)	Above $1 million AUD	Transportation	58	13,28 %	N/A	N/A
(Lundberg et al., 2011)	Above 500 million SEK	Road and rails	34	20,325 %	N/A	N/A
(Makovšek et al., 2012)	2,9 mill euro -> 431 mill Euros	Roads	20 36	30% 19%	N/A	N/A
(Miranda Sarmento & Renneboog, 2017)	N/A	Public Sector	243	24 %	-Election Year -Central gov. Worse than local and regional	-Size
(Odeck, 2004)	From NOK15 million to above NOK350 million	Transportation	620	9 %	N/A	-Size - Higher percentage for smaller projects
(Odeck et al., 2015)	Above NOK500 mill	Roads	40	47,50 %	N/A	-Size - Higher percentage for smaller projects
(Oglend et al., 2016)	12000MNOK	Oil & Gas projects	80	21 %	-Employment surprise	N/A
(Rui et al., 2017)	$765 million USD	Oil & Gas projects	206	18 %	-Government stability -Employee capacity -Content policy	-Size -Location
(Samset & Volden, 2013)	Every project above NOK500 million	Infrastructure and military projects	40	N/A	N/A	-Size - Higher percentage for smaller projects
(Terrill, 2016)	Every project above $20 million AUS	Transportation	836	24 %	N/A	-Prematurely announced projects
(Welde, 2017)	Every project above NOK500 million	Infrastructure and military projects	78	2,30 %	N/A	-Size -Location - Project in city/not
(Welde et al., 2019)	Every project above NOK500 million	Infrastructure and military projects	83	3,40 %	N/A	-Size

Table 3.2 - Summary of studies on cost performance. Extension from Spildrejorde (2021)

As one can perceive, some different determinants found to be relevant for the cost performance of the projects studied. Remember that most of the studies analysed their projects towards a wider range of determinants than what are listed here. The determinants listed are purely the ones that were found statistically relevant. The upcoming statistical analyses will regard the exogenous determinants. In specific, the focus is turned toward the exogenous macro variables. The variables related to the sub-group of exogenous economic determinants found relevant in the literature are shown beneath in Table 3.3.

Exogenous economic macro variables
Employment surprise
Greater public investment in % of GDP
Inflation
Economic growth
Financial crisis
Per capita income
Local inflation

Table 3.3 - Summary of exogenous economic macro variables

The economic exogenous variables regarded in the analyses in chapter 5 are based on the ones in Table 3.3, other variables in the literature that were not necessarily found statistically significant towards cost performance, and some additional ones. Accordingly, these are all mentioned in chapter 4.3.2.

4 Quantitative research method

4.1 Short on quantitative and qualitative method

In broad terms, qualitative -and quantitative methods are the two main methods which divide all research. Qualitative research is recognised for its non-quantifiability and is often based on textual information, obtainable by, thorough questioning of a study object (Olsson, 2011). On the other hand, quantitative research generally uses experimental methods to test hypotheses and evaluate the relationship between one or more numeric variables (Bjørnnes & Gjevjon, 2019; Yin, 2018). In quantitative research, the experimental design, involving the manipulation of at least one independent variable and the evaluation of whether it has any relation to a given dependent variable, has become the most used approach (Lewin, 2005). Silverman (2015) presents four simple-minded differences between qualitative and quantitative research. The following table, showing these differences, is adapted from Justesen and Mik-Meyer (2012) and presented in Silverman (2015).

Quantitative research	**Qualitative research**
Generates data for appliance in numerical analysis	Describes phenomena in context
Uses statistical calculations	Interprets processes or meanings
Uses statistical software and pre-tested scales	Uses theoretically based concepts
Seeks explanations and correlations	Seeks understanding

Table 4.1 - Differences between quantitative -and qualitative research

Arguments have been made that quantitative and qualitative methods make up a so-called continuum, and that the two methods are not clearly different (Iversen, 2011). However, the choice of research method primarily depends on the research questions addressed along with the type of data available (Lowhorn, 2007). In this regard, a quantitative research method has been chosen for the data analysis. More specifically, the report will regard the experimental design described by Lewin (2005) as it is sought to understand the relations between a larger amount of obtained data through numerical data analysis.

4.2 Measurement standards

Flyvbjerg et al. (2018) claim to have identified a best practice, consisting of four points of matter, for how to evaluate and calculate cost overrun among large-scale projects:

- Measuring cost performance in percentage deviation of estimated cost.
- Measure cost in local currency.
- Measure cost in constant prices.
- Measuring against a congruent, concise baseline.

These regards measuring and evaluating cost overrun, or rather cost performance, are also used as the baseline in this report. Measuring in percentage cost overrun along with the usage of local currency allows for precise comparability of results between studies (Flyvbjerg et al., 2018). The measuring in constant prices allows for projects having estimated costs and total actual costs in different years, which is usually the case for large government investment projects, to have the two cost figures compared on the same price level. In other words, following good practice, one should price adjust the estimates such that they are represented in the same years' prices and indeed are comparable (Bailey et al., 1963). At last, the fourth point refers to the importance of using the same baseline for when the estimated costs are calculated to ensure stability in the figures (Cantarelli et al., 2013). In this report, all initially estimated costs, that goes for the steering frame and cost frame, will refer to the frames decided at the Parliamentary decision, hence after the QA2. This is in line with what the literature refers to as the "Time of decision to build" (ToD) and is a consequent baseline when wanting to measure the decision-making capabilities or the accuracy of the information available for the decision-makers (Flyvbjerg et al., 2018).

4.3 Data collection

4.3.1 Project specific data and adjustments

The data about the projects in the report are taken from Trailbase. This is the central database used by the research program Concept to do research on and evaluate large government investment projects in Norway. This data includes the information about the contract initiations that were obtainable through media clips and other documents stored in Trailbase. The projects registered in Trailbase have all, at some point in time, been subject to, or are going to be subject to, the Norwegian State project model. For this report, all projects analysed have undergone QA2 per March 2022. Furthermore, they have all both estimated costs and total costs available so that it is possible to do the necessary comparisons, calculations, and analyses.

Most of the projects within Trailbase are already price adjusted, such that the estimated costs and the total costs are given at the same price level. However, the adjusting has been done manually for those projects where this does not apply. Seeing that the projects that needed to be price adjusted were road projects, they were all adjusted using the construction cost index for road construction delivered by Statistics Norway (Statistisk sentralbyrå). Using this particular index for price adjusting road project costs in Norway is the same method used by The Norwegian Public Roads Administration (Statens vegvesen) (Welde, 2014). For factual information, The Norwegian Public Roads Administration is the executive agency subjected to The Ministry of Transport, which is the responsible department for all major government road projects in Norway.

4.3.2 Exogenous economic variables

Although the project-specific data was obtainable through Trailbase, the exogenous variables used in this report had to be found elsewhere. For this matter, Statistics Norway has been used. Statistics Norway's main task is to clarify the need for official statistics, maintain and develop a national system for statistics, produce it and use the statistics for analytical purposes (Sentralbyrå, 2017). They are Norway's National Statistical Institute and are the leading provider of quality statistics that can, and are meant to be, used for a wide range of applications and analyses (Bjerkholt, 2000). The following factors have been obtained through the databases of Statistics Norway.

- Consumer Price Index – Adjusted for tax changes and excluded for energy goods.
- Wages for employees within construction work.
- Number of employees within construction work.
- Gross Domestic Product (GDP) for Mainland Norway.
- The construction cost index for road construction.
- I-44, the Import-weighted krone exchange rate.

Within the Statistics Norway database, all of the available statistics are gathered through different indexed tables. It will be stated clearly in the results which particular table from

Statistics Norway that has been used to obtain the variable or index. If necessary, it will also be explained how it has been re-adjusted to represent the wanted factor.

4.4 Regression analysis

4.4.1 Linear regression analysis

Regression analysis is one of the most popular methods applied for multifactor data analysis due to its conceptually logical usage of expressing relations between variables using equations (Montgomery et al., 2021). In particular, regression analysis is a valuable tool to get more insight into problems where multivariate data is to be found (Løvås, 2008). Within the broad field of regression analysis, one has a more specified field called linear regression analysis. Linear regression analysis is a statistical method used for analysing and exploring possible relations between different variables obtained from a set of related data by approximating a linear equation to the corresponding variables to be explored (Alexopoulos, 2010; Montgomery et al., 2021). Linear regression can be divided into three different methods depending on how many variables that are included in the analysis (Løvås, 2008; Montgomery et al., 2021).

1. *Simple linear regression* – One independent variable and one dependent variable.
2. *Multiple linear regression* – Multiple independent variables and one dependent variable.
3. *Multivariate multiple linear regression* – Multiple independent variables and multiple dependent variables.

The analyses considered in this report are solely simple linear regressions.

As explained, the core idea behind linear regression is that the relationship between the variables within the model can be expressed by a linear mathematical model or equation. The general form of a linear regression model can be written as done below (Yan & Su, 2009).

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon.$$

In the model, *n* denotes the total amount of independent variables. Further on, Y represents the dependent variable that is to be considered to have a linear relationship with the independent variables. The independent variables are denoted x_i, where *i* refers to the i^{th}

independent variable. Moreover, all the coefficients denoted β_1, β_2, …, β_n are called the regression coefficients. Each regression coefficient β_i represents the mean increase in Y per unit increase in x_i, assuming the other independent variables are kept fixed (Alexopoulos, 2010; Montgomery et al., 2021). β_0 refers to the interception between the modelled linear line and the y-axis. The β_i-values are estimated during the application of the regression analysis and are unknown before the analysis, as opposed to the Y -and x_i values. The last term in the model is ε. This term represents the error term and describes the value of the dependent variable when no change in the independent variables is regarded (Løvås, 2008). Generally, the error term ε is assumed to follow the normal distribution with an expected value of zero, an unknown variance σ^2 and additionally be uncorrelated to the other errors in the distribution (Montgomery et al., 2021; Yan & Su, 2009).

The simple linear regression model is obtained by only using the variables β_0, β_1, x_1 and ε on the right side of the previous equation. In compliance with the definition of the simple linear regression model, the equation will take the form shown below.

$$Y = \beta_0 + \beta_1 x_1 + \varepsilon$$

With the observation and collection of all the data, that is, the values of the independent variables and the dependent variable, the regression analysis is usually computed utilising statistical software. The regression analysis computation will result in estimations for the regression coefficients β_I and β_0, the error terms ε and other indicators which may be used to observe and analyse the validity of the proposed model (Menard, 2002). To obtain a calculated model, it is necessary to collect a set of observations that can be applied to the model (Løvås, 2008). The observations obtained for a simple linear regression model can be described mathematically using the equation below.

$$Y_i = \beta_0 + \beta_1 x_{1i} + \varepsilon_i.$$

It is the gathering of all the observations and the assumption of their dependency on the multiple or single dependent variable(s) that constructs the estimated linear model in the end. For the analyses done in this report, Y always represents the percentage deviation in cost between actual costs and cost -or steering frame. All analyses are done in Microsoft Excel. Additionally, the analyses will mainly elaborate on the p-values obtained, explaining the significance of the relationship between the dependent -and independent variable. Since the several variables influence the cost performance for the projects, the R^2 measurement is not emphasised as the analyses in this report are to be regarded as indicating potential relations rather than finding the model best explaining the total picture of cost performance indicators. A relation is deemed significant if the p-value is 0,05 or beneath, which is a commonly used threshold within statistics (Løvås, 2008)

4.4.2 The method of ordinary least squares

To estimate the best model for the observed and applied data, linear regression uses the method of ordinary least squares. First of all, the method is used to calculate the regression coefficients β_0, β_1, …, β_n (Montgomery et al., 2021). The least square method principle for simple linear regression is to estimate β_0 and β_1 so that the sum of the squared distance between the dependent variable Y_i for each observation and the resulting model, being the calculated trendline, reaches the minimum value for all possible choices of the regression coefficients β_0 and β_1 (Montgomery et al., 2021; Yan & Su, 2009). Mathematically, the principle can be described as such (Yan & Su, 2009).

$$(b_0, b_1) = \arg \min_{(\beta_0, \beta_1)} \sum_{i=1}^{n} [y_i - (\beta_0 + \beta_1 x_i)]^2.$$

Here, b_0 and b_1 represent the fitted regression coefficients for the linear regression model. The overall motivation behind the method is to find the estimation of parameters by implicitly calculating the linear trendline, which is the closest one to all the observations (x_i, y_i) combined (Yan & Su, 2009). The theory regarding the method of ordinary least squares is the same for multiple linear regression as for simple linear regression. That is, the estimation process for multiple linear regression includes a larger amount of regression coefficients seeing that there is more than one independent variable. Here, the principle has purposely been explained for simple linear regression.

4.4.3 Assumptions of linear regression

In addition to the core assumption that a linear relationship exists between the independent and dependent variable, there are three main assumptions of a simple linear regression (Løvås, 2008). They all regard the residuals in the model, being the difference between the observed and the fitted value of the dependent variable. Furtherly, the assumptions are listed below.

- Homoscedasticity – The variance of the residuals is constant and independent of the value of the independent variable.
- Independence – The residuals are independent of each other, with no correlation between successive residuals in the time series.
- Normality – The residuals should be approximately normally distributed.

If the listed assumptions are not met for the model used, the obtained p-value will not be justifiable and, the potential significance of the independent variable is to be questioned. It is appropriate to generate residual plots to validate the assumptions for the models at hand (Montgomery et al., 2021). One plot for each assumption. The residuals' independency from each other is commonly regarded as the most crucial assumption, whereas the normality distribution is deemed the least important as an approximately normal distribution is considered sufficient (Løvås, 2008). The Appendix in this report will regard residual plots for all analyses deemed relevant to investigate further. The plots are given in the following order. First, a scatter plot will be used to analyse the homoscedasticity. Here, the assumption is deemed valid if no pattern in the values is seen. Second, based on the time of the ToD, the independence between the residuals is analysed. Arbitrary leaps in the consecutive values will validate this assumption. Third, a visualisation of the residual distribution is shown to analyse if the residuals approximate a normal distribution. In this report, all the assumptions are fulfilled for the models of interest.

4.5 Hodrick-Prescott filter

A Hodrick-Prescott filter, HP filter, can be used to estimate and analyse the long-term trend within a time series (Hodrick & Prescott, 1997). Although there is a range of different methods which are used for the same application, the HP filter has become the standard within the literature on business cycle analysis (Benedictow & Johansen, 2005; Ravn & Uhlig, 2002). This is the main factor why this particular method is chosen for this report. Essentially, the method aims to estimate the deviation between actual production and the potential production, called the production gap, by defining the potential production as a smoothing of the actual production (Benedictow & Johansen, 2005). With the assumption that the potential production varies in a smooth manner over time and that a cyclical curve exists, the HP filter estimates the deviations in the production gap, minimising the following formula (Hodrick & Prescott, 1997).

$$\min\left(\sum_{t=1}^{T}(y_i - g_t)^2 + \lambda\sum_{t=1}^{T}[(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2\right)$$

In the formula, g_i represents the potential production for a given time t, while y_t represents the actual production at the given time t. The first part of the formula or equation is the squared difference between actual and potential production. The second part of the equation is the squared change in the growth of the potential production. Further, the parameter λ is a positive value chosen by the performing analyst based on how well it is assumed to predict the actual trendline (Benedictow & Johansen, 2005). Essentially, the parameter λ penalises the variability in the potential series, the larger the value, the smoother the resulting series will be (Hodrick & Prescott, 1997). For a straightforward interpretation, the function of the parameter λ can be explained by using its two extreme values. If the value of λ equals 0, the second part of the equation will 0. Followingly, *y* will equal *g*, and the production gap will be 0 at any point in time. On the other hand, if λ is set to be close to infinite, it is only the variation in the second part that practically will be evaluated, and the trend will become constant. Due to the extensive work it is to assess precisely what value of λ is most suitable for a certain time series, the choice of the value for the parameter is based on suggestions from the literature.

There have been several suggestions as to what the value of λ should be when analysing business cycles using annual GDP data. Both Ravn and Uhlig (2002) and Marcet and Ravn (2004) suggest that the value should be as low as 6,25. Backus and Kehoe (1992) suggest a value of 100, while Cooley and Ohanian (1991), on the other hand, claim that a value of 400 supplies good results. Nonetheless, to capture the deep and prolong recession that was predominant in Norway in the late 1980s, it is necessary to choose a high value of λ to get a trendline which matches the underlying picture of the GDP in Norway over time (Johansen & Eika, 2000). Accordingly, the value chosen for the parameter in this report is 400. As this value has been reported good in the literature along with the argument from Johansen and Eika (2000) about the necessity of choosing a high value, it should be a reasonable choice. Below, in Figure 4.1, is a visualisation of how the business cycles and deviation from the calculated trend in Norway are to be viewed when applying λ=400 to the Hodrick-Prescott filter. As a comparison, the visualisation when using λ=40,000 to the filter is also shown in Figure 4.2 to perceive the difference in smoothing and values.

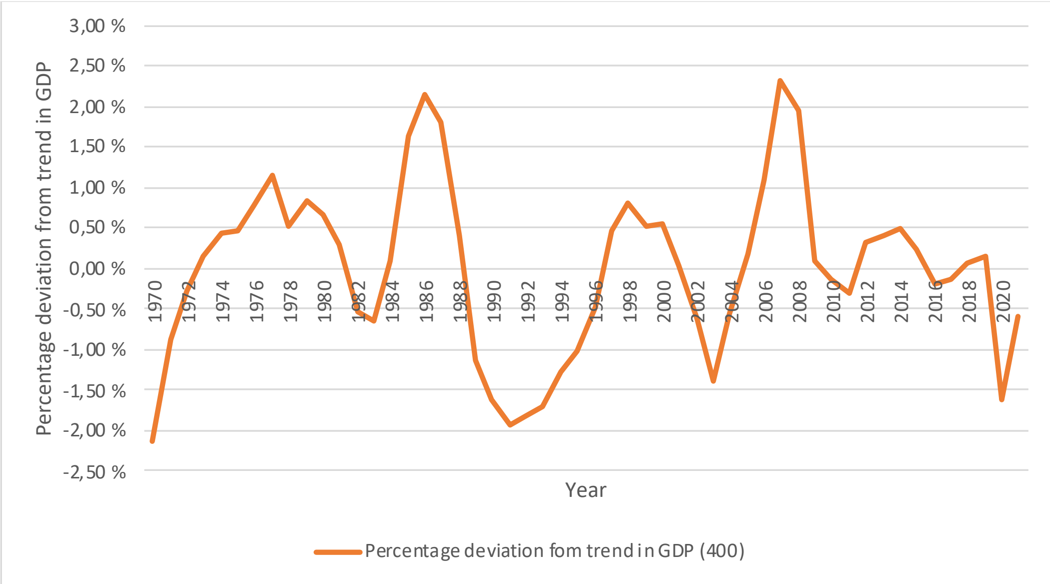


Figure 4.1 - Percentage deviation from trend in GDP Mainland Norway with λ = 400

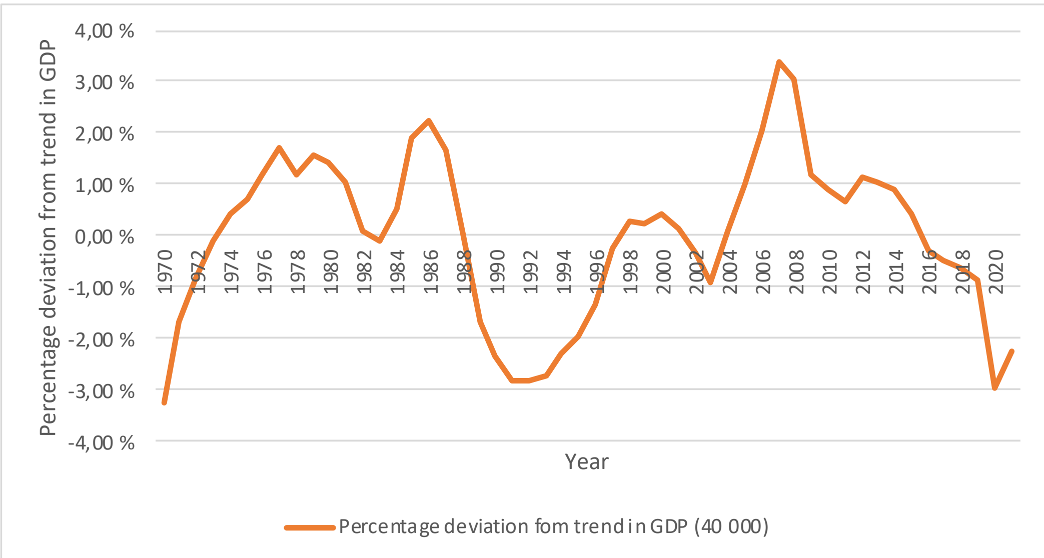


Figure 4.2 - Percentage deviation from trend in GDP Mainland Norway with λ = 40,000

It goes to say that the usage of the HP-filter method has been somewhat criticised. Benedictow and Johansen (2005) argue that although it is an advantage that the HP-filter is easy to apply and use, there are some shortcomings to the method. Along with the disadvantage that λ, to some extent, is chosen arbitrary, they point out weakness in that the potential production is more influenced by the level of actual production in the beginning and end compared to the rest of the series. This is because the filter at any given time makes use of values both backward and forward in time to estimate the potential production. In other words, at the beginning of the time series, the only values available are those for actual production forward in time. Vice versa, only the values for actual production backwards in time is available in the end. In the middle, values for actual production are available both forward and backward. The higher the value of λ, the bigger the problem (Benedictow & Johansen, 2005). The calculations related to the HP filter are done in Microsoft Excel.

