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Cost Overrun in Swedish Infrastructure Transport Projects

An Analysis of Cost Overrun in Swedish Infrastructure Transport Projects between 2010 - 2022

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Abstract

Cost Overrun is something that plagues infrastructure projects, both in Sweden and globally. The repercussion of it can be severe since it not only hurts the public's perception of how the public authorities manage and allocates its resources, but also due to the immense opportunity costs that arise when the increased costs need to be covered. In general, the factors that lead to cost overrun in infrastructure transport projects can often be derived from technical, psychological, political, and economical factors, and it is not uncommon that there is a combination of these factors, which is why the subject of cost overrun is so complex. With a highly unique dataset, this paper examines cost overrun in Swedish infrastructure transport projects to see if there is a statistical relationship between cost overrun and the size of a project, its regional location, and whether it is a road- or railway project. Furthermore, an evaluation of the process of estimating and forecasting costs will be conducted. The results shows that the characteristics of regional locations have a significant relationship with projects experiencing cost overrun and that cost overrun is more common in smaller projects. There were no significant differences in cost overrun between types of projects, but it was found that between the period 2018 to 2022, cost estimates had been underestimated by approximately 34%.

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1. Introduction

The first part of this study will introduce the research topic and provide a background of the problem and its extent. Furthermore, the purpose of the study will be presented, followed by limitations, and lastly, a disposition.

The cost of infrastructure projects in Sweden has been increasing over the years. On average, the projects become more expensive, the benefits smaller, and the completion time longer (Trafikverket, 2023). Several investigations have been conducted by The Swedish National Audit Office, showing that cost overrun is a recurring problem in Swedish infrastructure projects (Riksrevisionen, 2019; 2020), with projects ending up significantly more expensive than first estimated. The problem of cost overrun is also a global phenomenon, and the issue seems to plague infrastructure projects chronically. In an earlier study conducted by Flyvbjerg et al. (2003), the authors declared that cost overrun existed in 20 nations across five continents, with an average cost overrun of 28% for all the 258 projects included in the study. The results showed that the cost overrun problem had remained constant over the past 70 years, thus showing no improvement.

Cost overrun refers to infrastructure projects whose actual costs exceed its' estimated costs, expressed either in percentage form or as a ratio of actual cost divided by estimated cost. The repercussions of cost overrun can have several significant impacts, both regarding the public's perception of the ability and effectiveness in how the public sector manages and allocates its resources, but also that severe price increases diminish the socioeconomic benefits as well as increase the risk of displacing other projects when the limited budgeted means must be used to cover the increasing costs (Riksrevisionen, 2021). There is also an emergence of substantial opportunity costs for the funds that becomes tied to cover the increased costs, funds that could have been used more efficiently towards other types of investments and reforms.

In a report from 2011, The Swedish National Audit Office declared that *Botniabanan*, a 190-kilometer-long railway that stretches between Nyland and Umeå in the north of Sweden, will exceed its' initial budgeted cost by more than 140% and that the final cost of the project will reach up to 26 billion SEK. This was because important measurements regarding reparations and reconstructions in surrounding networks were left out in the estimations of how much the project was expected to cost. The increase in cost could also be related to environmental issues,

with inspections taking longer than expected, as well as increases in technical requirements and the use of resources. At the opening of *Botniabanan* in August 2010, the final cost was 16.8 billion SEK in current prices. Not as much as feared, but well above the estimated 8.2 billion SEK at the start of the project (Riksrevisionen, 2011). Other objects whose costs have significantly increased are *Ostlänken*, the expansion of *the blue line* in Stockholm's subway system, and *Förbifart Stockholm* (Riksrevisionen, 2021). The costs of these four projects have increased with a total sum of 30.9 billion SEK, as seen in table 1.1 below.

Table 1.1 - Summary of cost over budget

Project	Cost Over Budget (Billion SEK)
Botniabanan	8.6
Ostlänken	10
Expansion of the blue line	9
Förbifart Stockholm	3.3
Total	**30.9**

It was also shown in an article by Svenska Dagbladet that the costs for the bus terminal at *Slussen* in Stockholm had increased. The most recent estimation amounted to a cost of 5.7 billion SEK, which can be compared to the previously estimated costs of 2.7 billion SEK. No explanations were provided as to why the cost had increased to such a large extent (Svenska Dagbladet, 2023). However, the bus terminal at *Slussen* is only one part of the entire project. A subsequent article showed that the total cost for the entire project is estimated to amount to 20.77 billion SEK, compared to the previous estimates of 15.8 billion SEK from 2020. The first estimate that was done at the implementation decision projected a total cost of 12 billion SEK, thus resulting in a total cost underestimation of 73%. The reason for the significant increase in costs, it was said, was due to the considerable complexity of the project. The project is not expected to be finished for at least another two years (Svenska Dagbladet, 2023).

Although the cost increase for these projects is significant, these are only a few examples of projects that have experienced cost overruns. In a report by The Swedish National Audit Office from 2021, covering road and railway projects included in the national infrastructure investment plans from 2004, 2010, 2014, and 2018, it was concluded that for the objects included in the two latest plans, the calculated cost had increased with 58 billion SEK in current prices, and with 36 billion SEK in constant prices. This translates to an increase in costs of 39% per object.

For the entire period of study, the increase in railway projects amounted to 232% and to 55% for road projects. The numbers were calculated after allowing for adjustments in the road- and railway indices used by the Swedish Transport Authority (Riksrevisionen, 2021).

The national plans for infrastructure investments in transport projects describes how the public infrastructure should be maintained and enhanced and includes estimates of costs for each project that is included. They concern the operations and maintenance of state-owned roads and railways, investment in state-owned roads, railways, and fairways, measures to reduce the environmental impact of infrastructure, support to municipalities to promote sustainable urban environments, and research and innovation funding. The purpose of these plans is to provide a basis for the government for the coming infrastructure propositions to plan, maintain and develop the infrastructure per the Swedish government's transport policies. The government issues a directive to the Swedish Transportation Authority to bring forth a proposal for each consecutive plan, usually every twelfth year and with a revision after every mandate period, i.e., every fourth year. For the latest plan covering 2022-2033, the total allocation of funds for investments in infrastructure transport projects amounts to 799 billion SEK (Trafikverket, 2023).

Several ways have been proceeded with to explain the causes of cost overruns, with different approaches and with various areas of focus as to when and where the problem emerges. The subject has gathered the attention of researchers, auditors, academics, and practitioners. Some have been focusing on trying to understand the root causes of the problem, with much emphasis on psychological factors and their theoretical embeddedness (Flyvbjerg, 2007). Others have focused on technical factors and characteristics related to the project itself, such as project size, project type, regional location, the form of contract, and the number of tenders in the procurement process to determine what factors that might lead to the problem of cost overrun (Odeck, 2004; Swedish National Road and Transport Research Institute, 2019)[1]. Often, it is a combination of several factors that leads to cost overrun.