4.6 Calculation formulas

4.6.1 Cost performance

In line with the previously mentioned best practice of calculating cost performance, being either cost overrun or cost underrun, the respective calculations are done in percentage cost performance. The formula utilised is the following:

$$Y_i = \frac{x_i - \hat{x}_i}{\hat{x}_i} * 100$$

In the formula, Y_i represents the percentage deviation between actual final costs and estimated costs in a given project indexed i. Depending on what one wants to measure, $\hat{x}_i$ represents either the estimated cost frame or the estimated steering frame at the time of the decision to build. Further on, x_i denotes the actual final total costs of the project. The percentage deviation will represent either the deviation between actual total costs and the cost -or steering frame.

4.6.2 Absolute change variables

Some of the variables used in the analyses are recognisable by being so-called absolute change variables. For a given variable or determinant, the absolute change variable is defined as the absolute difference between the value of the variable at the time of the finalising and the time of decision to initiate the project. The corresponding formula is the following.

$$\Delta x = x_f - x_{ToD}$$

Here, x_f represents the value of the variable at the of finalising, while x_{ToD} is the value of the variable at the time of decision to initiate the project. Ultimately, one ends up with Δx, which as mentioned, is the absolute difference between the two variable values. The variables which eventually are also being incorporated to create the absolute variables are mainly regarded as somewhat volatile. These variables may generate cost surprises within a project and are often related to business cycles (Dahl et al., 2017). This report mainly explores the absolute change in *the average wage*.

4.6.3 Percentage change variables

Ansar et al. (2014) found that countries with long-time inflation rates suffered larger cost overruns than others. Moreover, both inflation and economic growth have been proven to impact cost performance for infrastructure projects situated in Portugal (Catalão, 2019; Catalão et al., 2019). This report also regards variables measured through percentage change, which could be either growth or decrease. The percentage change variables are constructed by measuring the value of the same variable or determinant for two different points in time. The percentage change variables are all constructed from determinants where the value is given as an index. The following formula is applied to calculate the percentage difference between the two points of measurement.

$$x_{\%} = \left(\frac{x_j}{x_i} - 1\right) * 100(\%)$$

For the formula, $x_{\%}$ represents the percentage difference between the two index values measured at the two different points in time. These are denoted x_j and x_i, where x_j represents the value at the latest point of time, mainly at the point of project finalising, and x_i represents the value at the earliest point of time, generally considered the same as the value at the time of the decision to initiate the project.

4.7 Data quality

The quality of research is often evaluated based on three conditions, the validity, reliability, and generalisability of the data used (Leung, 2015). This section considers the quality of the quantitative data and measurements. For elaboration on the quality of the literature review, it is encouraged to read chapter 2.1.3.

4.7.1 Validity and reliability

The validity of a study relates to the question of whether the measurements one is doing are actually what one wants to measure (Alversia, 2011). Reliability in the research refers to whether the tools used in the analyses are consistent and free of measurement error (Kumar, 2018). Flyvbjerg et al. (2018) argue that when studying large-scale projects, all relevant projects where the data obtained is deemed valid and reliable should be included in the analyses. Accordingly, there is a clear difference between the terms regarding the analyses as opposed to its relevance toward the data used. The validity and reliability of the obtained data should be considered good as both Trailbase and Statistics Norway are regarded as trustworthy and robust sources for the data they provide. To ensure compatibility between the actual measurements and the desired questions to be answered, the exogenous variables used are, to the largest extent possible, been tried to reflect the reality. Concerning the reliability of the analyses, the statistical tests used in this report are robust in that they will provide the same results given that the input data is the same. Deviations or limitations of measurements and compatibility are addressed in the respective results and discussion accordingly.

4.7.2 Generalisability

The generalisability of a study refers to what extent the results provided are to be generalised outside the respective study (Yin, 2018). The main concern of generalisability in this report revolves around the fact that all the projects analysed are Norwegian. This topic has already been touched upon in chapter 3.1.5. There are inherent differences in the type of government, state of the country and governance schemes that must be considered when comparing large-scale projects between countries (Love & Ahiaga-Dagbui, 2018). Accordingly, it would be challenging to state that the findings in this report would be directly relevant to similar projects in other countries. However, the variables regarded in the analyses arguably are to be found and obtained in most other countries. Hence, the results should have the power to indicate possible relations for similar projects elsewhere, and followingly provide for further research on the topic of the report.

5 Results

The results in this report are divided into seven distinct parts. Each part revolves around one specific determinant, and the analyses were done to determine its relation to cost performance for the large-scale projects related to it. The reasoning behind what projects are included in each analysis will be elaborated within each distinct subsection. As mentioned in chapter 4.3, all the project data has consequently been obtained from Trailbase. In addition to the project-specific data, external data such as indices and numerical data related to the determinants analysed have also been used. These have all been obtained from Statistics Norway. Appropriately, the exact tables from which the data is extracted will be mentioned in relevance to the specific determinant. The results will to a different extent be relevant to all the three research questions and will accordingly be laying parts of the basis for the upcoming discussion. All the analyses regard both the cost frame and the steering frame in relation to the cost performance of the projects. Additionally, some of the analyses are also done with road projects exclusively. Specifically, these analyses are undertaken if it is deemed probable that the results will indicate other findings than the analyses for all the projects, and sufficient data is obtainable. Analyses follow the best practice mentioned in chapter 4.2. All visualised analyses will have respective residual plots in the Appendix unless stated otherwise. Obtained p-values and corresponding tables used from Statistics Norway is summarised in the Appendix.

5.1 Inflation (CPI-ATE)

Several international studies have pointed toward inflation as a driver of cost overrun. Both Ansar et al. (2014) and Bacon and Besant-Jones (1998) found that long-term inflation rates in the host country for a project were significant toward cost escalation. Unforeseen inflation during the project phase has also been hypothesised to be relevant toward cost escalation for American transport projects (Pickrell, 1992). Since this report only regards Norwegian projects, the long-term inflation rate is naturally excluded as it is almost the same for all the projects. Hence, the approach used here is similar to the one in Pickrell (1992) as the focus is the inflation during the project phase.

In particular, it was analysed whether the percentage change in inflation from the ToD to the end of the project had any relation to the cost performance of the projects. The measurement for inflation used here is the *Consumer Price Index – adjusted for tax changes and excluded for energy goods* (CPI-ATE). In Norway, the CPI-ATE is often referred to as the core inflation and is assumed to be the best indicator for analysing the underlying inflation in the country (Johansen et al., 2006). The data for the CPI-ATE is obtained through table 12880 from Statistics Norway. This table gives out the yearly change in the index. Subsequently, it has been formed an index using the formula from chapter 4.6.3 to calculate and visualise the percentage change in inflation from the ToD to the end of the project more effectively. CPI-ATE is given out in both monthly, quarterly, and yearly terms. In this analysis, the annual value of CPI-ATE since the ToD and the time of the end of the project are more consistent on an annual basis. Hence, by using the yearly numbers, it was possible to include more projects in the analyses. Statistics Norway provides measurements of CPI-ATE starting from 2003. Therefore, only projects that had their ToD in 2003 or later are included in these analyses. The total number of projects included was 79.

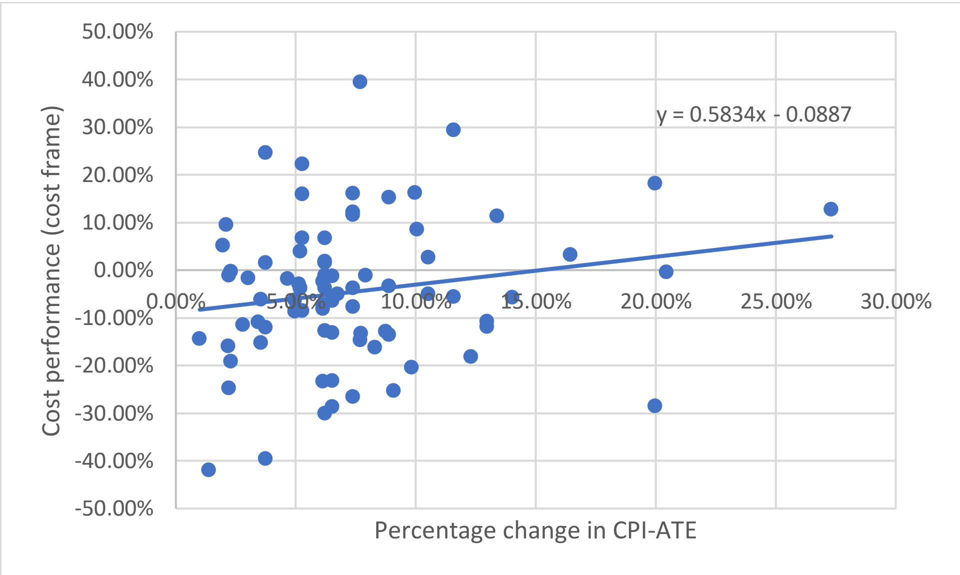


Figure 5.1 - Relation between cost deviation from the cost frame and percentage change in CPI-ATE (N=79)

At first, it was analysed whether the percentage change in CPI-ATE had any relation to the cost deviation from the cost frame. As one can see from Figure 5.1, the relationship is positive, meaning that a larger percentage change in CPI-ATE may lead to a larger cost overrun. The p-value obtained from the regression was 0,10. This indicates that the correlation between the dependent and the independent variable is significant at a 90 per cent level. However, it is to be remarked that this possible correlation may be influenced by outliers in the data set. For instance, by visually inspecting Figure 5.1, the regression line is heavily influenced by the rightmost datapoint. Performing a regression analysis where this specific point is excluded gives a p-value of 0,23, stating that the correlation is insignificant.

The same analysis was utilised when evaluating the correlation between the percentage change in CPI-ATE and the cost deviation from the steering frame. The regression with the corresponding trendline is given beneath in Figure 5.2.

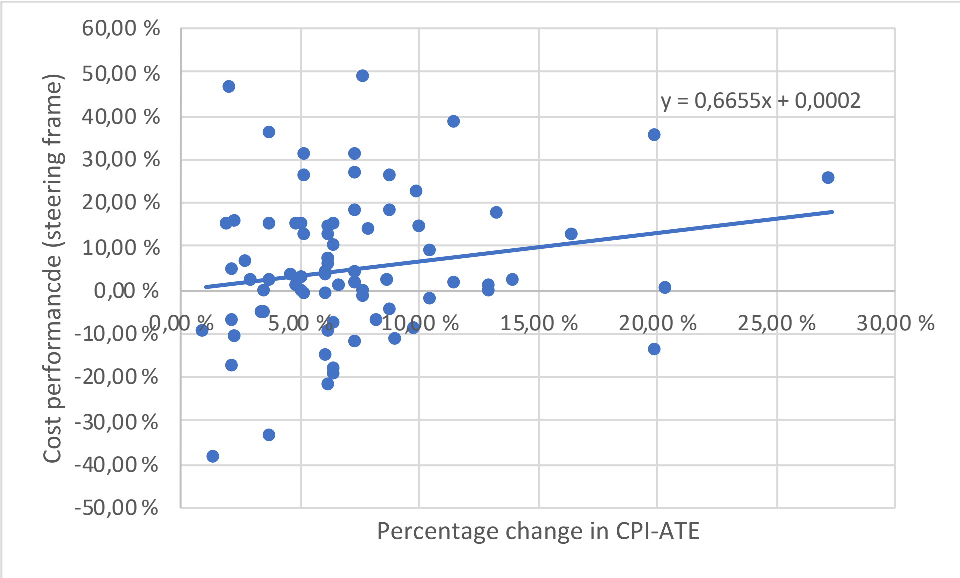


Figure 5.2 - Relation between cost deviation from the steering frame and percentage change in CPI-ATE (N=79)

The regression is relatively similar to the one shown in Figure 5.2. With the inclusion of the corresponding outlier pointed out before, the p-value obtained is 0,13. Excluding the outlier, the p-value becomes 0,31. Consequently, the relation is deemed not significant.

Additionally, the road projects within the sample were analysed separately due to the relatively large number of projects of this type among the 79 projects included. A total of 46 projects road projects were analysed. For the relation between the percentage change in CPI-ATE and cost deviation from the cost frame, the p-value obtained was 0,069. For cost deviation from the steering frame, the analysis gave a p-value of 0,037. Subsequently, the correlation is presumably significant within the 90 per cent level for the cost deviation from the cost frame and statistically significant for the cost deviation on the steering frame. However, when removing the rightmost outlier in a similar fashion to the previous analyses, it is proven that neither of the relationships is significant, with p-values of 0,25 and 0,22, respectively. Figure 5.3 and Figure 5.4 shows the regressions including the outlier.

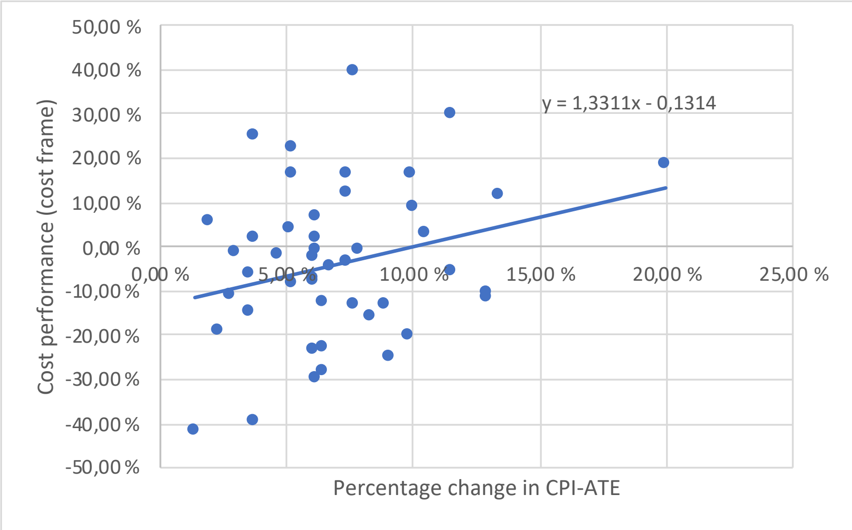


Figure 5.3 - Relation between cost deviation from the cost frame and percentage change in CPI-ATE for road projects (N=46)

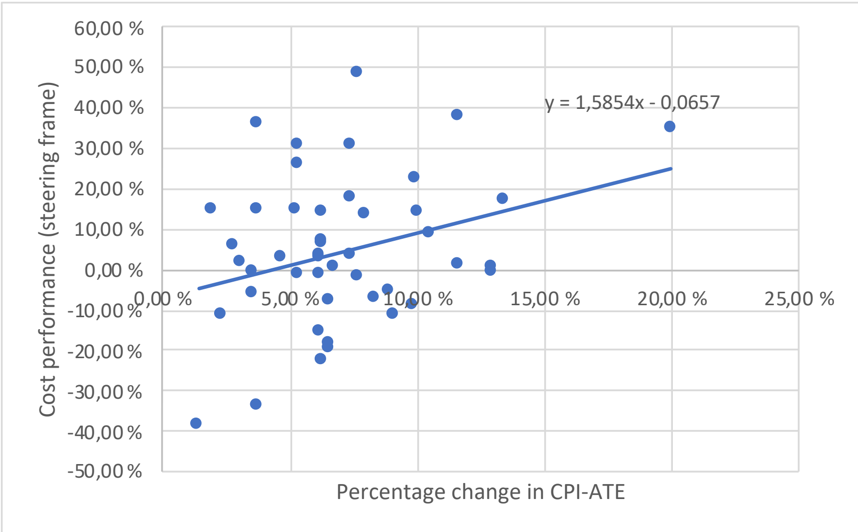


Figure 5.4 - Relation between cost deviation from the steering frame and percentage change in CPI-ATE for road projects (N=46)

5.2 Wage

The consequence of a higher demand for building projects, leading to upswings in the business cycles, has among other factors, been that labour rates tend to accelerate (Bon, 1998; Hillebrandt, 2000; Snyman, 1989). The tightened supply of workforce and increased rates for labour may lead to projects experiencing cost overruns (Dahl et al., 2017; Snyman, 2007). Makovšek et al. (2012) found that the increase in construction services was one of the main problems related to cost overruns.

This report has set to analyse whether the absolute change in wage within the construction industry has any relation to cost performance. Absolute change variables are explained in 4.6.2. Naturally, only the projects that are affected by the labour costs in the construction industry, such as road projects, railway projects, and construction projects, are included in these analyses. There were three tables used from Statistics Norway to extract the numbers related to the yearly average wage for employees in the construction industry. The respective tables were 05405 for the years 2000-2008, 07760 for 2009-2015, and 12314 for all the years from 2016 and out. The first two tables gave out the yearly average wage, while the latter gave out their average in quarterly terms. For simplicity, it was chosen to use the average wage at the first quarter as a reference for all the projects that either had their ToD, end of project or both in 2016 and after. A total of 74 projects were included in the analyses.

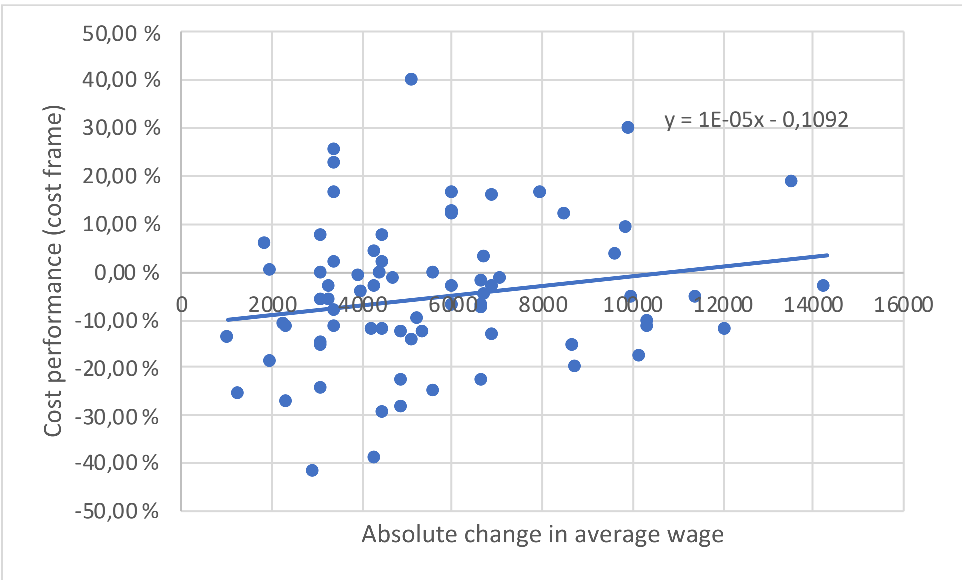


Figure 5.5 - Relation between cost deviation from the cost frame and the absolute change in average wage in the construction industry (N=74)

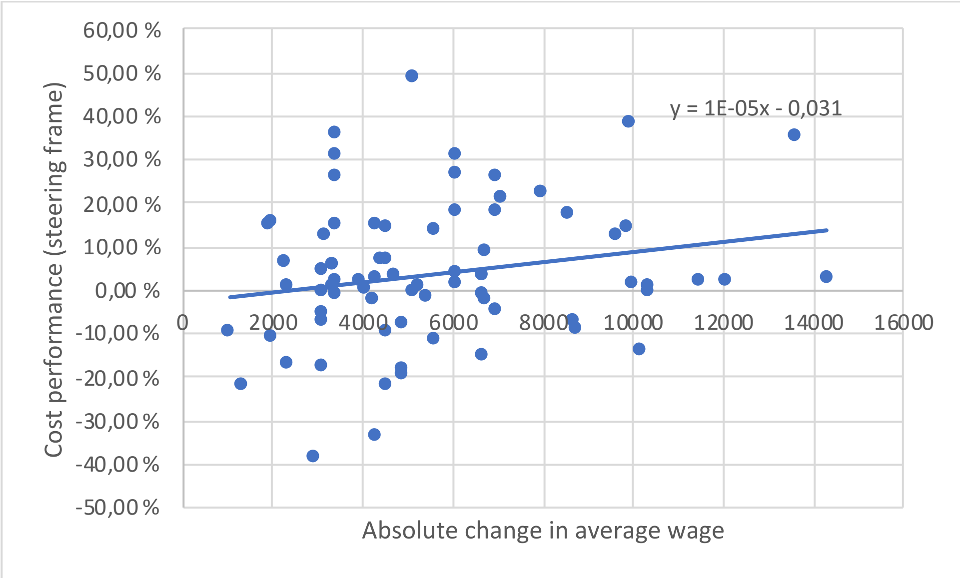


Figure 5.6 - Relation between cost deviation from the steering frame and the absolute change in average wage in the construction industry (N=74)

As for the relation between absolute change in wage and cost deviation from the cost frame in Figure 5.5, the p-value obtained is 0,099. When looking at the deviation from the steering frame in Figure 5.6, the p-value is equal to 0,07. Further, both the relations are significant within the 90 per cent level. However, following common notion, both the relations may also be ascribed to chance as they are not within the 95 per cent interval of significance.

The same regression analyses were done for road projects exclusively. A total of 50 projects were included. The results are shown in Figure 5.7 and Figure 5.8.

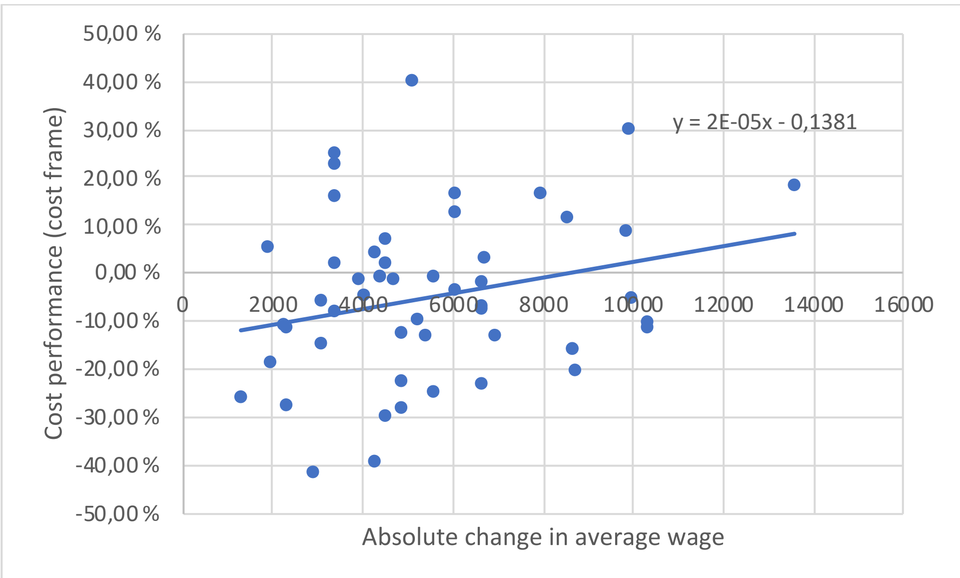


Figure 5.7 - Relation between cost deviation from the cost frame and the absolute change in average wage in the construction industry for road projects (N=50)

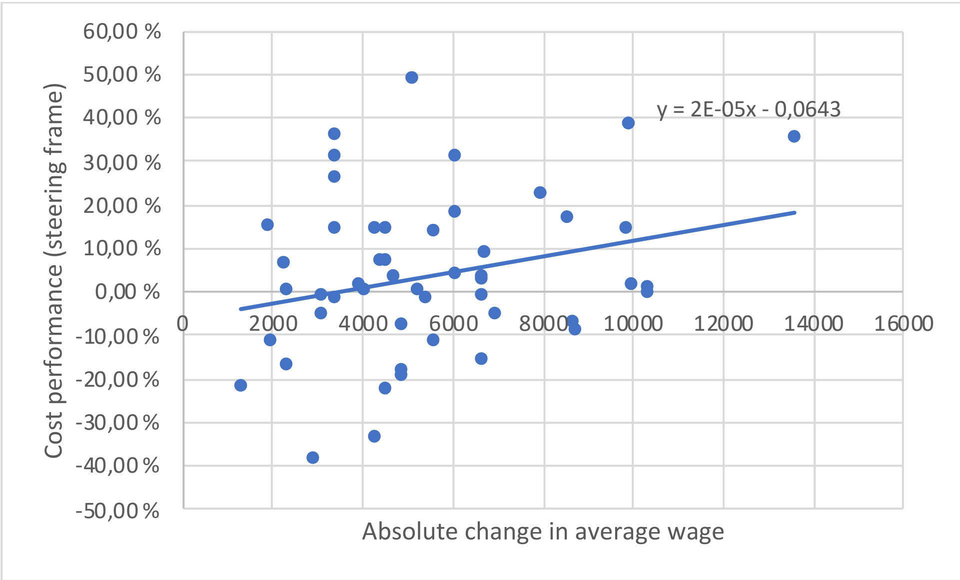


Figure 5.8 - Relation between cost deviation from the steering frame and the absolute change in average wage in the construction industry for road projects (N=50)

By visual inspection, the rightmost datapoint is a clear outlier in the data set. This regards both of the analyses. By removing this one outlier and reperforming both analyses, the p-values obtained are 0,21 and 0,23 concerning the cost deviation from the cost frame and steering, respectively. Thus, the analyses may be deemed scarce as removing the outlier has such an impact on the analyses. Including the outlier, the p-values obtained were 0,09 for cost deviation from the cost frame and 0,07 for cost deviation from the steering frame.

5.3 Employment

A consequence of experiencing a tight labour market is that there may be a lack of skilled employees within the construction industry, and one could followingly experience cost overruns as the productivity and quality of work may lack consistency (Bon, 1998; Snyman, 1989; Welde et al., 2019). The employment in a specific sector can indicate the overall activity within the market, where it is typical that a high level of activity may be related to a general decrease in the delivered quality and the occurrence of costly bottlenecks within the chain of operations (Dahl et al., 2017).

Two different types of independent variables have been used in analysing if the state of employment has any relation to the cost performance of large-scale projects. First, it is analysed whether the number of employees within the construction sector at the ToD may relate to the cost performance. Second, the possible relation between cost performance and percentage change in employment was also analysed. Since it is looked upon the number of workers specifically in the construction industry, only the projects assumed to be directly affected by this factor are included in the analyses. The table used from Statistics Norway to extract the data related to the number of workers in the construction industry was 09174. The number is given as the average number of workers within the related year. The total number of projects included in the analyses was 74.

Figure 5.9 - Relation between cost deviation from the cost frame and the state of employment at ToD (N=74)

The relation between the state of employment and the cost performance is shown above in Figure 5.9. As the data extracted from Statistics Norway comes in yearly averages, the state of employment is the same for many of the projects. Perceivably, the slope of the regression line is slightly positive. An interesting remark is that all the projects with the most employees at ToD, being the year 2013, all experienced cost underruns. The regression analysis obtained a p-value of 0,099 and was followingly significant within the 90 per cent interval. It is to be noted that the trendline, representing the expected value of cost performance, never exceeds a negative value for the projects in the sample.

Further on, the same analysis was done with regard to the cost deviation from the steering frame for all the 74 projects. The regression is visualised below in Figure 5.10.

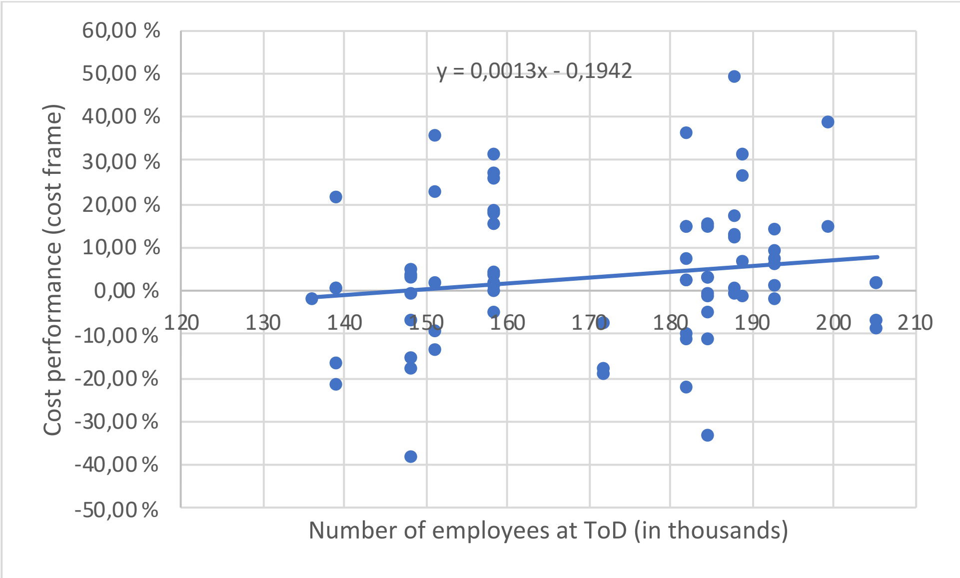


Figure 5.10 - Relation between cost deviation from the steering frame and the state of employment at ToD (N=74)

From the formula of the regression trendline, the slope is slightly less steep for this analysis compared to the one using the cost frame within the calculation of cost deviation. Additionally, the p-value obtained for this analysis was 0,166, implying that the correlation between the state of employment and cost deviation from the steering frame is insignificant.

Lastly, in a similar fashion to Dahl et al. (2017), it was analysed whether the percentage change in employment, namely the relative difference in the state of employment between the ToD and the end year of the project, could prove any relation to cost performance. The obtained p-values from these regression analyses were 0,505 and 0,843 for cost deviation from the cost frame and the steering frame, respectively. In other words, none of the relations proved significant towards the cost performance.

5.4 CCI

The difference between the CCI and the actual market price development has, in periods, been substantial (Berntsen & Sunde, 2004). Since the CCI includes hourly rates for workers and material prices but not the prices in the market directly, there have been occasions where the development in the market prices has been substantially higher than what the CCI has been able to detect (Welde et al., 2019). If there has been an upturn between the cost estimating for a project and the reference projects that the estimate is based on and price adjusted for using the CCI, the estimates will underestimate the actual market prices if not considered carefully (Welde, 2017). Considering the uncertainty that has been argued towards the CCI, it has been analysed whether it may correlate with the cost performance of the projects.

The CCI only affects projects that regard some construction within the process. Subsequently, the likes of military procurement -and ICT projects have been excluded from these analyses. In total, 74 projects were deemed affected by the CCI and therefore included. Two different analyses have been conducted using the CCI. First, the percentage change in the index between the ToD and the end of the project has been analysed to see if having any correlation with the cost performance. Second, the value of CCI at ToD has been analysed for the same. The data regarding the CCI has been extracted from table 08662 from Statistics Norway. Figure 5.11 and Figure 5.12 visualises the analyses regarding the relationship between percentage change in CCI and cost performance.

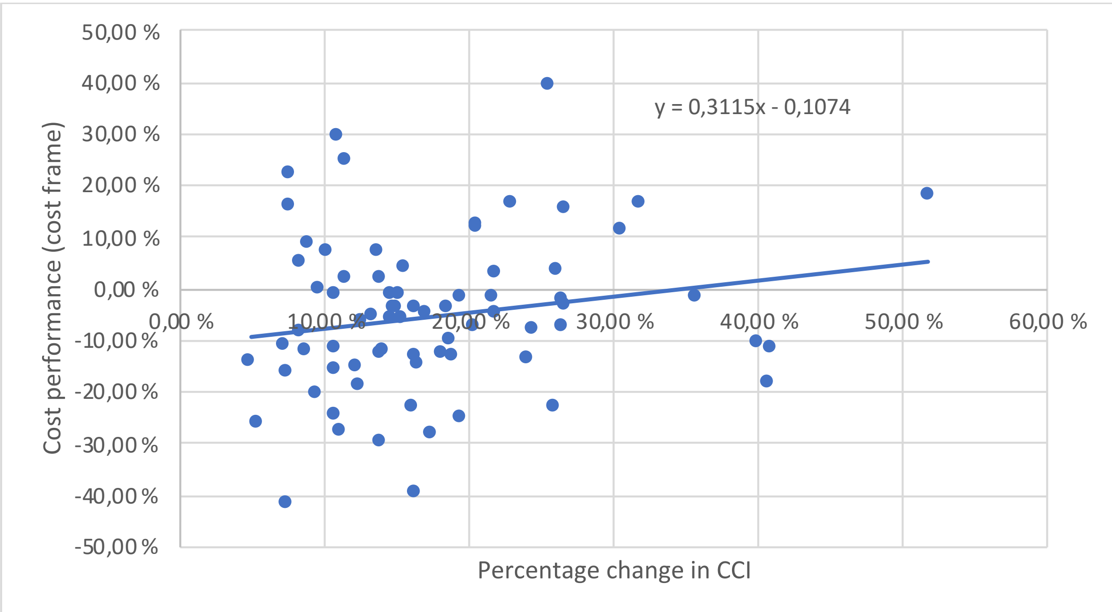


Figure 5.11 - Relation between cost deviation from the cost frame and the percentage change in CCI (N=74)

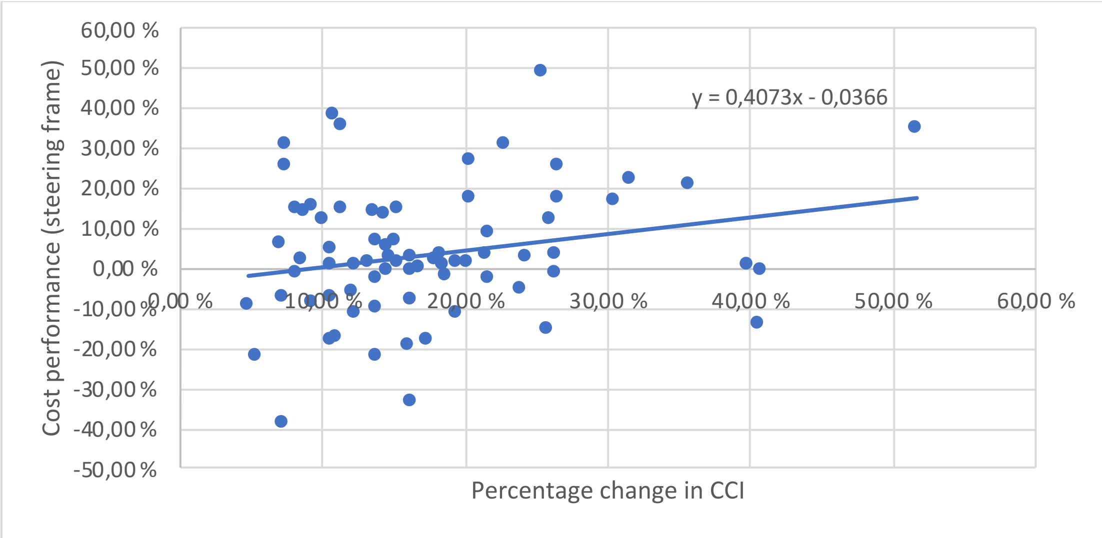


Figure 5.12 - Relation between cost deviation from the steering frame and the percentage change in CCI (N=74)

The p-values obtained from the analyses were 0,11 and 0,05 for cost deviation from the cost frame and the steering frame, respectively. This would imply that there is no strong correlation between the percentage change in CCI and the cost deviation from the cost frame, whereas this relation is significant regarding the deviation from the steering frame. Visually for both Figure 5.11 and Figure 5.12, one can also perceive that most projects experiencing a 20 per cent change in CCI or more seem to obtain a cost overrun. Visually, the slopes for both the regressions are positively rather steep. However, the rightmost datapoint is a clear outlier in both analyses. By removing this specific datapoint from both the data sets, the p-values obtained become 0,31 for cost deviation from cost frame and 0,22 for cost deviation from steering frame. In other words, the outlier in the analyses affects the results quite heavily, and there is no significance in the correlation between cost performance and percentage change in CCI without it. In addition, the same regression analyses were done for road projects only, including a total of 50 projects. The p-values obtained from these were 0,29 and 0,22. Hence no perceived significant correlation was found in either of the two.

At last, it was also analysed if the CCI at ToD was to be found to correlate with the cost performance of the projects. For the cost deviation from the cost frame, the p-value obtained was 0,22, whereas for the cost deviation from the steering frame, it was found to be 0,26. In other words, no significant relationship was obtained.

5.5 GDP Mainland Norway

Pinheiro Catalão et al. (2019) hypothesised that growth in the economic environment within a country might be correlated with worse cost performance. Furtherly in Catalão et al. (2019), it is shown that for their set of projects, the growth in GDP within the host country has relevant effects on the size of cost overruns. Bacon and Besant-Jones (1998) found that for hydropower dam project, the GDP deflator was significant towards the cost performance when measuring in current prices. For specification, the GDP deflator refers to the actual average cost growth rate in a country between two different points in time (Bacon & Besant-Jones, 1998).

In regard to analysing the relation between cost performance and GDP in Norway, two types of analysis have been carried out. First, it is looked at the relation between the cost performance and the percentage change in GDP between the ToD and the end of the project. Second, in a similar fashion to the analysis done in Bacon and Besant-Jones (1998), the independent variable the percentage change in GDP between the ToD and the contract initiation.

In Norway, when evaluating the business cycles, one tends to put the main emphasis on the so-named GDP Mainland Norway (Eika, 2008). As opposed to the standard GDP, GDP Mainland Norway excludes the revenue from the oil sector and shipping in foreign waters. The table from Statistics Norway used to extract the numbers for GDP Mainland Norway was 12880, and the data are given in constant 2015 prices, with each measurement corresponding to one distinct year. It is to be remarked that, unlike Bacon and Besant-Jones (1998), it is not performed analyses for current costs in addition to the constant costs, as this report follows the four best practices of Flyvbjerg et al. (2018). All the projects that could provide a solid reference to both the ToD and the end of the project were included. Consequently, a total of 89 projects were analysed. Figure 5.13 beneath shows the regression analysis for the relation between cost deviation from the cost frame and the percentage change in GDP Mainland Norway.

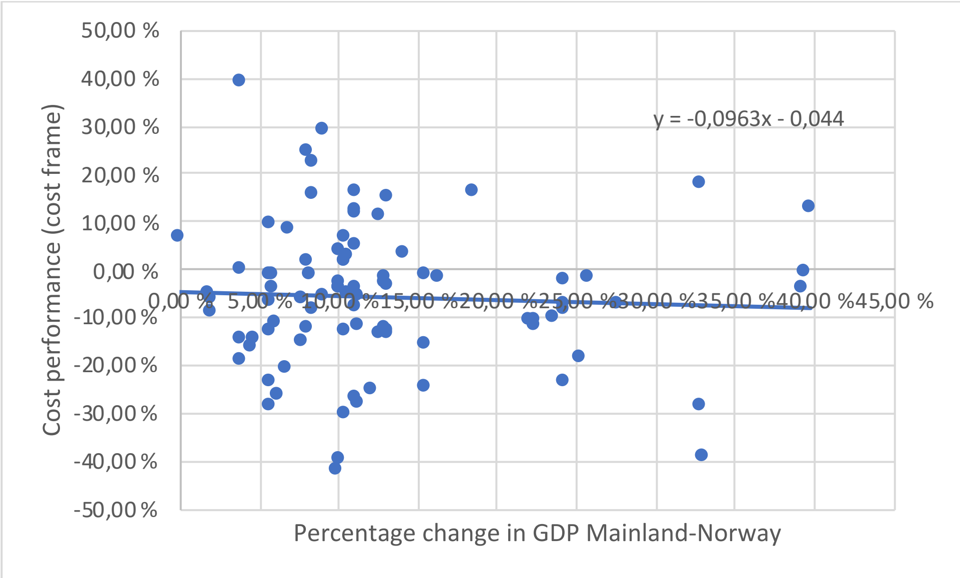


Figure 5.13 - Relation between cost deviation from the cost frame and the percentage change in GDP Mainland Norway (N=89)

As one can see, there is no clear correlation between the cost deviation and the change in GDP Mainland Norway. This view is further confirmed by the p-value obtained, which equalled 0,60. With respect to the cost deviation from the steering frame, the same p-value of 0,60 is obtained, proving no statistical significance in the relation. The analyses are also performed on road projects only, with a total of 50 projects. The p-values equalled 0,79 and 0,63 concerning the cost deviation from the cost frame and the steering frame, respectively. Hence, neither proved any significant relationship. Residual plots are not given for these analyses.

5.6 Business cycles

The business cycle is best explained by a contraction and downturn in a nation's aggregate economy, followed by an expansion, where the economic activity should be measured with reliable and comprehensive measures such as employment, real income, and real expenditures (Zarnowitz, 1992). Dahl et al. (2017) concluded that cost overruns in the form of unrealistic ambitions and optimistic behaviour are likely to correlate with the business climate at the time. Makovšek et al. (2012) pointed out that economies dealing with changes in the economy and market fluctuations need to consider the related factors carefully when estimating costs for large-scale projects. Welde (2017) stated that although the economy was in an upturn in regard to large-scale government investment projects at the time of the study, the analyses could reassure that the cost control within the projects had been reasonable and that the foundation for cost performance estimations in upcoming projects was relatively solid.