In this paper, an analysis of cost overruns in infrastructure projects regarding roads and railways in Sweden will be conducted. The projects are those that are included in the national infrastructure investment plans between the years 2004 to 2022 and projects that have been

[1] The Swedish National Road and Transport Research Institute will be referred to as VTI for the remainder of this paper.

completed and opened for traffic according to The Swedish Transportation Authority's annual reports. The aim is to examine if there is a statistical relationship between projects experiencing cost overrun and the variables project size, project type, and regional location. To further extend our analysis, we will test whether there has been any improvement in the process of estimating costs in the last decade. To the author's knowledge, an analysis with respect to these variables that includes data from the latest national plan and annual reports has not been conducted in Sweden. This makes this paper highly relevant for the ongoing work of understanding and curbing the problem of cost overrun in infrastructure transport projects.

1.1 Purpose

This paper aims to analyze if there is a statistical relationship between Swedish infrastructure transport projects experiencing cost overrun and the variables project type, project size, and regional location. Further, an evaluation of the process of estimating costs in infrastructure transport projects will be conducted to determine if the process has been improved over time.

To the authors' knowledge, an examination of this subject has not been conducted in Sweden previously that includes the latest data available on projects that have been opened for traffic, as well as projects included in the latest national infrastructure investment plan. The problem of cost overrun has been studied on a global level, but the research done concerning the situation in Sweden is in comparison limited.

Previous research has been done regarding the problem of cost overrun, and there are different theories on how and why it arises. Alas, although the problem is of considerable extent, little seems to be done to mitigate it. Despite significant cost increases, projects are seldom stopped after they have been included in the national investment plans. The Traffic Committee states that projects can be stopped if it is determined that they cannot be completed due to environmental issues, technical factors, or economic reasons. Between 2014 and 2018, the total cost increase for projects included in the investment plans amounted to 58 billion SEK. Few, if any, were stopped. This can be compared to the entire investment grant for the period of 87 billion SEK (Riksrevisionen, 2021).

Although there might be several other factors than the variables examined in this paper that contribute to the problem of cost overrun, this paper will hopefully increase the awareness of the problem and contribute to the studies focusing on cost overrun in Swedish infrastructure transport projects.

1.2 Limitations

The availability of data is the main limitation of this paper. The Swedish Transportation Authority does not have a continually updated dataset of changes in costs of infrastructure projects. Neither are they performing any continuous evaluations on what it is that causes these changes, something that they have been criticized for previously by the Swedish National Audit Office (Riksrevisionen, 2021). The data used in our paper has been received from the Swedish National Audit Office, initially made for them by the Swedish Transportation Authority upon request. The data was first used in a previous report by the Swedish National Audit Office, and it therefore did not include data from the latest national infrastructure investment plan, which has been added afterwards. This could potentially lead to some projects missing or other misinterpretations that could affect our results in the end.

Further, there are other factors that might lead to cost overruns other than the variables examined here, which is important to bear in mind. Therefore, the model may only explain a part as to why cost overruns occur.

1.3 Disposition

The disposition of this paper is organized as follows: the second section reviews previous research trying to identify the underlying problem of cost overrun, as well as a review of explanatory variables that might lead to cost overrun. The third section states the hypotheses that are tested for based on the findings in section two. Section four introduces and describes the dataset used in the analysis. It also contains a description of the econometric model and the variables used. In section five, the empirical results are analyzed and discussed. The sixth section contains a conclusion, related discussions, and suggestions for future research.

2. Literature Review

The second part will present a review of related literature and research. Firstly, a thorough review of explanations behind the underlying problem of cost overrun will be presented. Secondly, a review of previous literature focusing on different variables that lead to cost overrun will be conducted.

2.1 Explanations Behind the Underlying Problem of Cost Overrun

The problem of cost overruns has become something that plagues infrastructure projects, and its causes and explanations as to why the problem occurs have been studied and discussed widely. Studies and reports have been conducted to measure the extent of the problem, both in terms of how much and how often the problem of cost overrun occurs, as well as assessments to address the causes behind the problem. But although the problem is recognized, the causes and explanations are still somewhat ambiguous, and different theories and explanations have been applied to address the problem. The subject can be described as interdisciplinary with several dimensions, as researchers, auditors, and practitioners have proposed both technical, economical, psychological, and political approaches to deal with the issue (Abderisak et al. 2015).

Bent Flyvbjerg is the leading researcher on this topic and has investigated different factors that leads to cost overruns, with a lot of emphasis on trying to understand the root causes behind the problem and the explanations of the underlying factors leading to cost overruns. Flyvbjerg (2007) lists three main explanations as to why cost overruns occur: technical-, psychological-, and political-economic explanations.

Technical explanations refer to factors such as inadequate forecasting techniques, project type, insufficient data, poor project design, scope changes, or other types of complications that have arisen during the project's construction that leads to increased costs. Flyvbjerg states that technical explanations are variables that influence cost overruns rather than explaining the problem itself (Cantarelli et al. 2010).

The second explanation, which concerns psychological factors, is based on ideas from behavioral studies developed by the works of Kahneman and Tversky (1979) and Kahneman and Lovallo (1993; 2003), research that later awarded Kahneman with the Nobel Prize in economics. Optimism bias and planning fallacy are the main psychological explanations, where optimism bias refers to the tendency of planners and project managers to overemphasize a project's potential benefits and underestimate its costs. Optimism bias has previously been stated by Mackie and Preston (1998) and Pickrell (1992) as one of the main reasons behind cost overruns in transport projects.

The other main phycological explanation, planning fallacy, occurs when planners and project promoters make decisions based on delusional optimism instead of a rational weighting of gains, losses, and probabilities. This leads to inaccurate estimates even though similar projects have experienced increases in both costs and time (Lovallo & Kahneman, 2003). Decision-makers tend to view problems as unique and thereby isolate current choices and neglect statistical aggregations of the past. Kahneman and Lovallo (1993) state that overly optimistic predictions result from anchoring predictions on plans and scenarios. This relates closely to anchoring bias, which is another psychological factor that Flyvbjerg (2009) points out as a major cause behind cost overruns. Anchoring bias refers to when actors are anchoring their estimates of a project's cost on previous similar projects, but whose costs further into the process have proven to be either too high or too low, and adjustments tend to be insufficient, thus rendering in inaccurate cost estimates.

To overcome these biases, Flyvbjerg (2008) suggest using "reference class forecasting", which means that planners and project managers base their projections of costs on the actual performance of a reference class of comparable projects. These theories are also based on the works of Kahneman and Lovallo (2003), who explains that cognitive biases stem from planners and managers taking what they call an "inside view", rather than the "outside view", in order to temper the problem of optimism bias.

The third explanation, which concerns political and economic explanations, focuses on the problem of strategic misrepresentation by planners and forecasters, where they deliberately and strategically overestimate a project's benefits and underestimate its' costs to increase the likelihood of a project gaining acceptance and further funding. Strategic misrepresentation can often be the result of political and organizational pressure (Flyvbjerg, 2007). Studies have

shown that planners and project managers strategically manipulate costs, benefits, and other decision-making frameworks to get public projects approved, as they all compete for the same, limited amount of resources. Politics and ideology clearly affect agents' actions and pressure individuals to act according to their ideological beliefs (Flyvbjerg, 2003; Wachs, 1989).

In Cantarelli et al. (2010), the three explanations previously presented by Flyvbjerg are elaborated on further and divided into four separate explanations. To understand each explanation more thoroughly, each explanation is connected to a theoretical framework that helps to provide a more comprehensive view. Theories can help to better understand the causes that lead to cost increases in infrastructure projects. Cantarelli et al. (2010) state that "…*the plausibility of an explanation is partly based on its theoretical embeddedness. When there are models, assumptions, premises or concepts behind the explanation, the likelihood of understanding the phenomenon of cost overruns increases".* The theories behind the technical explanations are forecasting theory, planning theory, and decision-making theory. Behind the economical explanations, there are the theories of neoclassical economics and rational choice theory. The psychological explanations are explained by planning fallacy, optimism bias, and prospect theory. Lastly, the political explanations can best be explained by agency theory, Machiavellianism, or ethical theory. The table below illustrates the four types of explanations, the causes related to each explanation, and the appropriate theories that are suggested to understand them.

Table 2.1 - Explanations, causes, and theories of cost overrun.

Explanations	**Causes**	**Theories**
Technical explanations	Forecasting errors	Forecasting theory
	Scope changes	Planning theory
	Uncertainty	Decision-making theory
	Inadequate organizational structure and/or planning process	
Economical explanations	Delibirate underestimation due to:	Neoclassical economics
	Lack of incentives	Rational choice theory
	Lack of resources	
	Inefficient use of resources	
	Poor financing	
	Strategic behaviour	
Political explanations	Deliberate cost underestimation	Agency theory
	Manipulation of forecasts	Machiavellianism
	Private information	Ethic theory
Psychological explanations	Optimism bias	Planning fallacy & optimism bias
	Cognitive bias	Prospect theory
	Cautious attitude towards risk	Rational choice theory

Siemiatycki (2015) also elaborates on the causes of cost overrun under the explanatory framework of technical challenges, over-optimism, and strategic misrepresentations. He states that as those who manage the projects gain more experience, factors that affect cost overruns, such as poor monitoring of projects, scope changes, inaccurate forecasting, and coordination problems, should decrease over time since they are factors that could be anticipated and controlled for. Siemiatycki further argues that if this had been the case, and if cost overruns in infrastructure projects merely were the results of these factors, it is likely that the problem would have been solved by now. He argues that deep psychological, political, and economic factors contribute to the persistence of the problem.

According to Love (2011), however, the explanations of the causes to cost overrun presented by Flyvbjerg are not adequate to elucidate why infrastructure projects experience cost overruns to such a large extent. Love recognizes that Flyvbjerg has made a significant contribution to the subject but also states that optimism bias and strategic misrepresentation, which Flyvbjerg declares as some of the leading causes behind cost overrun, are misleading. This is because a significant amount of projects has experienced cost overruns without these factors being present. Love states that simply relating the problem of cost overrun to optimism bias and strategic misrepresentation is insufficient due to the "…*complex array of conditions and variables that interact with one another during the project's procurement*". He criticizes Flyvbjerg further and explains that intermediary conditions and events that lead to cost overruns are not examined and that the likelihood that a project experiences cost overrun is significantly high when taking factors such as technical complexity, procurement arrangement, contractual conditions, managerial effectiveness, location, size, and type of project into account (Love, 2011).

Eliasson and Fosgerau (2013) also criticize Flyvbjerg and argue that the bias in infrastructure appraisals where costs are systematically underestimated and benefits systematically overestimated, i.e., optimism bias and strategic misrepresentation, is an argument that is invalid for explaining the causes of cost overrun. They argue that the bias of underestimating costs and overestimating benefits arises due to selection bias when deciding which projects to analyze.

2.2 Variables Affecting Cost Overrun

Apart from studies that analyze the theoretical scope behind the underlying factors of cost overrun, several other studies have been conducted to determine which variables that lead to projects experiencing cost overrun and if there is a significant difference between these factors.

Morris (1990) concluded that 70% of the total amount of cost overrun could be related to delays, inefficiency, and effects from scope changes, where inadequate project preparation leading to scope changes during the implementation phase of the project was the most decisive reason for cost overruns. In a study conducted in Malaysia, Memon et al. (2011) concluded that factors such as poor design, delays, late delivery of materials and equipment, and poor site management affected cost overrun the most. Although these factors may not explain the problem itself, it is evident, as Love (2011) declares, that they should not be neglected in order to fully understand the problem, since they clearly contribute to increases in costs.

Early studies show a correlation between project size and cost overrun. The larger a project is, the greater the cost overrun will end up being (Jahren & Ashe, 1990). Comparable results were found by Shrestna et al. (2013), were a larger project size led to a more substantial cost overrun. That larger projects induce a greater risk of cost overruns compared to smaller projects is further supported by Sing (2010) since larger projects are more vulnerable to uncertainty, changes in regulations, external shocks, and the pendulum of economic cycles. Infrastructure projects in recent years have become bigger and more expensive, and it is not uncommon that these projects are referred to as megaprojects due to their large size, expensiveness, and extensive impact on society. However, the definition of a megaproject differs depending on the geographical setting (Flyvbjerg, 2014), and how to define a large project is arbitrary. Nonetheless, the trend towards larger projects with increased complexity is apparent, resulting in greater risk and uncertainty, especially in terms of costs (Abdelgawad & Fayek, 2010; Abderisak et al. 2017). For large projects, there are also strong incentives for planners and project managers to underestimate the costs of a project in order to increase the likelihood of gaining approval and funding, since every project being decided upon competes for the same amount of resources (Flyvbjerg et al. 2009). This can lead to significant and deliberate underestimations of costs in large transport projects, ultimately leading to even higher cost overruns. This connects to the psychological and political explanations by Flyvbjerg that was

presented earlier, which shows that there might be a combination of several factors that lead to cost overrun.