For the analyses regarding the relationship between business cycles and the cost performance for the projects, the Hodrick-Prescott filter has been used. For more details about the method, it is recommended to look at chapter 4.5. Nonetheless, the HP filter is commonly viewed as a standard for analysing the business cycles within an economy (Benedictow & Johansen, 2005). Two main analyses are performed to evaluate the correlation between the business cycles and the cost performance. First, the percentage deviation from the trend in GDP Mainland Norway at ToD is analysed as the independent variable. Second, the same is done using the deviation in the trend at the time of contract initiation as the independent variable. The latter analysis is performed to indicate whether forecasters were able to satisfyingly forecast the business cycle trend at the time of contracting during the time of estimating. In addition, two different values of the parameter λ are used. The value in focus for these analyses will be λ=400, whereas λ=40,000 will act more as a comparison to perceive how the tuning of λ in the method of the HP filter affects the analyses. The data regarding GDP Mainland Norway is extracted from table 09189 from Statistics Norway and given in constant 2015 prices by yearly measurements. Furtherly, the trend in the GDP Mainland Norway is calculated using data from 1970 up until 2021. Consequently, the analyses are done both for the cost deviation from the cost frame and the steering frame. A total of 90 projects were included in the analysis when using the measurement at ToD, whereas 66 of these were found to have satisfying contract initiation data and furtherly included in the analyses that used the time of contract initiation as the time of measurement. Figure 5.14 visualises the analysis on the relationship between the business cycles and the cost deviation from the cost frame using $\lambda = 400$.

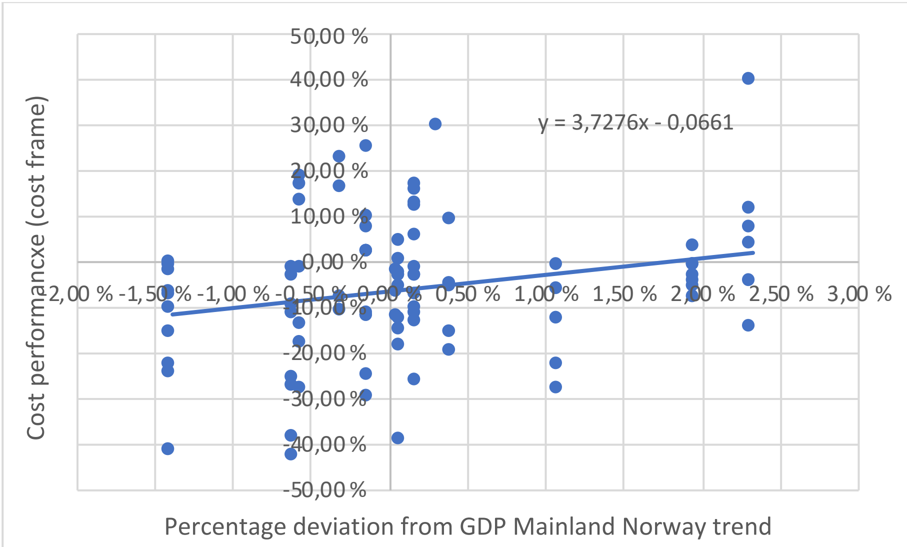


Figure 5.14 - Relation between cost deviation from the cost frame and the percentage deviation from the trend in GDP Mainland Norway at ToD with λ = 400 (N=90)

Perceivably, for the projects that fluctuate between ±0,5 per cent from the calculated GDP trend, the pattern in cost performance may look quite arbitrary if something it is slightly positive. However, for the projects with larger deviations from the trend, there are more apparent distinctions in the data. It is to be seen that none of the projects that deviated around -1,5 per cent from the trend experienced cost overruns. Additionally, the projects that deviate between 2-2,5 per cent from the trend at ToD have perceivably worse cost performance than those with the ToD at a negative deviation from the GDP trend. According to the equation for the fitted line, an increase in 1 per cent deviation from the trend in the economic growth implies an approximate 3,72 per cent increase in cost escalation. The regression analysis regarding the percentage deviation from the GDP Mainland Norway trend and the cost deviation from the cost frame obtained a p-value of 0,02. In other words, the correlation is presumably statistically significant.

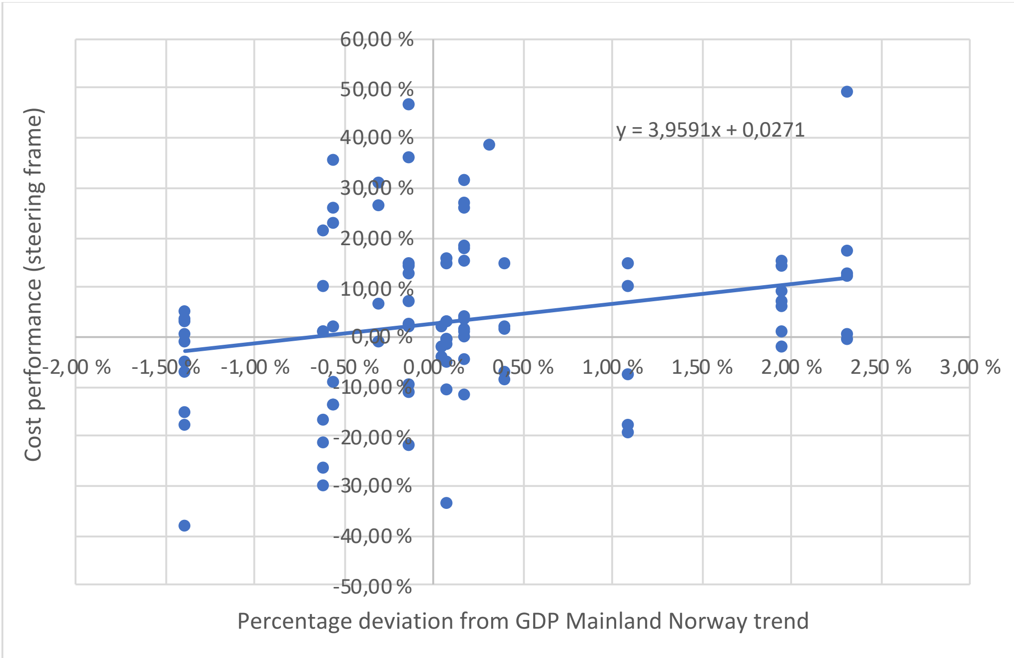


Figure 5.15 - Relation between cost deviation from the steering frame and the percentage deviation from the trend in GDP Mainland Norway at ToD with λ = 400 (N=90)

Above in Figure 5.15 is the visualisation of the analysis done on the relation between the business cycles and the cost deviation from the steering frame. The difference in cost performance when comparing the data points for the two outmost trend deviation values is rather catching. Almost all the projects that deviate from the economic growth by 1,95 per cent or more at ToD experienced cost overruns. Following the equation for the fitted trendline, an escalation in the deviation from the economic growth by 1 per cent would imply an increase in cost escalation equal to around 3,96 per cent, slightly higher than the equation on cost deviation from the cost frame. In similar fashion to the analysis of cost deviation from the cost frame, the cost performance for the projects between ±0,5 per cent deviation does not show any clear pattern or correlation Figure 5.15 either. The p-value obtained from the analysis was 0,024, which for the set of data proves a statistically significant relationship between the business cycles and the cost deviation from the steering frame.

As mentioned, the regression analyses were also done by using the contract's time of initiation as the measuring point. Several projects had multiple contracts initiated over a longer interval of time. In these situations, the deviation from the economic growth trend in the middlemost year of the interval was chosen as the measurement for the whole project.

This may provide limitations in drawing the complete picture of the market situation at the time of contract initiation. Nevertheless, the visualisation of the analyses for the total of 66 projects is shown below.

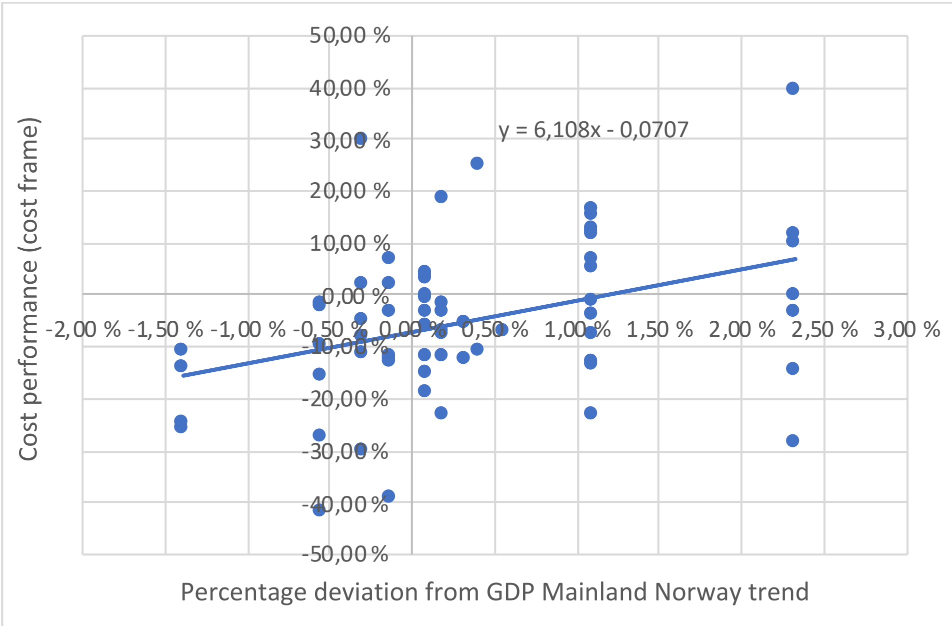


Figure 5.16 - Relation between cost deviation from the cost frame and the percentage deviation from the trend in GDP Mainland Norway at contract initiation with λ = 400 (N=66)

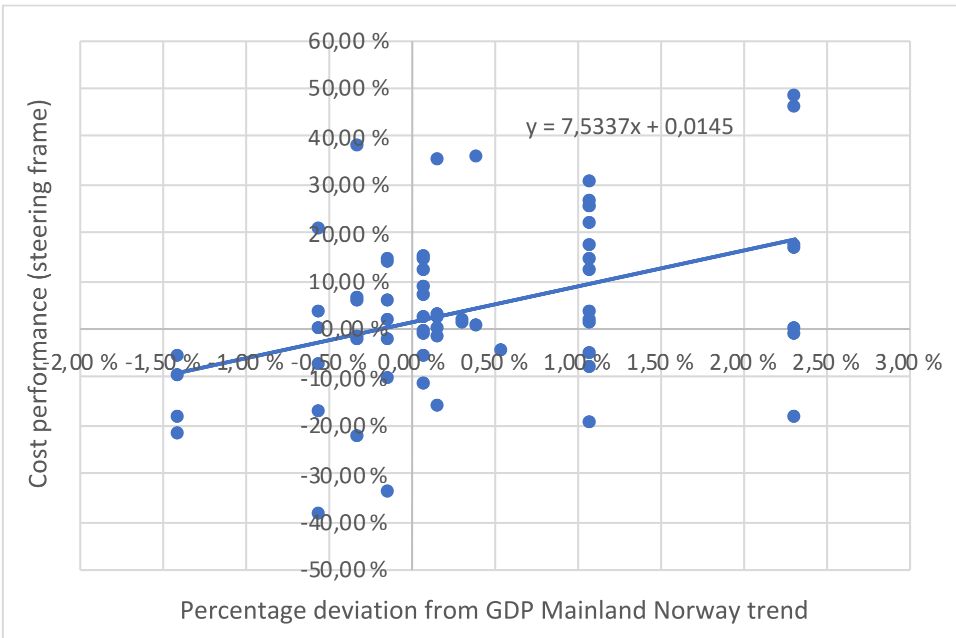


Figure 5.17 - Relation between cost deviation from the steering frame and the percentage deviation from the trend in GDP Mainland Norway at contract initiation with λ = 400 (N=66)

For both visualisations, the slope of the trendline is far steeper than for the same analyses done with the ToD as the point in time of measurement. This is seen in the two equations as well. Perceivably according to the equations, 1 per cent escalation in deviation from the GDP Mainland Norway trend would presumably result in around 6,1 per cent and 7,5 per cent cost escalation from the cost frame and steering frame, respectively. Especially for the analysis regarding the deviation from the steering frame, the majority of the projects having contracts initiated in times where the deviation in trend was above 1 per cent experienced cost overrun. The p-values obtained from the analyses were 0,001 and 0,0007 for the correlation between the business cycles and the deviation from the cost -and steering frame, in that order. Hence, assuming that the interpretation of contract initiation is relatively correct, the correlations are well within being statistically significant.

At last, for comparison matters, it is deemed plausible to show how the tuning of the parameter λ in the HP filter affects how the business cycles are perceived. Figure 5.18 below shows the percentage deviation from the economic growth and its relation to the steering frame when applying λ = 40,000 to the HP filter.

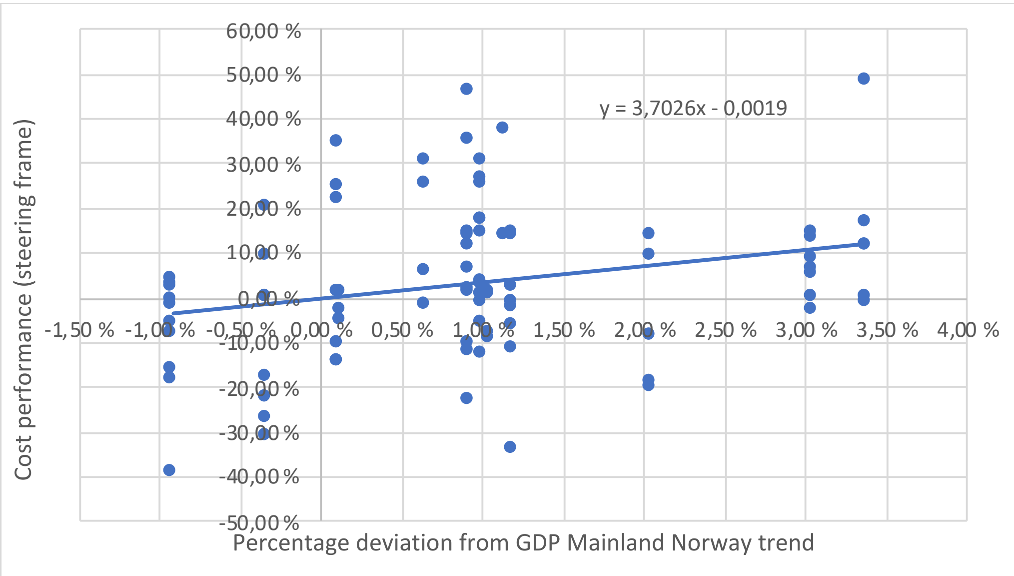


Figure 5.18 - Relation between cost deviation from the steering frame and the percentage deviation from the trend in GDP Mainland Norway at ToD with λ = 40,000 (N=90)

As one can see, Figure 5.18 shows that the use of λ = 40,000 promotes a perception where more projects are initiated in larger upturns regarding the economic growth compared to the scenarios where λ = 400 are used. As explained, this visualisation is mainly just for comparison reasons as it was deemed plausible to show the effects the use of the parameter λ has on the analyses. Nonetheless, the p-values were obtained, equalling 0,01 and 0,011 for the relation between the business cycles and the deviation from the cost -and steering frame, respectively.

5.7 Exchange rate – I44

For large government investment projects, especially for military procurement projects, the currency uncertainty has been one of the systematic uncertainties underestimated in its relation to cost performance (Berntsen & Sunde, 2004). Welde et al. (2019) theorised that a higher frequency of problems concerning cost performance could be related to currency uncertainty, but since this factor of uncertainty explicitly has been omitted in the uncertainty analysis undergone in QA2, there is little to no experience and knowledge in how the fluctuations in the currency may influence the large government investment projects in Norway.

Two main types of analyses have been undertaken when analysing the relationship between the currency uncertainty and the cost performance for the projects in this report. The Import-weighted krone exchange rate (I-44) was used to evaluate the currency uncertainty. In short, this is a geometrically weighted and calculated index that outputs the relative strength of the Norwegian krone measured up against the 44 countries that account for the highest share of imports to Norway (Jore, 1999). The weights are recalculated yearly to continually obtain the accurate picture of import shares. A rise in the index corresponds with a depreciation of the krone and vice versa. For the analyses, it was first looked at the possibility that the percentage change in I-44 between the ToD and contract initiation could correlate with the cost performance of the projects. In particular, the analyses using this independent variable aimed to explore whether the change in I-44 between the ToD and the contract initiation on average had been accounted for satisfyingly during the estimation process. For the projects obtaining several contract initiations over a longer period of time, the middlemost year was used as a reference towards the value of I-44. Second, it was analysed whether the exchange rate at ToD had any relation to the cost performance. The data for the import-weighted krone exchange rate was extracted from table 12880 from Statistics Norway. A total of 58 projects were included in the analyses. The visualisations of the analyses in regard to the change in I-44 and its possible relation to the cost performance are shown below.

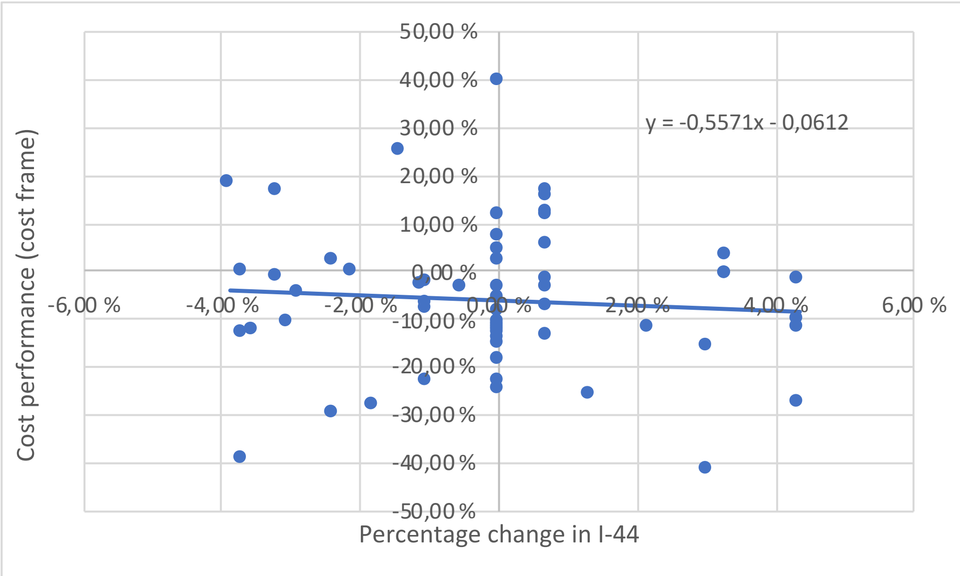


Figure 5.19 - Relation between cost deviation from the cost frame and the percentage change in I-44 between ToD and contract initiation (N=58)

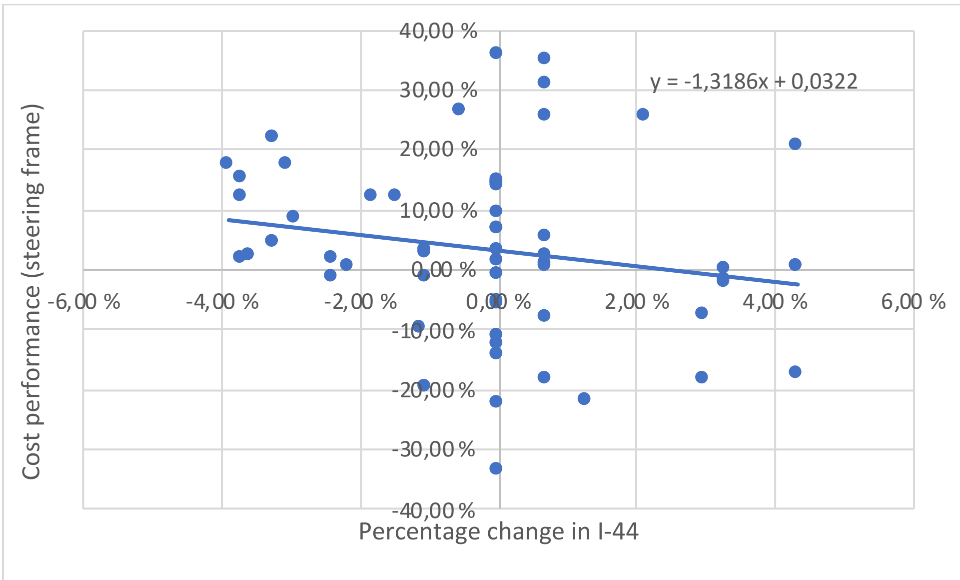


Figure 5.20 - Relation between cost deviation from the steering frame and the percentage change in I-44 between ToD and contract initiation (N=58)

Perceivably from Figure 5.19 and Figure 5.20, the distribution of values looks rather arbitrary. In addition, a fair number of the projects did not experience any change in I-44 between the ToD and the contract initiation, as both most likely occurred within the same year. Much of the same goes for the analysis of cost deviation from the steering frame. However, a distinction here is that the projects that experienced an adverse change in the import-weighted import exchange rate more often than not experienced cost overruns. As mentioned, an escalation in the I-44 reflects a depreciation of the krone. As such, the analyses may indicate that an appreciation in the krone between the ToD and the contract initiation could imply a cost escalation for a given project. Nonetheless, the p-values obtained were 0,55 for the deviation from the cost frame and 0,14 for the deviation from the steering frame. In other words, none of the analyses is statistically significant. The same analyses were done for 40 road projects exclusively. However, no significant correlation was found, obtaining p-values of 0,49 and 0,51 for cost deviation from cost frame and steering frame, respectively.