Even though there seems to be a strong correlation between large projects and higher cost overruns, other studies have found contradicting results. Odeck (2004) found in his study focusing on cost overruns in Norwegian road construction projects, that cost overruns appeared to be more predominant among smaller projects. He concluded that the larger projects were under better management and control than smaller projects and were, therefore, less prone to cost overruns. The same results were found by Cantarelli et al. (2012). Therefore, a project's size may result in two opposing hypotheses; large projects are under better management and control, resulting in smaller cost overruns. Or, larger and more expensive projects are more complex and span over longer periods, resulting in greater uncertainty and greater risk for larger cost overruns. However, Odeck (2004) found that cost overrun increased within a certain range of a project's completion time, after which it declined. A possible explanation for this is that even though a longer completion time may render in greater uncertainty, it provides management with better opportunities to monitor and control the project in question, so that appropriate remedies can be made in time.

Odeck (2004) further found that cost overruns varied with regional location and related his findings to differences in terrain and weather. Differences in topography and climate, such as rougher terrain and harsher weather can easily create complications that leads to increased costs. Regional location is also interesting in terms of demography. Construction of projects in more densely populated areas, such as the regions of west and east of Sweden, which includes the metropolitan areas of Stockholm and Gothenburg, may create difficulties in completing the projects within time and budget due to congestion and areas that are hard to access, and reasons such as unforeseen site conditions that require the redirection of traffic flows (Abderisak et al. 2017).

This matches the results found by VTI in a report on cost overruns in the Swedish Transport Authority's construction contracts. They found that cost overruns were on average larger in the regions of west and east of Sweden (VTI, 2019). A case study conducted on cost overruns in the Netherlands by Cantarelli et al. (2012) found a significant difference between geographical regions and projects that experienced cost overruns. This concludes that geography is essential to consider when examining cost overruns and that regional location is of importance.

Subramani et al. (2014) stated that cost overruns are more frequent in developing countries, indicating that there also is a difference in whether transport projects experience cost overrun across nations and economies as well.

Regarding project type, several studies have concluded that there is a difference in cost overruns depending on whether it is a road- or railway project (Flyvbjerg et al. 2002; Lundberg et al. 2011; Flyvbjerg & Bester, 2021). In the report by Flyvbjerg and Bester (2021), the authors conducted a test with a sample of over 1000 individual road and railway projects. The results showed that the average actual cost for railway infrastructure projects was 40% higher than the estimated cost, while the average cost overrun for road projects was 24% higher than the estimated cost.

VTI (2019) points out that the number of contractors in the road sector is larger compared to the railway sector in Sweden, which indicates that the degree of competition is higher for contractors in the road sector. This can potentially force actors to increase their productivity and offer lower tenders in the procurement process. The higher degree of competition thus has the potential to create incentives for actors to engage in strategic price settings in order to win the contracts, resulting in a higher risk for discrepancies between the estimated cost and the actual cost of a project. Allahaim and Liu (2006) found that assigning the contracts to the lowest bidder at the tender stage was the third major cause contributing to cost overrun, while Park and Papadopoulou (2012) found it was the cause contributing the most. However, Ganuza (2007) showed that cost overrun could occur as a consequence of lack in competition and that policies that promote competition in the procurement process reduces the risk of cost overruns. Mansfield et al. (1994) argue that identifying and screening competing alternatives is a crucial part of the process and that decisions made at this stage can significantly affect a project's future success.

To understand the emergence of cost overruns, there have also been studies trying to understand when in the process of a project the increase in costs occurs. The Swedish National Audit Office (2021) concluded that systematical underestimations of costs occurred during the planning phase, rather than the construction phase. This matches the findings of Lind & Brunes (2015), who found that a majority of the cost increases occurred in the planning stages prior to the final design of a project and that the increase in costs was predominantly related to changes in designs and increases in the required amount of inputs. The authors further stated that if the increase in

costs occurred at an early stage of the project due to design changes, changes in price, and underestimations of the amount of inputs needed, a combination of strategic behavior and optimism bias was most likely the explanation, which is in accordance with the reasonings of Flyvbjerg. When in the process cost overrun occurs is also attributable to which party that might bear the responsibility (Doloi, 2013), which is important since it allows for mitigating the problem in a more direct and efficient way if it is possible to know when in the process the problem emerges.

In conclusion, the causes of cost overrun can often be attributed to technical, psychological, economic, and political factors (Abderisak et al. 2017; Cantarelli et al. 2010). Different studies examine different factors and focus on different phases as to when and where the problem occurs, and cost overruns are often the consequences of other risks that occur because of internal and external factors (Abderisak et al. 2017). It is not uncommon that there is a combination of the different factors presented in these sections that leads to cost overrun, which is important to understand. It is also why it is such a complex subject. Nonetheless, it is still equally important to analyze all the factors that might lead to cost overrun to fully understand and mitigate the problem.

3. Hypotheses

The third section of this study will present the four hypotheses that have been formulated based on the research questions and the literature review.

The theories presented in section two conclude that cost overrun is a common problem in infrastructure transport projects, both in Sweden and globally. Based on the theoretical framework and literature review, hypotheses are constructed accordingly.

According to previous research, the results regarding the relationship between cost overrun and project size have varied. Odeck (2004) and Cantarelli et al. (2012) found that cost overrun was to a larger extent present in smaller projects, while Sing (2010) and Jahren and Ashe (1990) concluded that cost overrun was higher in larger projects. Odeck (2004) argues that larger projects are under better management and better control than smaller projects, resulting in smaller cost overruns. Sing (2010) and Jahren and Ashe (1990), however, declare that due to their large size and complexity, as well as sensitivity to uncertainty and changes in regulations and market conditions because of their long completion time, large projects are more prone to cost overruns. Since all projects compete for the same limited funds, there is also a significant risk that planners and project managers deliberately underestimate the cost of large projects due to strategic misrepresentation to increase the likelihood of gaining approval and funding, which ultimately leads to significant cost overruns (Flyvbjerg et al. 2009). Based on previous literature, we thus make the following hypothesis about *project size*:

H_1: *Larger projects experience higher cost overrun compared to smaller projects.*

Previous studies seem to be unanimous regarding cost overruns dependent on project type. Cost overrun is more likely to be found in railway projects, as was previously found by Flyvbjerg and Bester (2021), The Swedish National Audit Office (2021), and VTI (2019). Reasons for this could be due to variations in the complexity of construction between the different types of projects and the degree of competition due to different number of actors in each sector. To answer the question if there is a difference between road and railway projects in Sweden, the hypothesis is formed as follows:

H_2: *Railway projects show a higher degree of cost overrun.*

Regional location is of interest for both geographical and demographical reasons, and the differences in characteristics between regions might affect projects' costs. Differences in topography and climate, as well as traffic flows and how easy the areas are to access, are factors that might affect the cost of a project and ultimately lead to cost overrun. According to theory, there is a significant difference in regional location and projects experiencing cost overrun. Odeck (2004) and Cantarelli et al. (2012) found a significant difference in the degree of cost overrun between regional locations, suggesting that the attributes of the regions in which the projects are being built might lead to complications that eventually results in cost overruns. Our hypotheses related to *regional location* is thus as follows:

H_3: *There is a statistical difference in the degree of cost overun between regions.*

Previous research about the problem of cost overrun and the accuracy in forecasting and estimation of costs in infrastructure transport projects by project managers goes somewhat apart. Sing (2010) concluded that cost overrun has decreased since the 80s, both in absolute terms and in percentage of estimated costs, suggesting that the process of forecasting and estimating projects' costs have improved over time. Flyvbjerg et al. (2002) however, states that there have been no improvements in the process of forecasting and estimating costs in infrastructure transport projects, and that the magnitude of the problem is the same as it was 70 years ago. As Flyvbjerg (2003) argues, one reason for this is the structural presence of strategic misrepresentation and optimism bias. Our hypothesis for evaluating the process of estimating costs is thus the following:

H_4: *The process of estimating and forecasting costs has improved over the period* $2018 - 2022$, *compared to the period* $2014 - 2018$.

4. Method

The fourth section of this paper will provide an overview of our dataset and how we have processed it, as well as an explanation of variables used in our empirical model. Finally, a description of the econometric method used is presented.

4.1 Data Collection and Processing

Our dataset has been received upon request from The Swedish National Audit Office and consists of objects included in the national infrastructure investment plans. The dataset was initially used in The Swedish National Audit Office's report *Cost Control in Infrastructure Investments* from 2021. It comprised 286 individual objects from the national plans from 2004, 2010, 2014, and 2018. The objects included in the dataset are objects where construction has, or is soon to be, started, along with sequential cost estimates from each respective plan in which the objects are included. The dataset also includes projects that are completed and have been opened for traffic, along with the latest estimated cost before the start of construction and the final cost of each project. The Swedish Transportation Authority originally compiled the data upon request by The Swedish National Audit Office.

We have further processed the dataset a posteriori by adding information from the latest revised national infrastructure investment plan from 2022 and The Swedish Transportation Authority's latest annual report from 2022. For us to be able to make correct inferences, we have excluded objects where information has been incomplete or unclear. This makes our dataset highly unique, as an investigation regarding the development of cost overrun and cost estimates in public infrastructure projects has not been conducted with the most recent data, at least not to the authors' knowledge. For every object included in the national plan from 2018, the most recently made cost estimates from the latest national plan of 2022 have been added to examine the development of cost estimation in public infrastructure projects. Regarding projects that have been completed and opened for traffic, we have added objects from The Swedish Transportation Authority's latest annual report from 2022, which includes the latest cost estimate made before the start of construction and the actual cost at the time of completion. In total, 114 projects have been completed between the period 2004 to 2022. These 114 objects are used in our regression analysis to test whether there is a statistical difference in cost overrun

among projects, with respect to the variables project type, project size, and regional location. The Swedish National Audit Office did not conduct a regression analysis in their report, and we thus broaden the research with a multiple regression model.

To examine if there has been any improvement in the process of estimating costs in infrastructure projects, we analyze objects included in the national plans from 2014, 2018, and 2022, for which estimations of costs for each period are available. This provides us with two different periods for analysis. The first period concerns the years 2014 to 2018, where cost estimates done in 2014 are compared to the revised estimates done in 2018. The second period refers to cost estimates done in 2018, which are compared to the revised estimates done in 2022. In total, there are 135 objects for each period.

4.2 Variables

In the following paragraphs, a presentation of the variables chosen is conducted. These variables have been used in previous research but with different results, which makes it interesting to investigate these variables further.

4.2.1 Dependent Variable

Cost Overrun

The dependent variable in our analysis is *Cost Overrun*. It refers to how much the actual cost of a project exceeds the estimated cost and reflects the deviation between the estimated cost for a project and what the actual cost ended up being. The variable is measured as a ratio of actual cost divided by estimated cost or in percentage form. In this paper, it will be expressed in percentage form.

4.2.2 Independent Variables

Project type

Previous research (Flyvbjerg et al. 2002; Lundberg et al. 2011; Flyvbjerg & Bester, 2021) found that there was a significant difference in cost overrun depending on project type. Our model defines the variable *Project Type* as either a road or railway project.

Project size

The variable *Project Size* is categorized according to the following metrics: Small projects (<500 MSEK), Medium (500 MSEK – 1500 MSEK), Large (1500 – 5000 MSEK), and Very large (>5000 MSEK). This categorization of sizes has been done in consonance with Flyvbjerg's previous estimations of project size (Flyvbjerg et al. 2012)

Regional Location

Regional location has previously been studied and the results declare that the different characteristics of regional locations have a significant impact on projects' costs (Odeck, 2004; Abderisak et al. 2017; Cantarelli et al. 2012). In our model, the variable *Regional Location* is categorized into six different groups: South, West, East, North, Middle, and Stockholm.

4.3 Methodology

To determine the relationship between cost overrun and the variables project type, project size, and regional location, we use the OLS method (Ordinary Least Squares). The OLS regression analysis allows us to estimate the relationship between our dependent variable and our independent categorical variables to see if there is a statistical difference between them. Using the OLS method, we also obtain coefficients for each independent variable which can further help us explain their relationship with our dependent variable.

Further, we ran a Breusch-Pagan test to see if our data suffered from heteroscedasticity. Our Chi-square value was significant, so we thus rejected the null hypothesis that the data was homoscedastic. Under the presence of heteroscedasticity, the estimators are no longer minimum or efficient (the estimators are not BLUE), which can lead to inaccurate estimates and

misinterpretations of our results (Gujarati & Porter, 2009). To solve this issue, we ran a new OLS regression, but this time with robust standard errors. This provides us with more accurate standard errors that are consistent.

In our attempt to test whether there has been any improvement in cost estimations over time, a two-sample paired t-test is used. A paired t-test helps us to compare the means of two related samples. We compared the mean cost estimation for the two periods, 2014 to 2018 and 2018 to 2022, to determine whether there is a statistical difference between them. The t-tests help us to better understand if there have been any improvements in cost estimation and forecasting for infrastructure projects over time, or if estimated costs have been significantly underestimated.