Lastly, it was also analysed whether the value of I-44 at ToD had any relevance to project cost performance. 58 projects were included. Such analyses could have the possibility to evaluate whether the exchange rate has been satisfyingly considered when performing the estimates. However, the p-values obtained were 0,71 and 0,57 for the deviation from the cost frame and the steering frame. Hence, no statistical significance was found in any of the correlations. Residual plots are not given for these analyses.

6 Discussion

This part of the report will first and foremost elaborate on and connect the theory with the results. With a basis on the research questions, different aspects of the theory will be regarded along with the findings in the results in order to lay the foundation for the upcoming conclusion. Critical remarks towards the report will also be included in this chapter. Implications for future research will also be mentioned during this part of the report based on the findings or lack thereof.

6.1 The state of large-scale project research

6.1.1 The implications of research methods

The importance in elaborating the state of the research within the literature lies within interpreting how previous scholars have approached the research and, more specifically, to what extent the different findings and arguments are to be viewed as causalities on one end or theorised perceptions in the other. Presumably, as with many fields of research in general, the literature on cost performance in large-scale projects has been diverse in research methods, including document studies, questionnaires, and case studies (Locatelli, Mikic, et al., 2017; Welde, 2017). However, while Cantarelli et al. (2013) argue that the majority of studies on cost performance for large-scale transportation projects have been conducted as empirical studies, Welde (2017) questions why the literature seems to be lacking studies utilising this approach to explore possible relations between cost performance and underlying determinants. In this report, the number of studies empirically investigating large-scale projects is recalled in Table 3.2. The number of unique analysed large-scale project datasets found in this report totalled out to be 20. Here, the datasets with many projects beneath NOK500 million are excluded. Within a field that presumptively obtains a reasonable amount of numerical data, the number of studies that takes advantage of this is relatively low. Flyvbjerg et al. (2002) argued that the low number of studies that tested empirical data statistically at the time was due to the insufficient volume of data. Twenty years later, it should be reasonable to assume that this claim does not stand as strong today. With that said, the contribution from studies approaching the domain using other research methods should not by any means be discredited. Questionnaire-based studies such as Cheng (2014), Zhao et al. (2017) and Durdyev et al. (2017), exploring cost drivers by interviewing experts in project management, are valuable knowledge to be regarded. The same goes for case studies, which aim to seek a more profound understanding within single projects (Yin, 2018). However, these studies have an inherent limitation of being oriented towards building theory rather than actively and statistically testing it (Locatelli, Mikic, et al., 2017). Quantitative research has the power to explain correlations between variables based on statistical calculations and numerical analysis using the data available (Silverman, 2015). To obtain robust findings that could support the theory of explanations, and without deliberating what is deemed the correct volume of quantitative studies, there is reason to believe that Welde (2017) and De Jong et al. (2013) had valid opinions that it could be beneficial for the literature to obtain more studies enhancing the power of quantitative research. Further on, some of the explanations behind the presumably low number of quantitative studies may also be related to how the literature has focused on possible causes not necessarily compliant with statistical evidence.

6.1.2 Focus on underlying explanations

The literature regarding causes of cost performance for large-scale projects can be categorised into four different categories, namely technical-, economic-, psychological-, and political explanations (Flyvbjerg, Bruzelius, et al., 2003; Flyvbjerg et al., 2002). Excluding the technical explanations, these categories emphasise a range of explanations which hardly can be tested robustly by statistical methods. Explanations such as strategic misrepresentation, planning fallacy and optimism bias (Flyvbjerg et al., 2018; Kahneman & Tversky, 2013; Wachs, 1990), agency theory and deliberate underestimation (Cantarelli et al., 2013; Flyvbjerg et al., 2002; Noreen, 1988), and selection bias (Jørgensen, 2014) are to be viewed common in explaining the causes of cost overrun in the literature. However, these theories that, in long lines, revolve around different incentives to underestimate projects have lacked solid proof and consensus in the literature (Welde, 2017). In fact, little to no studies have proved deliberate deception to be the root cause of cost overruns (Siemiatycki, 2009). Despite the criticism given to the explained theorised explanations, the study of Flyvbjerg et al. (2002), that in large regard fronted strategic misrepresentation to be the leading cause of cost overruns, is deemed one of the most influential studies in the domain of cost performance for large-scale projects. It is to be argued that the thematics elaborated in the most well-known study in a domain may have the possibility of setting the tone for subsequential research. As for large-scale projects, the debate of where the shoe pinches in regard to the causes of cost performance have been ongoing recently (Flyvbjerg et al., 2018). Whether the literature in general has been scarcer due to the lack of robust proof of non-quantifiable theories is ambiguous. However, looking from a comparison point of view, it is unfortunate that a large part of the literature has focused on underlying causes that are hard to validate statistically. Further on, there are other notable matters of complication in this regard.

6.1.3 Skewness in the focus on underlying determinants

The recurrent statement through this report has been that the focus within the literature on cost performance for large-scale projects has been strongly skewed toward seeking endogenous determinants related to cost performance rather than exogenous ones (Catalão et al., 2019; Pinheiro Catalão et al., 2019). It has been so because the statement provides some important background to different aspects in the domain of large-scale projects. In this particular case, the fact that literature presumably is skewed may indirectly provide the perception in the domain that endogenous determinants are of a stronger relevance towards cost performance than exogenous determinants, regardless of whether this is actually correct or not. For instance, out of all the studies that reported the project size to be relevant to cost performance, only three studies out of eleven, Ansar et al. (2014), Bacon and Besant-Jones (1998), and Catalão et al. (2019) also analysed whether exogenous variables had any impact on cost performance. Now, of course, it was not necessarily plausible for all of these studies to include analyses of exogenous determinants based on factors such as the scope of the study or the research questions at hand. However, it still exemplifies how endogenous determinants may have been more prevalent in the domain, at least when regarding quantitative statistical studies.

There could be many possible reasons to why the state of quantitative analyses in the literature is leaning more towards endogenous determinants. During the estimating process, the endogenous variables are arguably more likely to be determined and known than the exogenous economic ones. For example, exogenous variables like the exchange rate and market growth are considered systematic uncertainties (Berntsen & Sunde, 2004). Additionally, variables such as the percentage change in employees, GDP, CPI-ATE, CCI and last but not, least the business cycle are all to be considered predictions when estimating the costs. One of three common explanations for why cost overruns occur is humans' inherent inability to predict (Samset et al., 2015). It could be that scholars historically have valued obtaining knowledge towards the endogenous variables rather than the exogenous ones, as the potential of reducing cost escalation could be seen larger here as the variables are determined at the time of estimating rather than uncertain. However, Welde et al. (2019) concluded that one of the main two areas of improvement for large-scale projects in Norway was to better recognise and differentiate between the projects with high -and low uncertainty in cost performance. Catalão et al. (2019) stated that although previous studies have focused on endogenous determinants, it is also profoundly important to enhance exogenous determinants' significance towards cost performance. Considering these arguments, although skewness of focus in the literature is perceived, recent scholars do not seem to disvalue exogenous determinants under endogenous determinants when the topic is addressed.

6.1.4 Inherent differences between projects and databases

Due to differences inherent in the data being explored within the literature on cost performance, such as type of government, the economic state of a country, variety in decision-making methods, cultural differences, and access to project development expertise, it may be challenging to compare studies on the same premise between markets, sectors and countries (Love & Ahiaga-Dagbui, 2018; Mišić & Radujković, 2015). The fact that projects, to some extent, cannot be viewed alike if they are situated in two different countries is a reasonable challenge to be aware of. There is a limited course of action that scholars within the domain can apply to deal with the inherent region-specific differences. The same would arguably apply to projects of different types as well. Bacon and Besant-Jones (1998) argued that analyses should differentiate on project types if wanting to reduce variability in the cost performance. Several studies have also found differences in cost performance and underlying causes when differentiating projects on project type (Ansar et al., 2016; Cantarelli, van Wee, et al., 2012; Welde, 2017). In this report, no clear findings suggested that the cost performance for road projects had unique underlying determinants compared to the rest of the sample. However, it is plausible to believe that other factors not tested for in this report are more related to certain project types than others.

A proclaimed best practice consisting of four measuring standards, measuring in total percentage cost, using cost in local currency, using constant prices, and a concise baseline, has been proposed to narrow down the volume of differences among studies and make comparisons more precise (Flyvbjerg et al., 2018). The first three are to be deemed purely calculational in nature and call for the measurements between studies to be succinct. However, they all rely on the latter standard, the use of concise baselines. The use of ToD as a consistent baseline for determining estimated costs is quite common in the literature (Cantarelli, Molin, et al., 2012; Flyvbjerg, Bruzelius, et al., 2003). The same could be reasonable to say for the actual costs, being the obtained costs after the completion of the project. However, there is posed a concern about the actual consistency in the use of ToD as a baseline since this referment and information at hand at the time can differ widely between different actors depending on what point in time for the project the ToD is performed (Welde, 2017). If the baseline for the measurements is inherently different between actors, the three calculation methods will also be so. Hence, the comparisons between projects that have undergone different estimation schemes could be misleading. It could well be that the ToD between different actors and estimation schemes may not be differentiating too much, such that the strength in comparisons may be reasonably good. However, without proposing a better and more robust baseline for the measurement of estimated costs, these differences should be remarked on when comparing projects from different studies. That goes for the proposed differences mentioned at the start of this section as well. Nonetheless, quantitative cost performance studies from the literature are still of value as they can go a long way in indicating possible concerns related to other projects as well as their own.

6.2 Exogenous variables – their role and importance

Within the literature, there has been a general focus on endogenous determinants in relation to studying cost performance, whereas exogenous determinants have been partially ignored or undermined (Catalão et al., 2019; Pinheiro Catalão et al., 2019). Exogenous variables differ from endogenous ones by being out of the control of the clients and the contractors (Isik et al., 2010; Welde et al., 2018). These variables are often considered as systematic uncertainties and are essential to monitor and evaluate during cost estimation processes (Berntsen & Sunde, 2004). Although some studies like Welde et al. (2019), Snyman (2007) and Englund et al. (2013) argue the importance of these variables, few studies have actually statistically studied how they affect the cost performance. The following sub-sections will further elaborate on the importance of the exogenous variables by looking into the results and the theory in parallel.

6.2.1 Inflation (CPI-ATE)

Several different regression analyses were undertaken to analyse how the change in CPI-ATE between the ToD and the end of the project influenced the cost performance of the projects. With the inclusion of visual outliers, the relation between CPI-ATE and cost deviation from the cost frame was found to be significant within a 90 per cent level for all the projects and the road projects exclusively. Additionally, the relation was found statistically significant when analysing road projects when looking at cost deviation from the steering frame. However, by removing the rightmost outlier for all the analyses, none of the relations was found significant. In other words, it shows that the data included in the analyses were too scarce to prove any statistically relevant evidence. This opposes the findings of Ansar et al. (2014) and Catalão et al. (2019), who argued that inflation is be undermined in the estimating process. Pickrell (1992) found that although projects having experienced unanticipated inflation also obtained higher cost overruns, this was due to all the same projects also experiencing hefty delays. As lightly mentioned, the use of inflation targeting as a monetary policy allows for actors in the economy to have a transparent view of the inflation trajectory in the country (Svensson, 2010). From the results, it looks like one has been able to utilise this power of transparency to ensure that inflation has been dealt with satisfyingly when estimating. Without having sufficient proof, it could also be that the Norwegian projects suffer less from long delays and followingly experience less anticipated inflation growth during the project phase as opposed to the findings in Pickrell (1992).

6.2.2 Wage

The analyses regarding what consequences the absolute change in wage in the construction industry had on cost performance showed varying results. When analysing all projects related to construction, the relationship proved significant within a 90 per cent level for both the cost deviation from cost -and steering frame. The results are somewhat in-line with what Dahl et al. (2017) found for the petroleum industry, that a higher relative wage surprise was significantly related to higher cost overrun. The findings can to some extent reflect the arguments of Hillebrandt (2000) and Bon (1998) that there is a relation between labour rates and cost performance. However, there are some precautions to take in about the results. First, they are not entirely statistically significant, only being significant within the 90 per cent level. Hence, it is a possibility that the relations are to be ascribed by chance. Second, the analyses regarding the road projects alone were not significant when removing the one clear outlier. It could be that road projects have generally been better in taking predicted wage growth into account when forecasting the project costs. On the other hand, it is also a possibility that the set of data for all the construction-related projects is scarce and includes outliers not so visually perceivable. Furtherly, there is no clear evidence to suggest whether one explanation weighs heavier than the other. However, judging visually from Figure 5.7 and Figure 5.8, the data points which occur in the most compact area do not seem to inhabit any pattern, suggesting that the relationship could be arbitrary. This, in turn, is somewhat reflected in the results by not being significant within the 95 per cent level.

6.2.3 Employment

In relation to a tight labour market, one can tend to experience that productivity and quality of work may decrease along with a higher frequency of costly bottlenecks within the production (Dahl et al., 2017; Welde et al., 2019). The state of employment in a given sector has the possibility of indicating the related state of activity, where a high level of activity often relates to a decrease in quality and productivity and an increase in costly fixes (Dahl et al., 2017). For the analyses done in this report, only the relation between cost deviation from the cost frame and the state of employment at ToD proved to have some relationship. However, some reflections are to be made on this result. From Figure 5.9, all projects implemented at the time when employment was at its highest experienced cost underrun. This perception is opposed to the theoretical basis given by Dahl et al. (2017). Nonetheless, this only regard three projects, which is way too low to draw any robust conclusion towards such a claim. More interesting is the trendline in Figure 5.9. According to the equation of the trendline, for any given number of employees in the sector at ToD related to the data points, the expected cost deviation should be negative for the projects in the set. This has arguably no root in reality, and the set of data is presumably more arbitrary than the given p-value suggests. A weakness in the data is that the state of employment is given in annual averages. This implies that all projects within the same year were initiated at the same state of employment. This simplification does not necessarily reflect reality. As mentioned, there are arguments suggesting that a high level of activity, reflected by the state of employment in the sector, could imply higher costs through a lower quality of work, decrease in productivity, and higher frequency of costly mistakes (Bon, 1998; Dahl et al., 2017; Snyman, 1989; Welde et al., 2019). The results in this report indicate that cost estimates have been handling these mechanisms in a satisfying manner.

6.2.4 CCI

The CCI is the main indicator in the calculation of input factors in the infrastructure sector, such as the hourly rate for workers and material prices (Welde et al., 2019). Furtherly, it is commonly used to convert prices on estimates and total costs on infrastructure projects, as well as to measure the activity in the mainland economy (Berntsen & Sunde, 2004; Welde et al., 2019). None of the analyses done in regard to the relation between the CCI and the cost performance could prove any significance when removing the visually clear outliers. Welde et al. (2019) and Welde (2017) both worried that the CCI for a time did not reflect the actual development in the market prices and that cost forecasts would be underestimated if this notion was not treated carefully. Even earlier, it was pointed out by Berntsen and Sunde (2004) that this deviation should be regarded as a systematic uncertainty. From the results, it could be indicated that the notion has been taken into consideration when estimating the costs. Whether it has been worked actively on this notified disproportion to ensure that estimates are more robust is not clear from the results themselves. However, it is reasonable to assume that since several papers have stated this recurrent problem, all of them within the Concept research programme, the forecasters have known about this proposed issue. Seeing that there has been a concern about the CCI and its usage, the results can, to some extent, be viewed with relief as they do not indicate that there has been any relation between the index and cost overrun.

6.2.5 GDP Mainland Norway

GDP is regarded as the main measurement of the size of the economy in a country (Coyle, 2015). Bacon and Besant-Jones (1998) found that the value of the GDP deflator has been relevant to the cost performance for large-scale projects. Studies like Ansar et al. (2014) and Ansar et al. (2016) found that the GDP within the host country of projects was unrelated to cost performance. Pinheiro Catalão et al. (2019) hypothesised that “good” times in the economy would imply favourable cost performance while finding that a larger share of public investment into GDP promoted increases in cost overrun. Furtherly, Catalão et al. (2021) found that growth in GDP within the country tended to increase cost deviations for their projects. Using a similar analysis as Bacon and Besant-Jones (1998), using the change in GDP between the ToD and end of project or contract initiation, there was not found any significant correlation between the change in GDP and cost performance. Both Pinheiro Catalão et al. (2019) and Catalão et al. (2021) argued that higher economic growth within a country would lead to a reduction in the controls on spending due to the higher number of projects and larger volumes of money circulating. Evidently, the change in GDP did not influence the cost performance for the set of data used in this report. However, if it was to be a correlation between the two variables, it is unlikely that the control on spending would be the underlying reason. Both Odeck et al. (2015) and Magnussen and Olsson (2006) found that projects implemented after the State project model was introduced obtained fewer cost overruns compared to those projects implemented before its introduction. The State project model, which in this case would be equivalent to the so-named controls on spending, would in other words most likely not have been the underlying reason for the increase in cost overrun. Further, a possible reason why the change in GDP does not relate to cost performance is the inflation targeting policy run in Norway. It is explicitly stated that Norway aims to be a flexible inflation target actor, namely that the inflation targeting system seeks to stabilise both the inflation and the gap in GDP (Svensson, 2010). With the transparency, such a policy obtains, it is arguably easier for forecasters to predict the future output as the target is announced and attempted to be stabilised. In summary, the change within GDP is implied to be handled in a satisfying manner by not being a relevant cause towards cost performance when estimating costs for the projects.

6.2.6 Business cycles

There have been indications that business cycles have been relevant to the cost performance of large-scale projects. Dahl et al. (2017) found that the business cycle affects the cost performance as the cost overruns became significantly higher during expansions. Welde (2017) argued that one of the main improvement points towards the cost estimating of the large government investment projects in Norway was to obtain better knowledge in regard to the dynamics of the market uncertainty. However, it was concluded that the cost control had been solid to the extent that one should be able to handle projects initiated in expansions based on the findings at the time. Makovšek et al. (2012) remarked that market fluctuations and rapid changes in the economy have to be reviewed with care when estimating project costs. In addition, several studies have pointed out market uncertainty and cyclical factors to be relevant to the cost performance of projects, either directly or indirectly (Berntsen & Sunde, 2004; Bon, 1998; Hillebrandt, 2000; Snyman, 1989; Welde et al., 2019).

When utilising the HP filter, statistically significant correlations were found between the business cycle and the cost performance for all the analyses. These results indicate that cost overruns increase along with the positive increase in current GDP deviation from the long-lasting lasting GDP trend. Visually perceiving Figure 5.14 and Figure 5.15, there are presumably clear indications that the projects initiated during strong expansions perform worse than those initiated during the lowest recessions. The findings are in-line with the claims of Dahl et al. (2017). Welde (2017) found that projects initiated during the global financial crisis had a higher occurrence of cost overrun than those initiated before and after. Further, market uncertainty has been identified as one of the most predominant uncertainty factors regarding Norwegian large-scale investments (Berntsen & Sunde, 2004; Welde, 2017; Welde et al., 2019). In that regard, the results obtained in the report may not be a huge surprise. Interestingly, although market uncertainty has been regarded as one of the main uncertainties, the results imply that one has not been able to account for this matter adequately. In other words, it is indicated that forecasters potentially have neglected the relevance of the business cycle toward cost performance. Further another potentially interesting topic is the uncertainty related to the deviation between the CCI and the actual prices in the market (Berntsen & Sunde, 2004; Welde, 2017; Welde et al., 2019). Although it was not found any significant evidence that one has underestimated project costs due to the state of the CCI, it could still be that the estimates still rely too heavily on this index, and furtherly that the real market prices are not appropriately concerned. However, without knowing in detail how the estimation process is, this is to be regarded as speculation. Nonetheless, given that the HP filter with the chosen parameter $\lambda = 400$ correctly estimates the market fluctuations, one can derive that the business cycle at the ToD and the contract initiation is a significant driver of the increase in cost overrun. This assumption does however bring some remarks.

Even though the HP filter is regarded as a standard method to apply when analysing the business cycle and market fluctuations, there has been criticism of its use (Ravn & Uhlig, 2002). As mentioned, there lie weaknesses in the fact that the parameter λ is chosen arbitrarily by the analyst and that the potential production is influenced skewed by the actual production (Benedictow & Johansen, 2005). From Figure 4.2, one can perceive how the parameter λ influences the graph representing the calculation of percentage deviation from the trend. In addition, Figure 5.18 shows how the analysis is influenced when choosing a much larger value for the parameter λ. It is hard for the analyst to do anything about how the method acts in terms of its skewed influence on the potential production. Furtherly, how the method differentiates the output based on the somewhat guesstimated value of λ is also a shortcoming in itself. Nonetheless, the analyses in this report has relied on the value presented in Eika (2008) of λ=400 in an attempt to paint the correct picture of the business cycles in Norway. The analyses are not to be regarded as invalid just because of their inherent weaknesses and should presumably still persist the power of indicating the relations between the business cycles and the cost performance for the projects. However, it is important to be aware of the weaknesses when interpreting the results.