4.4 Empirical Model

Based on previous research and the theoretical framework, as well as the works of Lundberg et al. (2011), we use the following model to test our hypothesis 1-3:

$$Cost\ Overrun = \beta_0 + \beta_1(Project\ Type) + \beta_2(Project\ Size) + \beta_3(Location) + \varepsilon$$

The independent variables are categorized as shown in Table 4.1:

Table 4.1 - Explanation of categorical variables

Variable	Category	Dummy
Project Type	Road	0
	Railway	1
Project Size	Small <500 MSEK	0
	Medium 500-1500 MSEK	1
	Large 1500-5000 MSEK	2
	Very Large >5000 MSEK	3
Regional Location	South	0
	West	1
	East	2
	North	3
	Middle	4
	Sthlm	5

5. Empirical Results and Analysis

The fifth section will present and discuss the empirical findings of this paper. First, the descriptive statistics are discussed, followed by the outcome of the regression analysis and the paired t-tests.

5.1 Descriptive Statistics

The largest cost overrun amounts to 478%, and cost overruns around and above 100% are not uncommon. The smallest cost overrun is – 92%, where a negative cost overrun means that the object(s) in question has become cheaper to construct. These high values, compared to the mean value of 16%, indicate that cost overrun is fat-tailed, with large upper-tail risks (Flyvbjerg, 2011; 2018). Smaller projects account for the largest share in the category size, while large and very large projects accounts for approximately ten and six percent, respectively. The relatively small number of very large projects can potentially make the analysis sensitive to extreme values, which is important to be aware of. The distribution between regional locations and type of project is relatively even.

Table 5.1 - Descriptive statistics

Variable	Mean	Std.dev.	Min	Max
Est_cost	1349.886	3062.416	29	22579
Final_cost	1446.632	3303.169	22	22901
Cost_overrun	.1634909	.62111123	-.9219858	4.778723
Size				
Small	.5877193	.4944185	0	1
Medium	.245614	.4323511	0	1
Large	.1052632	.3082471	0	1
Very_large	.0614035	.2411289	0	1
Region				
South	.245614	.4323511	0	1
West	.1842105	.38393673	0	1
East	.122807	.3296646	0	1
North	.1052632	.3082471	0	1
Middle	.1578947	.3662522	0	1
Sthlm	.1842105	.3893673	0	1
Type				
Road	.4736842	.5015115	0	1
Railway	.5263158	.5015115	0	1

N=114

5.2 Regression Analysis

We found that of all the regions included in our analysis, region 4 was significant at the five percent level (p-value equals 0.018). Region 4 includes objects that are located in the central parts of Sweden. We also find that region 3, which is the northern part of Sweden, is barely significant at the ten percent level (p-value equals 0.101). These findings suggest that projects located in the central and northern parts of Sweden tends to show higher cost overruns than our base category, which is the south of Sweden. We cannot draw any direct conclusions as to why projects located in the middle of Sweden, on average, experience higher cost overrun compared to the other regions. Several factors might lead to this, which our chosen model does not capture. More information concerning each project would be needed to determine why a larger share of the projects located in the central parts of Sweden experience higher cost overruns.

For the northern region, however, reasons as to why projects located in the northern parts of Sweden shows slightly higher cost overruns are most likely due to a harsher climate and a rougher topography. Differences in weather and terrain are factors that can easily create complications that lead to cost overruns. It can thus be concluded that regional location and the different characteristics that each location exhibits are essential elements to consider during a project's planning and construction phase. More accurate conclusions can thus be drawn by taking regional location into account when estimating a project's costs and benefits. Since there are significant differences between regional locations, and that the characteristics of different locations can potentially affect costs, putting more resources into proper geotechnical investigations before the start of construction might help prevent unnecessary cost overruns, something that Lind & Brunes (2015) also have suggested. The results regarding regional location are unanimous with the findings of both Odeck (2004) and Cantarelli et al. (2012), and we therefore do not reject our hypothesis that there is a statistical difference in cost overrun between regions. Compared to the results found by VTI (2019), however, we find no evidence that projects located in the west and east of Sweden, which includes the metropolitan areas of Stockholm and Gothenburg, show any significant difference in cost overruns compared to our base category (south of Sweden).

Regarding the difference in cost overrun between the type of project, our results indicated that railways show a higher degree of cost overrun compared to road projects, which is our base category for the variable *project type*. The results are, however, not significant, neither at a five nor ten percent significance level. We thus reject the hypothesis that railway projects experience a higher degree of cost overrun compared to road projects. Although the results are not significant, that railway projects tend to show a higher degree of cost overrun is in accordance with previous studies (Flyvbjerg et al. 2002; Lundberg et al. 2011). We believe that a larger dataset of both railway and road projects would be useful to appropriately test for the difference in cost overrun between the two types of projects.

When it comes to the relationship between cost overrun and the size of a project, the results show that cost overruns are, to a lesser degree, present in medium- and large-sized projects. The p-values for these two groups are significant at the five percent level (p-value equals 0.021 and 0.025 for medium- and large-sized projects, respectively), and their coefficients are negative. This indicates that larger projects do not experience cost overrun to the same extent as smaller projects, which confirms the results found by Odeck (2004) and Cantarelli et al. (2012) but is antithetical to the findings of Sing (2010) and Shrestna et al. (2013). We believe that the reasons for these results are, just as Odeck (2004) argues, that larger projects are under better management and control than smaller projects, and that a stricter scrutinization and follow-up during the construction of large projects results in smaller cost overruns. If it is assumed that larger projects are directly associated with a longer completion time, and even though a longer completion time might render in greater uncertainty, the longer the completion time of a project the more time project managers have to monitor and control the projects, giving them adequate room to handle complications that arises in time. These findings suggest that to mitigate the cost overrun problem, more attention should be given to smaller projects. If planners and project managers know that cost overrun is more likely to occur in smaller projects, they can concentrate more of their effort on the relatively smaller projects, since the largest cost increases are found there. We thus reject our hypothesis that large projects experience a higher degree of cost overrun compared to small projects.

Table 5.2 - OLS regression with robust standard errors

Linear regression					Number of obs =	114
					F(9, 104). =	1.98
					Prob > F =	0.0487
					R-squared =	0.1128
					Root MSE =	.60982

Cost Overrun	Coefficient	Robust std. err.	t	P>t	(95% conf. Interval)	
Type	.1562289	.171916	0.91	0.365	-.1844402	.496898
Region						
1	.0779907	.1121029	0.70	0.488	-.1443136	.300925
2	.1901714	.1369975	1.39	0.168	-.0814998	.4618427
3	.4089959	.2468426	1.66	0.101	-.0805093	.8985012
4	.2821493	.1174256	2.40	0.018	.04929	.5150087
5	.3167352	.2847328	1.11	0.269	-.2479007	.8813711
Size						
1	-.2792869	.1192715	-2.34	0.021	-.5158067	-.042767
2	-.2901973	.1271502	-2.28	0.025	-.5423408	-.0.380538
3	-.1875169	.1928248	-0.97	0.333	-.5698957	.1948618
_cons	.0090591	.1008777	0.09	0.929	-.1909851	.2091032

5.3 Paired T-test for Evaluating Cost Estimates

To examine if there has been any improvement in the process of estimating and forecasting costs in infrastructure transport projects (our 4th hypothesis), we conduct a paired t-test to see if there is a statistical difference in the mean of cost estimates between the years 2014 to 2018, and from 2018 to 2022. We thus conduct a paired t-test for each period, i.e., one test for the period between 2014 and 2018, and one test for the period 2018 to 2022. A significant result indicates a difference between the estimates, which implies that the estimated costs have either increased or decreased when they were revised. The sample for this analysis consists of 135 objects included in the national plans from 2014 and 2018, and 135 objects in the national plans from 2018 and 2022.

Our results from the test regarding cost estimates between the period 2014 to 2018 show no significance, which can be seen in table 5.3. This implies that the cost estimates that were done in 2014 were relatively accurate, and that no significant increase or decrease in costs occurred when the estimates were revised in 2018. None of the p-values for the alternative hypotheses are significant (at the five percent level). We thus accept the null hypothesis that the mean difference in the cost estimates in the period between 2014 and 2018 is equal to zero.

Table 5.3 - Paired T-test 2014 - 2018

Paired t test

Variable	Obs	Mean	Std. err.	Std. dev.	(95% conf. Interval)	
Est - 2014	135	288318	674295.5	7834605	1549679	4216957
Est - 2018	135	3069810	671851.2	7806206	1741006	4398615
diff	135	-186492.3	2938921	2938921	-686767.7	313783.1

mean(diff) = mean(Estimated_c-2014 – Estimated_c-2018) t = -0.7373
H0: mean(diff) = 0 Degrees of freedom = 134

Ha: mean(diff) < 0 Ha: mean(diff) ! = 0 Ha: mean(diff) > 0
Pr(T < t) = 0.2311 Pr(|T| > |t|) = 0.4622 Pr (T > t) = 0.7689

Concerning the cost estimates between the period 2018 to 2022, we see in table 5.4 that there is a significant difference. The p-value for the alternative hypothesis that the difference is less than zero is significant at the five percent level (p-value equals 0.0025). Since the difference in cost estimates between 2018 and 2022 is less than zero, we can conclude that the estimates that were done in 2018 were significantly underestimated compared to when they were revised in 2022. We thus reject our hypothesis that the process of estimating costs has improved in the period 2018 to 2022, compared to the period 2014 to 2018.

Table 5.4 - Paired T-test 2018 -2022

Paired t test

Variable	Obs	Mean	Std. err.	Std. dev.	(95% conf. Interval)	
Est - 2018	135	2862739	664457.3	7720296	1548558	4176919
Est - 2022	135	3686526	893842.3	1.04e+07	1918662	5454390
diff	135	-823787.3	288603.2	3353266	-1394594	-252980.4

mean(diff) = mean(Estimated_c-2018 – Estimated_c-2022) t = -2.8544
H0: mean(diff) = 0 Degrees of freedom = 134

Ha: mean(diff) < 0 Ha: mean(diff) ! = 0 Ha: mean(diff) > 0
Pr(T < t) = 0.0025 Pr(|T| > |t|) = 0.0050 Pr (T > t) = 0.9975

The average increase in cost estimates was 34% between 2018 and 2022. This translates to an approximate sum of 111 billion SEK in increased costs, and these calculations were made after adjusting for changes in the road- and railway indices used by The Swedish Transportation Authority in their contracts[2]. An increase of approximately one-third clearly shows that the estimates done in 2018 were underestimated. These results suggest that planners and project managers have not improved their ways of estimating and forecasting costs. A possible explanation is that optimism bias was present during the making of the estimates in 2018.

[2] All costs have been enumerated to June 2021's price level, according to the indexes used by The Swedish Transport Authority.

6. Conclusion and Related Discussion

The sixth and final section presents and discuss the conclusions of the study. In the end, our suggestions for further research are presented.

Our analysis found that there is a significant difference in cost overrun between regional locations, as well as between different sizes of projects. This implies that regional location is important to consider in the process of planning infrastructure transport projects and that it is important to include the characteristics of different regional locations into the calculations, as they can clearly create implications that leads to cost overrun. These are results which are in accordance with previous findings by Cantarelli et al. (2012). Further, to mitigate the problem of cost overrun, more attention should be given to smaller projects. Our findings declared that larger projects experienced cost overrun to a lesser extent than smaller projects, which confirms the findings of both Odeck (2004) and Cantarelli et al. (2012). A possible explanation as to why cost overrun occurs more frequently in smaller projects is that larger projects are under better management and better control than smaller projects. Planners and project managers should therefore concentrate more effort on smaller projects in order to unravel the problems of cost overrun in infrastructure transport projects.

Concerning cost overrun between different types of projects, we find no statistical evidence that there was a difference between road and railway projects. We believe that to accurately determine if there is a statistical difference in cost overrun between road and railway projects, a larger dataset with projects of both types would be needed.

We further found that there was a significant difference in the cost estimates between the period 2018 to 2022. There was no significant difference in the estimates between the period 2014 and 2018, which means that the cost estimates done in 2014 was relatively accurate. However, the estimations done in 2018 proved to be significantly underestimated compared to when they were revised in 2022. It is difficult to determine exactly what factors that leads to the increment in cost estimates due to the limited amount of information available. A possible explanation indeed, is that a degree of optimism bias and strategic misrepresentation by project planners and managers were present when the estimates in 2018 were conducted.

One important thing to note is that the OLS-regression model only explains 11.28% of the variation in cost overruns, based on our R^2-value of 0.1128. This leads to two conclusions: a more sophisticated model is needed and/or a larger sample size that includes more information about each project. We believe that it is most likely a combination of these two factors. Cost overrun is also hard to predict, due to a certain randomness. It is easy to measure and compare cost overrun statistically in percentages and nominal terms, but an entirely different matter to analyze it empirically. We argue that the main limitation is the lack of data and information concerning each project. The Swedish Transportation Authority is responsible for establishing and evaluating calculations regarding infrastructure transport projects and continuously revising previously made calculations to maintain a good cost control in infrastructure transport projects. This is something that they have been criticized for earlier by The Swedish National Audit Office. They found several deficiencies in the working process of The Swedish Transportation Authority and concluded that a systematic follow-up and evaluation of previous calculations was absent and that an overall assessment of what causes cost overrun was missing (Riksrevisionen, 2021). We believe that if more information concerning each project were available, such as scope changes, changes in design and eventual delays, and not only type of project, regional location, and size, but also other variables such as years of completion and reasons as to why changes in costs occur, a more thorough analysis to determine what it is that causes cost overruns could be conducted. This would also help prevent cost overruns in future projects and maintain the credibility of concerned agencies.