6.2.7 Exchange rate – I44

Berntsen and Sunde (2004) argue that currency uncertainty has been regarded as one of the more prominent systematic uncertainties for large-scale projects in Norway, especially procurement projects. However, there is a lack of knowledge on how this factor affects the projects since it has been disregarded when performing the QA2 analyses (Welde et al., 2019). For the analyses done in this report, no correlation was found between the exchange rate I-44 and the cost performance of the projects. These findings align with the likes of Ansar et al. (2014) and Ansar et al. (2016), which could not find any relation either. Be that as it may, there are some aspects of the analyses that should be considered. First, there have been no attempts to divide the projects based on their relevance to the exchange rate. That is, all projects are, in theory, regarded to be equally influenced by the exchange rate. Now, this is clearly a simplification of reality. There are most likely projects within the data that are more affected by the exchange rate than others. Procurement projects are arguably one of the types that are largely influenced (Berntsen & Sunde, 2004). Furtherly, the I-44 is a weighted average index based on 44 countries. Now, the index is constructed such that the currencies with the highest share of imports are weighted the most (Hungnes, 2020). Accordingly, there could be cases where projects heavily affected by one specific currency and its related exchange are not found to be so if the weight of that specific exchange rate is low within the I-44. This simplification is a weakness as the analyses need to assume that all projects are affected equally and according to the exchange rate weights given, which most likely is not the case as exemplified. At last, the index used is given in yearly values. Hence, many projects in the analyses did not experience any change in the exchange rate since the contract was assumed to have been initiated the same year. Again, another simplification that may not satisfyingly reflect reality. In summary, it is to be argued if the analyses of the possible relation between the exchange rate and the cost performance are relatively weak. With the number of simplifications and their inherent multiple weaknesses, the analyses may not be strong enough to provide any solid conclusions towards the actual relationship that was attempted to be analysed.

7 Conclusion

The field of large-scale projects has lacked studies that have focused on and analysed the relevance of exogenous determinants toward cost performance. This report has aimed to enlighten the knowledge on how exogenous economic determinants impact large government investment projects in Norway. To do so, this report has undertaken a literature review and performed statistical analyses on 90 large-scale government projects in Norway. This section will provide conclusions to the presented research questions and present suggestions for future research.

A range of different exogenous economic variables was tested, utilising simple linear regression to explore their potential relationship with the cost performance for the projects. Some of the factors analysed indicated to affect cost performance. The percentage change in CPI-ATE, CPI-ATE at ToD, the absolute change in the average wage, and the state of employment at ToD all, to some extent, proved relevant. However, most of these results could be neglected due to outliers, whereas the absolute change in average wage only was significant at the 90 per cent level when regarding deviation both from the cost frame and the steering frame. Furtherly utilising the HP filter, the business cycles proved significant towards cost performance. In specific, higher positive deviations from the GDP Mainland Norway trend promoted increases in cost escalations. This relationship was proved significant for the percentage deviation at ToD and at contract initiation, analysing both the cost deviation from the cost frame and the steering frame. Furtherly, the business cycle seems to have the most impact on the cost performance for large government investment projects in Norway out of the analysed exogenous determinants.

There lies great importance in monitoring the exogenous economic determinants to estimate costs for large government investment projects in Norway properly. Scholars within the domain have pointed towards the importance of macro variables such as inflation, market conditions and economic growth as important factors to consider. Despite the inherent differences between projects and studies in different countries, it should still be viewed as plausible to use international findings as indications for projects nationally. In Norway, there are given explicit measures in the estimation process to ensure that relevant exogenous variables are handled satisfyingly. It is important to note that although some variables were not found significant in their relationship to cost performance, they are not to be viewed as irrelevant. The change and state of GDP Mainland Norway, the CCI, and the I-44 exchange were not found to be cost drivers of cost overruns. However, it is deemed more likely that these variables are considered and dealt with adequately rather than not being relevant to the cost performance of the projects. Furtherly, no factors on their own can fully explain the cost performance for a portfolio of projects. The nature of projects makes individual analyses necessary for the cost estimation process. Exogenous economic determinants should be, and presumably have been, considered in these analyses as they are a part of the relevant determinants of cost performance for large-scale projects in Norway.

The skewness of focus in the literature may contribute to the perception that some underlying explanations are more salient than others, even if that is not necessarily the case. The well-renowned study of Flyvbjerg et al. (2002) set the premise by arguing that strategic misrepresentation and optimism bias were two of the root causes towards unsatisfiable cost performance for large-scale projects. Other scholars followed in their tracks, but the robust evidencing findings supporting these claims are not to be found. Furtherly, there seems to be an unbeneficial lack of quantitative statistical research within the domain. Additionally, those studies that fall into this category more than often neglect exogenous determinants in their analyses. This is done despite the fact that exogenous factors towards cost performance often are indicated to be relevant. Considering these perceptions, the contribution of exogenous determinants is within the literature commonly expected to be of low importance and, followingly, not explored much. The findings in this report, regarding both the literature and the results, suggest that exogenous economic determinants presumably play a more critical role toward cost performance than what is depicted in the literature compared to other explanations or determinants. That is, exogenous economic determinants are not to be viewed as more important than other determinants, but rather that the research in the field should regard them to a greater extent than what is present as of now.

In regard to future research on cost performance for large-scale projects, additional research on other exogenous variables is a potential path to explore. Both extending the list of analyses on economic variables, but also adding other sub-groups of exogenous variables, such as political determinants, should be of interest. Preferably, the analyses should be statistically quantitative in their form. Further on, more thorough analyses differentiating on project type would be possible the more projects that are added to Trailbase, potentially having the power to conclude differences between the types. At last, utilising multiple linear regression methods with a combination of relevant endogenous -and exogenous variables could be of great value as one can then can analyse what combination of determinants influences cost performance.

On a portfolio level, large government investment projects in Norway look to be concerning exogenous determinants in a relatively good manner with respect to cost performance. Constant evaluations, research, and analyses in the field of large-scale projects are of vast importance to enhance the knowledge, and further take an active stand in disallowing unanticipated tendencies of cost overruns. As a last interesting remark, the COVID-19 pandemic has led to disruptions in the worldwide economy. With a continuously extending set of project data being added to Trailbase, it sure will be interesting to explore if the relatively good handling of exogenous determinants as of today still applies for projects influenced by this troubling event.

References

Adams, R. J., Smart, P., & Huff, A. S. (2017). Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies. *International Journal of Management Reviews*, *19*(4), 432-454.

Akobeng, A. K. (2005). Understanding systematic reviews and meta-analysis. *Archives of disease in childhood*, *90*(8), 845-848.

Alexopoulos, E. C. (2010). Introduction to multivariate regression analysis. *Hippokratia*, *14*(Suppl 1), 23.

Aljohani, A., Ahiaga-Dagbui, D., & Moore, D. (2017). Construction projects cost overrun: What does the literature tell us? *International Journal of Innovation, Management and Technology*, *8*(2), 137.

Alversia, Y. (2011). Doing quantitative research in education with SPSS. In: Taylor & Francis.

Ansar, A., Flyvbjerg, B., Budzier, A., & Lunn, D. (2014). Should we build more large dams? The actual costs of hydropower megaproject development. *Energy policy*, *69*, 43-56.

Ansar, A., Flyvbjerg, B., Budzier, A., & Lunn, D. (2016). Does infrastructure investment lead to economic growth or economic fragility? Evidence from China. *Oxford Review of Economic Policy*, *32*(3), 360-390.

Awojobi, O., & Jenkins, G. P. (2015). Were the hydro dams financed by the World Bank from 1976 to 2005 worthwhile? *Energy policy*, *86*, 222-232.

Awojobi, O., & Jenkins, G. P. (2016). Managing the cost overrun risks of hydroelectric dams: An application of reference class forecasting techniques. *Renewable and Sustainable Energy Reviews*, *63*, 19-32.

Backus, D. K., & Kehoe, P. J. (1992). International evidence on the historical properties of business cycles. *The American Economic Review*, 864-888.

Bacon, R. W., & Besant-Jones, J. E. (1998). Estimating construction costs and schedules: experience with power generation projects in developing countries. *Energy policy*, *26*(4), 317-333.

Bacon, R. W., Besant-Jones, J. E., & Heidarian, J. (1996). *Estimating construction costs and schedules: experience with power generation projects in developing countries*. The World Bank.

Badampudi, D., Wohlin, C., & Petersen, K. (2015). Experiences from using snowballing and database searches in systematic literature studies. Proceedings of the 19th International Conference on Evaluation and Assessment in Software Engineering,

Bailey, M. J., Muth, R. F., & Nourse, H. O. (1963). A regression method for real estate price index construction. *Journal of the American Statistical Association*, *58*(304), 933-942.

Barakchi, M., Torp, O., & Belay, A. M. (2017). Cost estimation methods for transport infrastructure: a systematic literature review. *Procedia Engineering*, *196*, 270-277.

Barro, R. J. (1997). *Macroeconomics*. MIT Press.

Benedictow, A., & Johansen, P. R. (2005). Prognoser for internasjonal økonomi: Står vi foran en amerikansk konjunkturavmatning?

Berg, P., Andersen, K., Østby, L., Lilleby, S., Stryvold, S., Holand, K., Korsnes, U., Rønning, K., Johansen, F., & Kvarsvik, T. (1999). Styring av statlige investeringer. *Sluttrapport fra styringsgruppen, Finansdepartementet*, *10*.

Bernanke, B. S., Laubach, T., Mishkin, F. S., & Posen, A. S. (2018). *Inflation targeting: lessons from the international experience*. Princeton University Press.
Berntsen, S., & Sunde, T. (2004). Styring av statlige prosjektporteføljer i staten. *Concept rapport*(1).
Bjerkholt, O. (2000). *Kunnskapens krav: om opprettelsen av Forskningsavdelingen i Statistisk sentralbyrå*. Statistisk sentralbyrå.
Bjørnnes, A. K., & Gjevjon, E. R. (2019). Kvalitet i kvantitativ metode–et innblikk. *Sykepleien forskning*, *14*, 78806.
Blanc-Brude, F., Goldsmith, H., & Valila, T. (2006). Ex ante construction costs in the European road sector: a comparison of public-private partnerships and traditional public procurement.
Blanc-Brude, F., Goldsmith, H., & Välilä, T. (2009). A comparison of construction contract prices for traditionally procured roads and public–private partnerships. *Review of Industrial Organization*, *35*(1), 19-40.
Blanchard, O., & Sheen, J. (2013). *Macroeconomics; Australasian Edition*. Pearson Higher Education AU.
Bodie, Z., Kane, A., & Marcus, A. (2014). *EBOOK: Investments-Global edition*. McGraw Hill.
Bon, R. (1998). *Building as an economic process*. Massachusetts Institute of Technology.
Boynton, P. M., & Greenhalgh, T. (2004). Selecting, designing, and developing your questionnaire. *Bmj*, *328*(7451), 1312-1315.
Braeckman, J. P., Disselhoff, T., & Kirchherr, J. (2019). Cost and schedule overruns in large hydropower dams: an assessment of projects completed since 2000. *International Journal of Water Resources Development*.
Brookes, N. J., & Locatelli, G. (2015). Power plants as megaprojects: Using empirics to shape policy, planning, and construction management. *Utilities Policy*, *36*, 57-66.
Bukkestein, I., Welde, M., & Volden, G. H. (2020). Bruk og nytte av etterevalueringer av prosjekter.
Burns, A. F., & Mitchell, W. C. (1946). *Measuring business cycles*. National bureau of economic research.
Callegari, C., Szklo, A., & Schaeffer, R. (2018). Cost overruns and delays in energy megaprojects: How big is big enough? *Energy policy*, *114*, 211-220.
Cantarelli, C. C., Flyvbjerg, B., & Buhl, S. L. (2012). Geographical variation in project cost performance: the Netherlands versus worldwide. *Journal of Transport Geography*, *24*, 324-331.
Cantarelli, C. C., Flyvbjerg, B., Molin, E. J. E., & Van Wee, B. (2013). Cost overruns in large-scale transportation infrastructure projects: Explanations and their theoretical embeddedness. *arXiv preprint arXiv:1307.2176*.
Cantarelli, C. C., Flyvbjerg, B., van Wee, B., & Molin, E. J. (2010). Lock-in and its influence on the project performance of large-scale transportation infrastructure projects: investigating the way in which lock-in can emerge and affect cost overruns. *Environment and Planning B: Planning and Design*, *37*(5), 792-807.
Cantarelli, C. C., Molin, E. J. E., van Wee, B., & Flyvbjerg, B. (2012). Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases. *Transport Policy*, *22*, 49-56. https://doi.org/https://doi.org/10.1016/j.tranpol.2012.04.001
Cantarelli, C. C., van Wee, B., Molin, E. J. E., & Flyvbjerg, B. (2012). Different cost performance: different determinants?: The case of cost overruns in Dutch transport infrastructure projects. *Transport Policy*, *22*, 88-95.
Capka, J. R. (2004). Megaprojects--They Are a Different Breed. *Public Roads*, *68*(1), 2-9.
Catalão, F. M. P. (2019). Cost and time overruns in public investment projects: an exogenous determinants model, theory and practice.
Catalão, F. P., Cruz, C. O., & Sarmento, J. M. (2019). The determinants of cost deviations and overruns in transport projects, an endogenous models approach. *Transport Policy*, *74*, 224-238.

Catalão, F. P., Cruz, C. O., & Sarmento, J. M. (2021). Determinants of cost deviations and overruns in UK transport projects. Proceedings of the Institution of Civil Engineers-Transport,
Cavalieri, M., Cristaudo, R., & Guccio, C. (2019). Tales on the dark side of the transport infrastructure provision: a systematic literature review of the determinants of cost overruns. *Transport reviews*, *39*(6), 774-794.
Cheng, Y.-M. (2014). An exploration into cost-influencing factors on construction projects. *International Journal of Project Management*, *32*(5), 850-860.
Cooley, T. F., & Ohanian, L. E. (1991). The cyclical behavior of prices. *Journal of Monetary Economics*, *28*(1), 25-60.
Coyle, D. (2015). GDP. In *GDP*. Princeton University Press.
Creedy, G. D., Skitmore, M., & Wong, J. K. (2010). Evaluation of risk factors leading to cost overrun in delivery of highway construction projects. *Journal of Construction Engineering and Management*, *136*(5), 528-537.
Dahl, R. E., Lorentzen, S., Oglend, A., & Osmundsen, P. (2017). Pro-cyclical petroleum investments and cost overruns in Norway. *Energy policy*, *100*, 68-78.
De Jong, M., Annema, J., & Van Wee, G. (2013). How to build major transport infrastructure projects within budget, in time and with the expected output; a literature review. *Transport reviews*, *33*(2), 195-218.
Denicol, J., Davies, A., & Krystallis, I. (2020). What are the causes and cures of poor megaproject performance? A systematic literature review and research agenda. *Project management journal*, *51*(3), 328-345.
Denney, A. S., & Tewksbury, R. (2013). How to write a literature review. *Journal of criminal justice education*, *24*(2), 218-234.
Denyer, D., & Tranfield, D. (2009). Producing a systematic review.
Durdyev, S., Omarov, M., Ismail, S., & Lim, M. (2017). Significant contributors to cost overruns in construction projects of Cambodia. *Cogent Engineering*, *4*(1), 1383638.
Eika, T. (2008). Det svinger i norsk økonomi.
Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review*, *14*(4), 532-550.
Englund, A., Bergh, H., Møll, A., & Halsos, O. S. (2013). Store statlige investeringers betydning for konkurranse-og markedsutviklingen. In: Ex ante akademisk forlag.
Finansdepartementet. (2019). *Hva er statens prosjektmodell?* Retrieved 14/10/2021 from https://www.regjeringen.no/no/tema/okonomi-og-budsjett/statlig-okonomistyring/ekstern-kvalitetssikring2/hva-er-ks-ordningen/id2523897/
Fisher, G. (1953). Endogenous and exogenous investment in macro-economic models. *The Review of Economics and Statistics*, 211-220.
Flyvbjerg, B. (2017). *The Oxford handbook of megaproject management*. Oxford University Press.
Flyvbjerg, B., Ansar, A., Budzier, A., Buhl, S., Cantarelli, C., Garbuio, M., Glenting, C., Holm, M. S., Lovallo, D., & Lunn, D. (2018). Five things you should know about cost overrun. *Transportation Research Part A: Policy and Practice*, *118*, 174-190.
Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). *Megaprojects and risk: An anatomy of ambition*. Cambridge university press.
Flyvbjerg, B., Holm, M. S., & Buhl, S. (2002). Underestimating costs in public works projects: Error or lie? *Journal of the American planning association*, *68*(3), 279-295.
Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2003). How common and how large are cost overruns in transport infrastructure projects? *Transport reviews*, *23*(1), 71-88.
Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2004). What causes cost overrun in transport infrastructure projects? *Transport reviews*, *24*(1), 3-18.
Gil, N., & Lundrigan, C. (2012). The leadership and governance of megaprojects. *Manchester: Manchester University*.
Greiman, V. A. (2013). *Megaproject management: Lessons on risk and project management from the Big Dig*. John Wiley & Sons.

Halkjelsvik, T., & Jørgensen, M. (2018). *Time Predictions: Understanding and Avoiding Unrealism in Project Planning and Everyday Life*. Springer Nature.

Hillebrandt, P. M. (2000). *Economic theory and the construction industry*. Springer.

Hodrick, R. J., & Prescott, E. C. (1997). Postwar US business cycles: an empirical investigation. *Journal of Money, credit, and Banking*, 1-16.

Hu, Y., Chan, A. P., Le, Y., & Jin, R.-z. (2015). From construction megaproject management to complex project management: Bibliographic analysis. *Journal of management in engineering*, *31*(4), 04014052.

Hungnes, H. (2020). *Predicting the exchange rate path: The importance of using up-to-date observations in the forecasts*.

Isik, Z., Arditi, D., Dilmen, I., & Birgonul, M. T. (2010). The role of exogenous factors in the strategic performance of construction companies. *Engineering, Construction and Architectural Management*.

Iversen, A. B. (2011). 'Kvalitative og kvantitative metoder–et kontinuum?'. *Sosiologisk tidsskrift*, *19*(02), 175-183.

Johansen, I., Rodriguez, J., & Sandberg, L. (2006). Underliggende inflasjon: mange forslag-men ingen fasit.

Johansen, P. R., & Eika, T. (2000). Drivkrefter bak konjunkturforløpet på 1990-tallet.

Jore, A. S. (1999). Etterprøving av Norges Banks anslag.

Justesen, L. N., & Mik-Meyer, N. (2012). *Qualitative research methods in organisation studies*. Gyldendal.

Jørgensen, M. (2014). What we do and don't know about software development effort estimation. *IEEE software*, *31*(2), 37-40.

Kahneman, D., & Tversky, A. (2013). Prospect theory: An analysis of decision under risk. In *Handbook of the fundamentals of financial decision making: Part I* (pp. 99-127). World Scientific.

Kirchherr, J., Matthews, N., Charles, K. J., & Walton, M. J. (2017). "Learning it the Hard Way": Social safeguards norms in Chinese-led dam projects in Myanmar, Laos and Cambodia. *Energy policy*, *102*, 529-539.

Knopf, J. W. (2006). Doing a literature review. *PS: Political Science & Politics*, *39*(1), 127-132.

Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners*. Sage.

Le Moigne, G. (1985). Geological complications and cost overruns, A survey of Bank financed hydro-electric projects. *World Bank Energy Department Note*(61).

Lee, J.-K. (2008). Cost overrun and cause in Korean social overhead capital projects: Roads, rails, airports, and ports. *Journal of Urban Planning and Development*, *134*(2), 59-62.

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. *Journal of family medicine and primary care*, *4*(3), 324.

Lewin, C. (2005). Elementary quantitative methods. *Research methods in the social sciences*, 215-225.

Lo, W., Lin, C., & Yan, M. (2007). Contractor's opportunistic bidding behavior and equilibrium price level in the construction market. *Journal of Construction Engineering and Management*, *133*(6), 409-416.

Locatelli, G., Littau, P., Brookes, N., & Mancini, M. (2014). Project characteristics enabling the success of megaprojects: An empirical investigation in the energy sector. *Procedia-Social and Behavioral Sciences*, *119*, 625-634.

Locatelli, G., Mariani, G., Sainati, T., & Greco, M. (2017). Corruption in public projects and megaprojects: There is an elephant in the room! *International Journal of Project Management*, *35*(3), 252-268.

Locatelli, G., Mikic, M., Kovacevic, M., Brookes, N., & Ivanisevic, N. (2017). The successful delivery of megaprojects: a novel research method. *Project management journal*, *48*(5), 78-94.

Lopez del Puerto, C., & Shane, J. S. (2014). Keys to success in megaproject management in Mexico and the United States: Case study. *Journal of Construction Engineering and Management*, *140*(4), B5013001.

Love, P. E., & Ahiaga-Dagbui, D. D. (2018). Debunking fake news in a post-truth era: the plausible untruths of cost underestimation in transport infrastructure projects. *Transportation Research Part A: Policy and Practice*, *113*, 357-368.
Love, P. E., Edwards, D. J., & Irani, Z. (2011). Moving beyond optimism bias and strategic misrepresentation: An explanation for social infrastructure project cost overruns. *IEEE transactions on engineering management*, *59*(4), 560-571.
Love, P. E., Edwards, D. J., & Smith, J. (2005). Contract documentation and the incidence of rework in projects. *Architectural Engineering and Design Management*, *1*(4), 247-259.
Love, P. E., Sing, C.-P., Wang, X., Irani, Z., & Thwala, D. W. (2014). Overruns in transportation infrastructure projects. *Structure and Infrastructure Engineering*, *10*(2), 141-159.
Lowhorn, G. L. (2007). Qualitative and quantitative research: How to choose the best design. Academic Business World International Conference. Nashville, Tennessee,
Lundberg, M., Jenpanitsub, A., & Pyddoke, R. (2011). Cost overruns in Swedish transport projects. In: Centre for Transport Studies Stockholm, Swedish National Road & Transport ….
Løvås, G. (2008). Statistikk for universiteter og høgskoler, 2nd Edi-595 tion. *Universitetsforlaget, Oslo, Norway*.
Ma, C. (2010). Account for sector heterogeneity in China's energy consumption: Sector price indices vs. GDP deflator. *Energy Economics*, *32*(1), 24-29.
Magnussen, O. M., & Olsson, N. O. (2006). Comparative analysis of cost estimates of major public investment projects. *International Journal of Project Management*, *24*(4), 281-288.
Makovšek, D., Tominc, P., & Logožar, K. (2012). A cost performance analysis of transport infrastructure construction in Slovenia. *Transportation*, *39*(1), 197-214.
Marcet, A., & Ravn, M. O. (2004). The HP-filter in cross-country comparisons. *Available at SSRN 511369*.
Menard, S. (2002). *Applied logistic regression analysis* (Vol. 106). Sage.
Meunier, D., & Welde, M. (2017). Ex-post evaluations in Norway and France. *Transportation research procedia*, *26*, 144-155.
Miranda Sarmento, J., & Renneboog, L. (2017). Cost overruns in public sector investment projects. *Public Works Management & Policy*, *22*(2), 140-164.
Mišić, S., & Radujković, M. (2015). Critical drivers of megaprojects success and failure. *Procedia Engineering*, *122*, 71-80.
Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). *Introduction to linear regression analysis*. John Wiley & Sons.
Morris, P. W., & Hough, G. H. (1987). The anatomy of major projects: A study of the reality of project management.
Noreen, E. (1988). The economics of ethics: A new perspective on agency theory. *Accounting, Organizations and society*, *13*(4), 359-369.
Næss, P., Flyvbjerg, B., & Buhl, S. r. (2006). Do road planners produce more 'honest numbers' than rail planners? An analysis of accuracy in road-traffic forecasts in cities versus peripheral regions. *Transport reviews*, *26*(5), 537-555.
Odeck, J. (2004). Cost overruns in road construction—what are their sizes and determinants? *Transport Policy*, *11*(1), 43-53.
Odeck, J., Welde, M., & Volden, G. H. (2015). The impact of external quality assurance of costs estimates on cost overruns: empirical evidence from the Norwegian road sector.
Oglend, A., Osmundsen, P., & Lorentzen, S. (2016). Cost Overrun at the Norwegian Continental Shelf: The Element of Surprise.
Olawale, Y. A., & Sun, M. (2010). Cost and time control of construction projects: inhibiting factors and mitigating measures in practice. *Construction Management and Economics*, *28*(5), 509-526.
Olsson, N. (2011). *Praktisk rapportskriving*. Tapir akademisk.
Pickrell, D. H. (1992). A desire named streetcar fantasy and fact in rail transit planning. *Journal of the American planning association*, *58*(2), 158-176.

Pinheiro Catalão, F., Cruz, C. O., & Miranda Sarmento, J. (2019). Exogenous determinants of cost deviations and overruns in local infrastructure projects. *Construction Management and Economics*, *37*(12), 697-711.
Pitsis, A., Clegg, S., Freeder, D., Sankaran, S., & Burdon, S. (2018). Megaprojects redefined–complexity vs cost and social imperatives. *International Journal of Managing Projects in Business*.
Plummer, J. K. (2014). *Assessing the effects of pre-construction delay in hydropower projects* University of Cambridge].
Ravn, M. O., & Uhlig, H. (2002). On adjusting the Hodrick-Prescott filter for the frequency of observations. *Review of Economics and Statistics*, *84*(2), 371-376.
Rui, Z., Peng, F., Ling, K., Chang, H., Chen, G., & Zhou, X. (2017). Investigation into the performance of oil and gas projects. *Journal of natural gas science and engineering*, *38*, 12-20.
Røisland, Ø., & Sveen, T. (2005). Pengepolitikk under et inflasjonsmål. *Norsk økonomisk tidsskrift*, *119*, 16-38.
Samset, K. F., & Volden, G. H. (2013). Statens prosjektmodell Bedre kostnadsstyring. Erfaringer med de første investeringstiltakene som har vært gjennom ekstern kvalitetssikring. In: Ex ante Akademisk forlag Trondheim.
Samset, K. F., Volden, G. H., Olsson, N., & Kvalheim, E. V. (2015). Styringsregimer for store offentlige prosjekter. En sammenliknende studie av prinsipper og praksis i seks land. In: Ex ante akademiske forlag.
Samset, K. F., Volden, G. H., Olsson, N., & Kvalheim, E. V. (2016). Governance schemes for major public investment projects: A comparative study of principles and practices in six countries. In: Ex ante akademisk forlag.
Schlissel, D., & Biewald, B. (2008). Nuclear power plant construction costs. *Synapse Energy Economics, Inc*, *7*.
Sentralbyrå, S. (2017). Statistisk sentralbyrå. *Retrieved November*, *18*, 2017.
Siemiatycki, M. (2009). Academics and auditors: Comparing perspectives on transportation project cost overruns. *Journal of Planning Education and Research*, *29*(2), 142-156.
Silverman, D. (2015). *Interpreting qualitative data*. Sage.
Snowdon, B., & Vane, H. R. (2005). *Modern macroeconomics: its origins, development and current state*. Edward Elgar Publishing.
Snyman, G. (1989). How the business cycle influences building costs. *Juta's South African Journal of Property*, *5*(3), 38-44.
Snyman, J. (2007). Using knowledge of the business cycle to forecast building costs. CME 25 Conference Construction Management and Economics,
Solheim, H. G., Dammen, E., Skaldebø, H. O., Myking, E., Svendsen, E. K., & Torgersen, P. (2010). Konseptutvikling og–evaluering i store statlige investeringsprosjekt.
Sovacool, B. K., Gilbert, A., & Nugent, D. (2014). An international comparative assessment of construction cost overruns for electricity infrastructure. *Energy Research & Social Science*, *3*, 152-160.
Spildrejorde, S. (2021). Large governmal investments: An overview and quantitative analysis of large governmental projects in Norway. In.
Svensson, L. E. (2010). Inflation targeting. In *Handbook of monetary economics* (Vol. 3, pp. 1237-1302). Elsevier.
Tabassi, A. A., Roufechaei, K. M., Ramli, M., Bakar, A. H. A., Ismail, R., & Pakir, A. H. K. (2016). Leadership competences of sustainable construction project managers. *Journal of cleaner production*, *124*, 339-349.
Terrill, M. (2016). *Cost overruns in transport infrastructure*. Grattan Institute.
Torp, O., Magnussen, O. M., Olsson, N., & Klakegg, O. J. (2006). Kostnadsusikkerhet i store statlige investeringsprosjekter. *Cost uncertainty in large public investment projects) Concept-report*(15).
Torraco, R. J. (2003). Exogenous and endogenous variables in decision making and the implications for HRD research and practice. *Advances in Developing Human Resources*, *5*(4), 423-439.

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *science*, *185*(4157), 1124-1131.
Volden, G., & Samset, K. (2017). Statlige investeringstiltak under lupen. Erfaring med evalueringer av de 20 første KS-prosjektene. *Ex ante akademisk forlag, Trondheim, Concept rapport*, *52*.
Wachs, M. (1982). Ethical dilemmas in forecasting for public policy. *Public Administration Review*, *42*(6), 562-567.
Wachs, M. (1990). Ethics and advocacy in forecasting for public policy. *Business & professional ethics journal*, 141-157.
Welde, M. (2014). Prisomregning på tvers av sektorer. Praksis, konsekvenser, harmonisering.
Welde, M. (2017). Kostnadskontroll i store statlige investeringer underlagt ordningen med ekstern kvalitetssikring. In: Ex ante akademisk forlag.
Welde, M., Dahl, R. E., Torp, O., & Aas, T. (2018). Kostnadsstyring i entreprisekontrakter. In: Ex ante akademisk forlag.
Welde, M., Jørgensen, M., Larssen, P. F., & Halkjelsvik, T. (2019). Estimering av kostnader i store statlige prosjekter: Hvor gode er estimatene og usikkerhetsanalysene i KS2-rapportene? In: Ex ante akademisk forlag.
Yan, X., & Su, X. (2009). *Linear regression analysis: theory and computing*. World Scientific.
Yin, R. K. (2018). *Case study research and applications*. Sage.
Zarnowitz, V. (1992). What is a business cycle? In *The business cycle: Theories and evidence* (pp. 3-83). Springer.
Zhao, L., Mbachu, J., & Domingo, N. (2017). Exploratory factors influencing building development costs in New Zealand. *Buildings*, *7*(3), 57.

Appendix

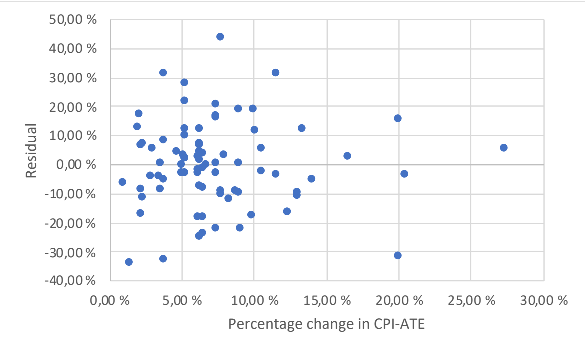
Appendix A: Residual plots of relevant analyses

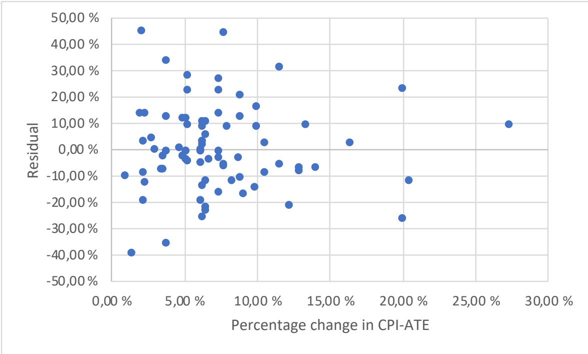
Appendix B: Summary of the results

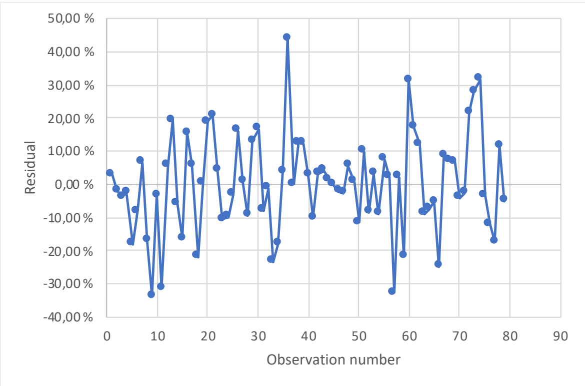
Appendix A: Residual plots of relevant analyses

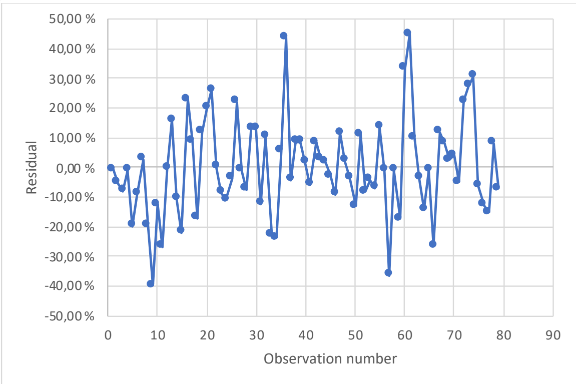
Inflation – CPI-ATE

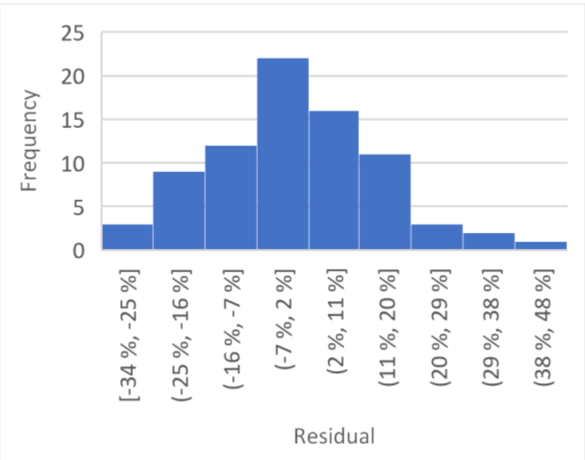
Cost deviation from cost frame (left), steering frame (right)

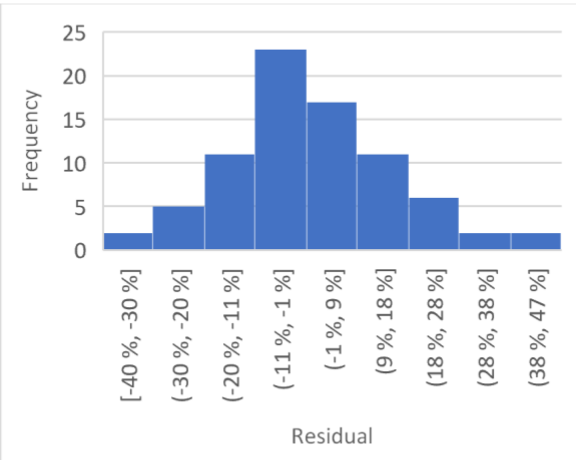




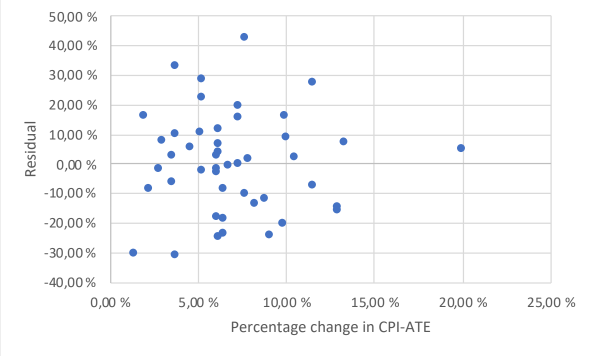


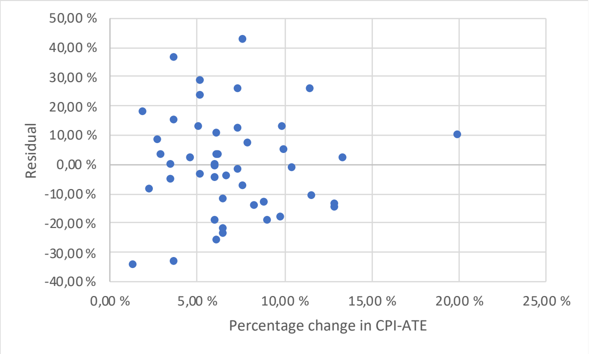


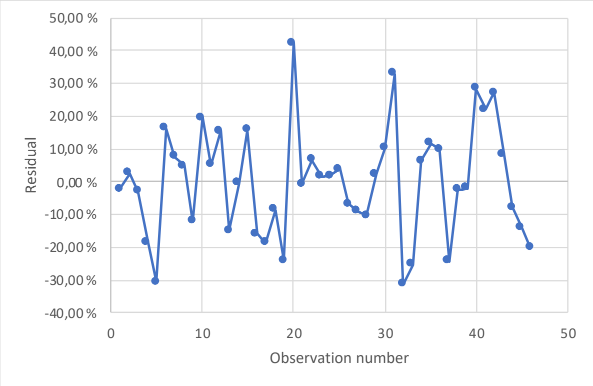


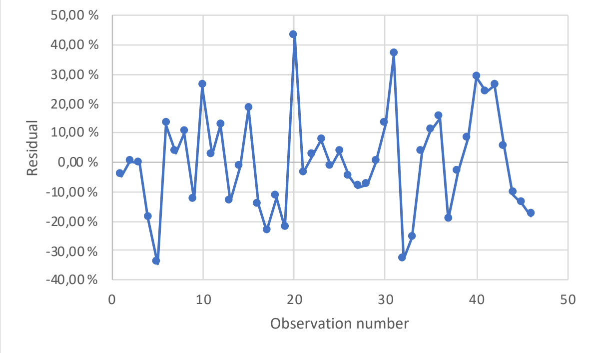


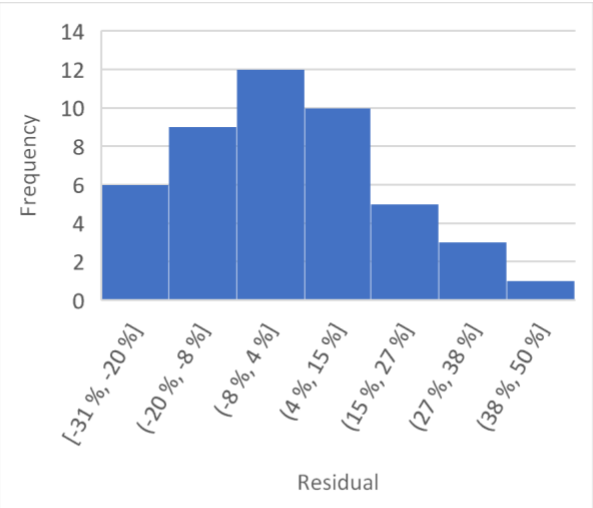
Cost deviation from cost frame (left) and steering frame (right), road projects

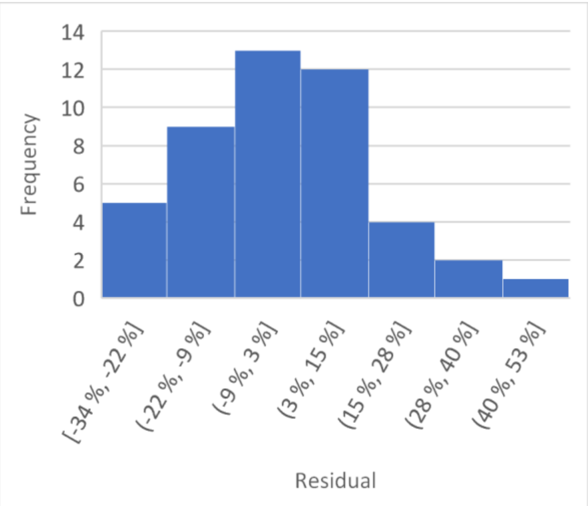






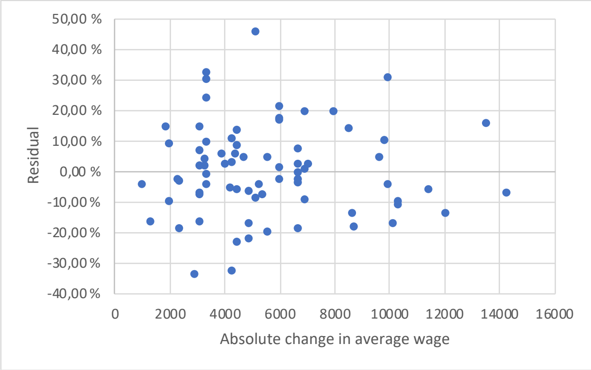


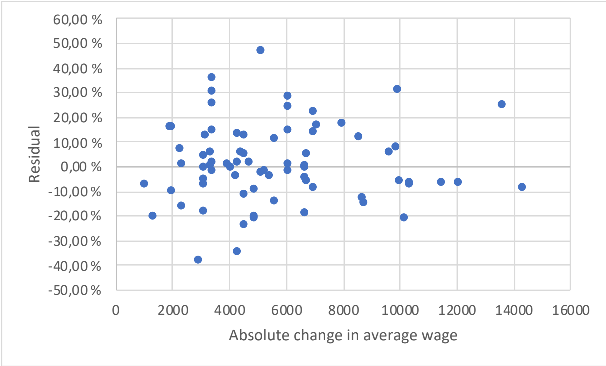


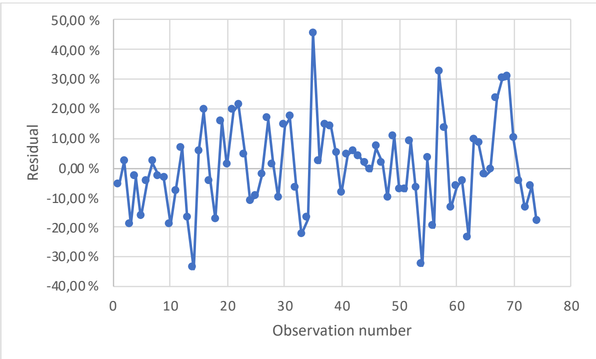


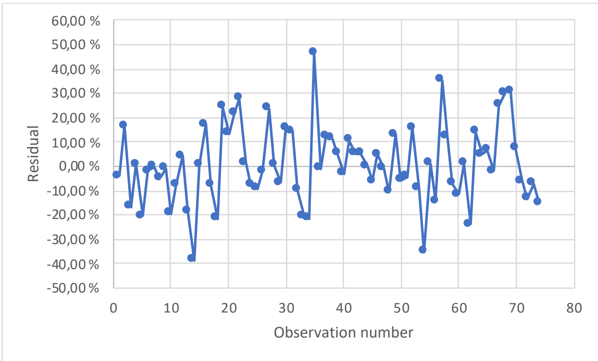
Wage

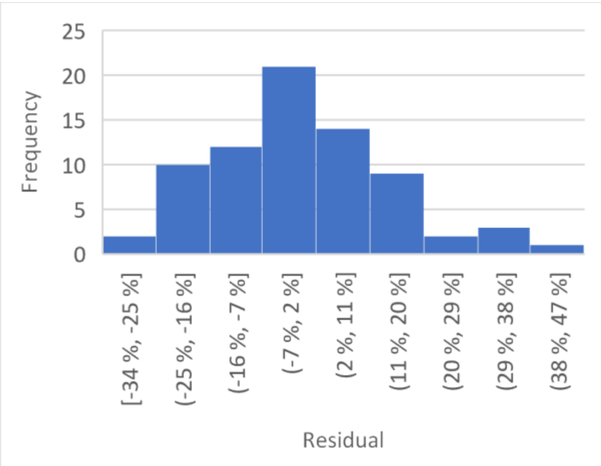
Cost deviation from cost frame (left) steering frame (right)

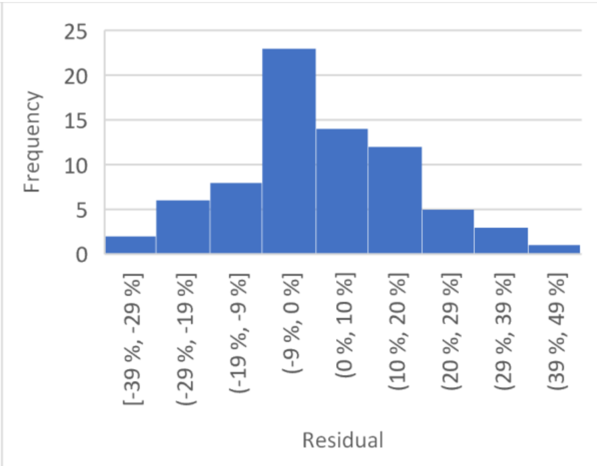




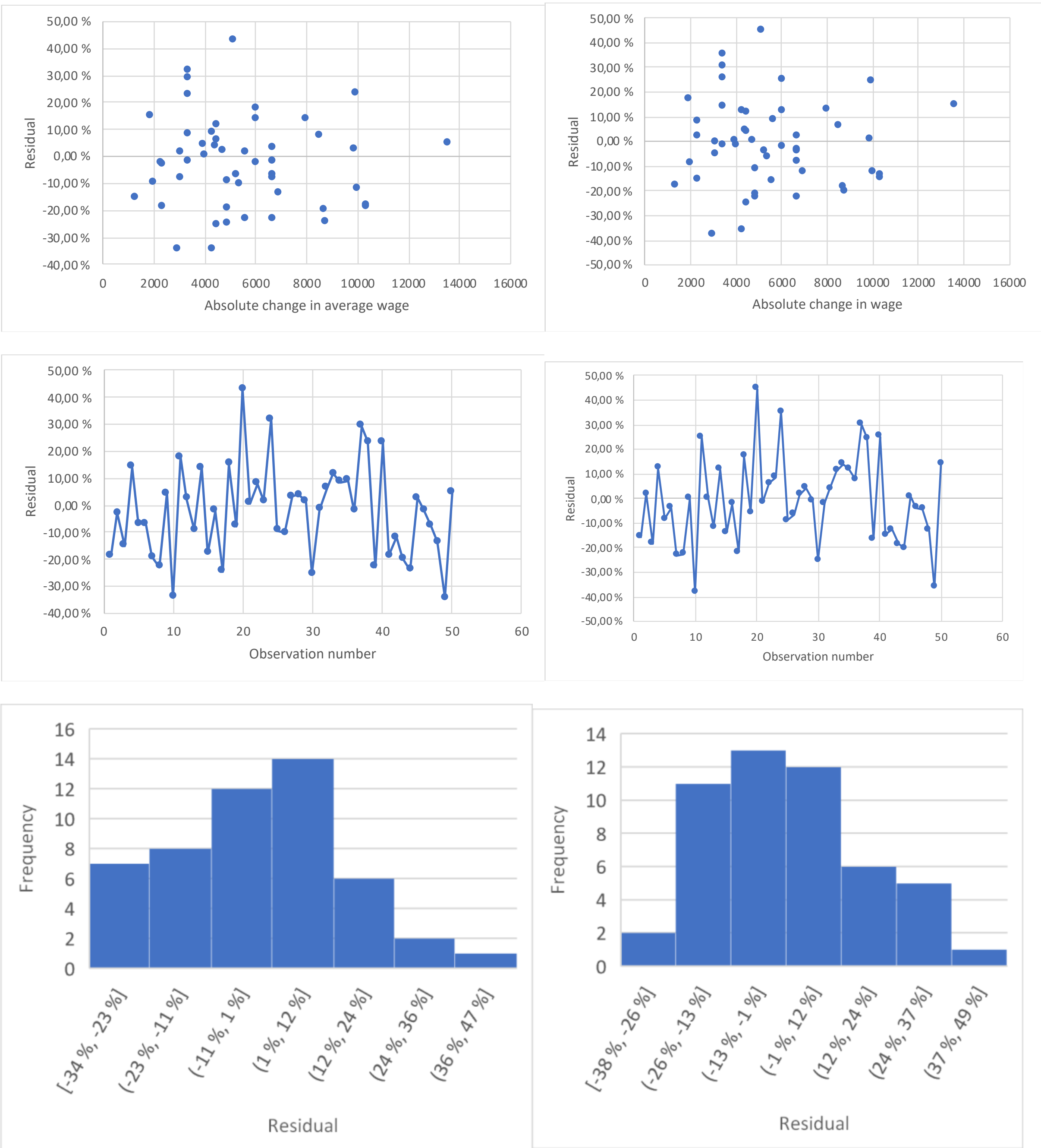






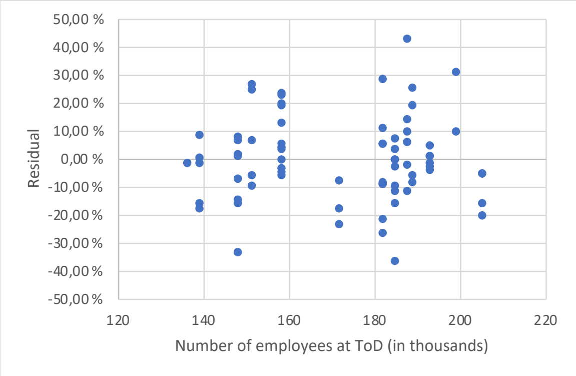


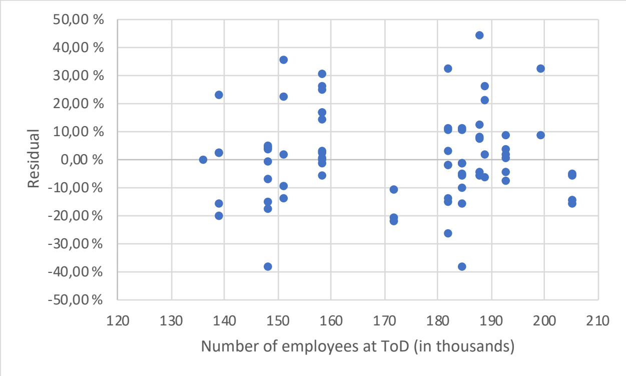
Cost deviation from cost frame (left) and steering frame (right), road projects

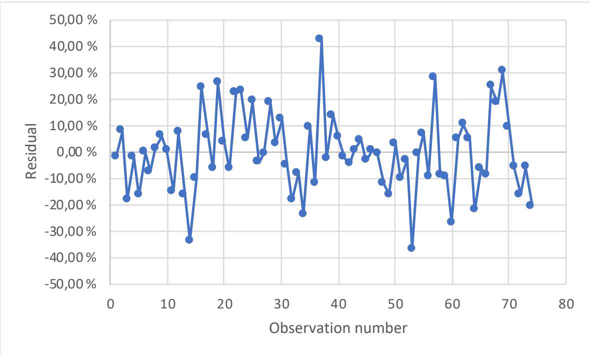


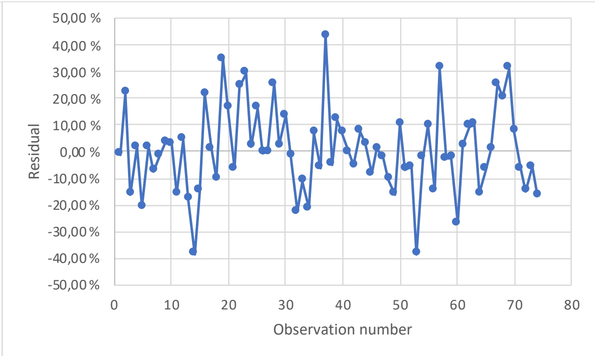
State of employment at ToD

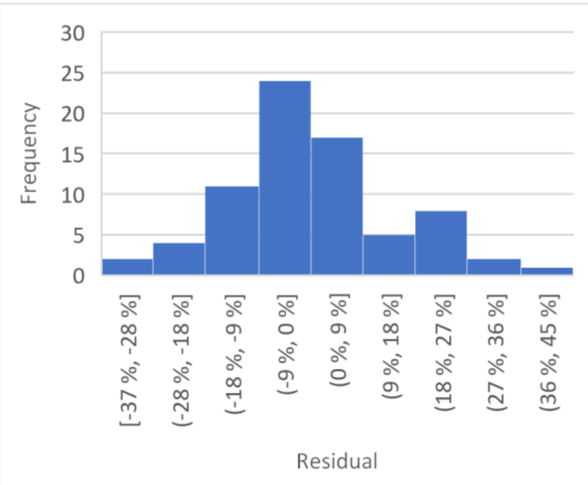
Cost deviation from cost frame (left) and steering frame (right)

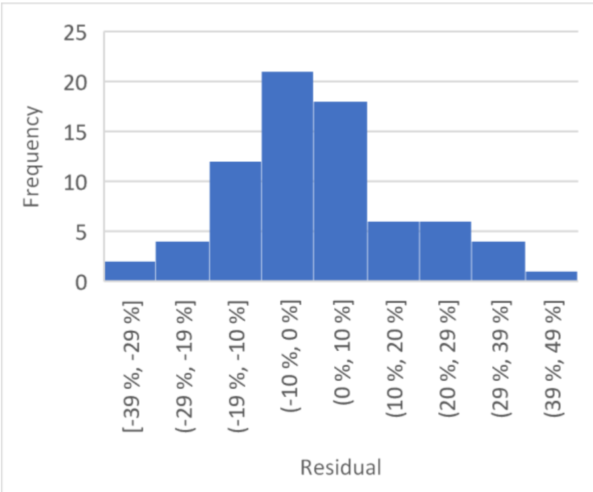






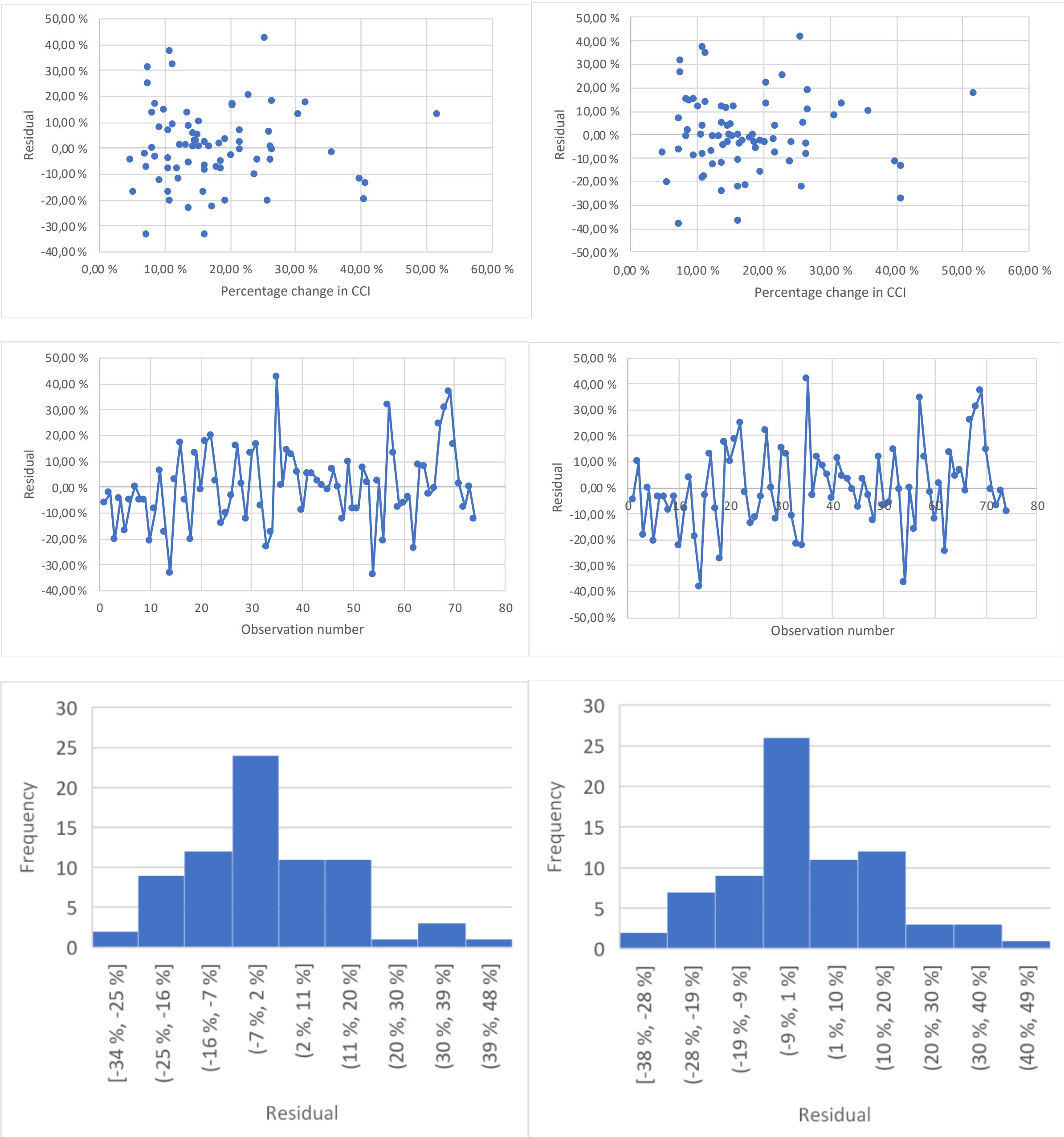






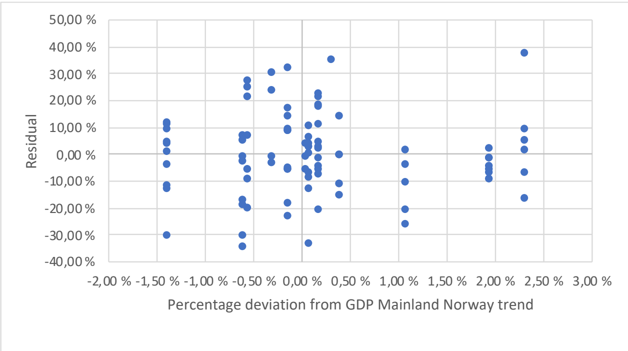
Percentage change in CCI

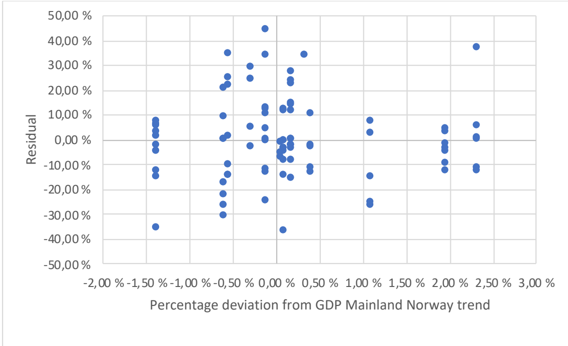
Cost deviation from cost frame (left) and steering frame (right)

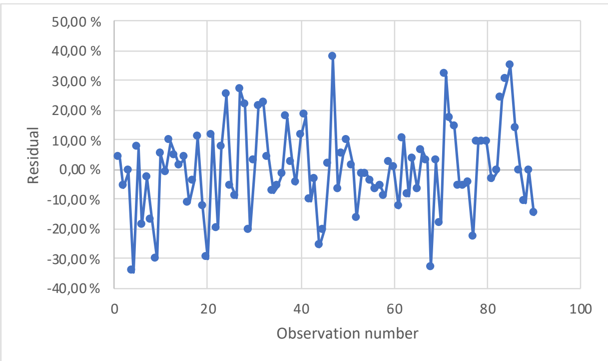


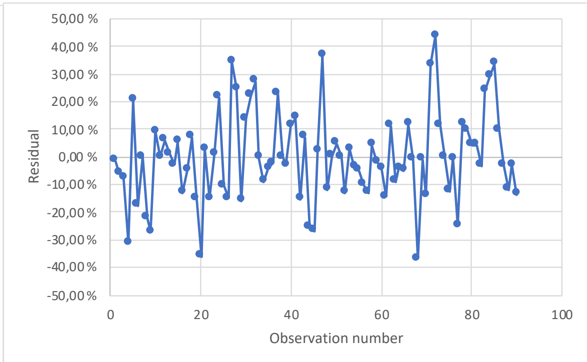
The business cycles

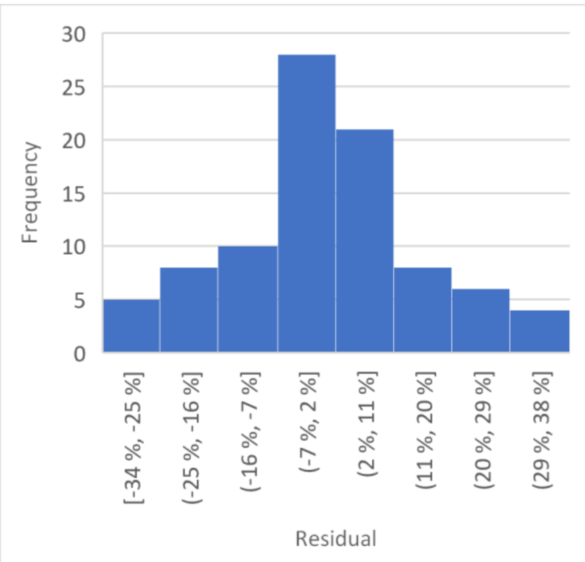
Cost deviation from cost frame (left) and steering frame (right), λ=400

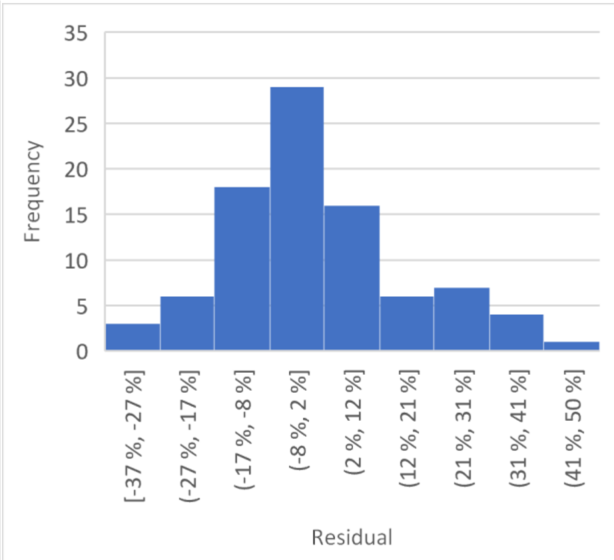












Cost deviation from cost frame (left) and steering frame (right), deviation from trend at contract initiation. λ=400

Appendix B: Summary of the results

Determinant	**N**	**Statistics Norway Table number**	**P-value cost frame**	**P-value steering frame**
CPI-ATE change	79	12880	0,23	0,31
CPI-ATE change, road	46	12880	0,25	0,22
Wage absolute	74	05405, 07760, 12314	0,099	0,07
Wage absolute, road	50	05405, 07760, 12314	0,21	0,23
State of employment	74	09174	0,099	0,166
Employment change	74	09174	0,505	0,843
State of CCI	74	08662	0,22	0,26
CCI change	74	08662	0,31	0,22
CCI change, road	50	08662	0,29	0,22
GDP change	89	12880	0,60	0,60
GDP change, road	50	12880	0,79	0,63
Business cycles, 400, ToD	90	09189	0,02	0,024
Business cycles, 400, contract initiation	66	09189	0,001	0,0007
Business cycles, 40,000, ToD	90	09189	0,01	0,011
I-44, change, contract initiation	58	12880	0,55	0,14
I-44, change, road	40	12880	0,49	0,51
I-44, state at ToD	58	12880	0,71	0,57