It might also be the case that there are several other factors that causes costs to increase, which is important to bear in mind when it comes to understanding the problem of cost overrun in infrastructure transport projects. As presented earlier, the reasons behind it can often be attributed to technical-, psychological-, political-, and economic factors. And most likely, it is a combination of these factors. Nonetheless, it is equally important to consider various potential factors leading to cost overruns to fully understand and mitigate the problem. By analyzing the implications of several different variables, the more it allows one to understand and a more comprehensive view of the problem can be achieved, which further allows for proper, accurate measures to be taken. The dilemma of cost overrun is almost like a puzzle, where one ad piece by piece to see the whole picture. Our analysis has mostly addressed the technical factors related to the projects themselves, hopefully adding to understanding and curbing the problem of cost overrun by providing important insights.

Furthermore, it is important to know that estimating the costs of infrastructure projects is complex, and making completely accurate forecasts is more or less impossible. This means that for individual projects, there will always be some variation in costs as compared to budget. Changes in conditions during the lifecycle of a project might also justify increases in costs, which means that previous estimations of a project's cost do not necessarily have to be incorrect. Simply trying to reduce the amount of cost overrun as much as possible is not entirely desirable either. By trying to reach cost targets and stay within budget, projects might be constructed with lesser quality and below intended standards. In such cases, the total cost risks ending up much higher, as potential deficiencies must be corrected at a later stage as cost for maintenance increases (Lundberg et al., 2011).

However, as increases in costs starts to amount to several billion SEK, as it did for the projects *Botniabanan, Ostlänken* and *Slussen,* whose combined cost overrun amounts to 21.6 billion SEK, it is clearly a problem that needs further attention. Considering the fact that only three different projects account for this large amount of increases in costs, it is hard not to think of what the total amount would be if all projects were taken into account. There are considerable opportunity costs for these funds which could have been used in more productive ways, and the increase in costs risks preventing other investments from being made, since the granted funds must be used to cover the large cost increases. This can ultimately affect both the competitiveness of Swedish companies, as well as limiting both travel and commuting alternatives for consumers. It is evident that the problem needs to be addressed further, and hopefully, our findings will help to better understand and mitigate the problem of cost overrun.

6.1 Suggestions for further research

For future research, it would be beneficial to analyze other factors that contributes to the problem of cost overrun, both political and economic factors, as well as factors related to the project itself. Factors such as changes in government, economic downturns and fluctuating market conditions can all significantly impact projects' budgets and timelines. Most important would be to do an in-depth analysis on how and why projects' costs develop over time, along with more detailed information on each project, especially why smaller projects and projects located in the northern and central parts of Sweden experiencing higher cost overrun. For this,

collection of relevant data is crucial. It would also be interesting to examine cost overrun with the use of different models, for example, a logit model to estimate the probability of cost overrun.

Further, an analysis of how cost overrun relates to the procurement process would be of interest. Previous studies (VTI, 2019; Park and Papadopoulou, 2012) have shown mixed results about whether the number of tenders and assigning the contract to the lowest bidder leads to cost overrun. A thorough analysis of the procurement process in Swedish infrastructure transport projects would be beneficial so that the problem can be mitigated at an early stage. It would also be of interest to analyze the extent of cost overrun in other types of infrastructure projects, such as airports, dams, bridges, and public buildings. Since the problem cost overrun devours such vast amounts of money and resources, it is crucial to further investigate the problem in order to mitigate it, so that the funds can be used in more productive and efficient ways to increase the socioeconomic welfare.

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Appendix

Appendix 1 – OLS regression without robust standard errors

Source	SS	df	MS		
Model	4.91733895	9	.546370994	F(9, 104)	= 1.47
Residual	38.675811	104	.371883184	Prob > F	= 0.1691
Total	43.59319	113	.385780443	R-squared	= 0.1128
				Adj R-squared	= 0.0360
				Root MSE	= .60982

Cost_overrun	Coefficient	Std. err.	t	P>|t|	(95% conf. Interval)	
Type	.1562289	.1245479	1.25	0.213	-.0907543	.4032121
Region						
1	.0779907	.1827486	0.43	0.670	-.2844067	.440388
2	.1901714	.2132977	0.89	0.375	-.2328059	.6131487
3	.4089959	.214137	1.91	0.059	-.0156458	.8336377
4	.2821493	.1861804	1.52	0.133	-.0870534	.6513521
5	.3167352	.1807542	1.75	0.083	-.0417071	.6751775
Size						
1	-.2792869	.1399131	-2.00	0.049	-.5567397	-.001834
2	-.2901973	.2066325	-1.40	0.163	-.6999537	.1195627
3	-.1875169	.2698459	-0.69	0.489	-.7226315	.3475976
_cons	.0090591	.1391492	0.07	0.948	-.2668791	.2849972

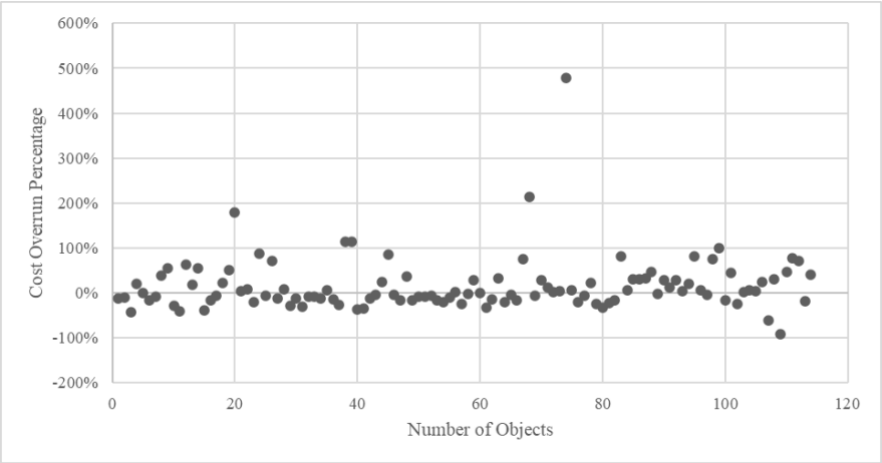
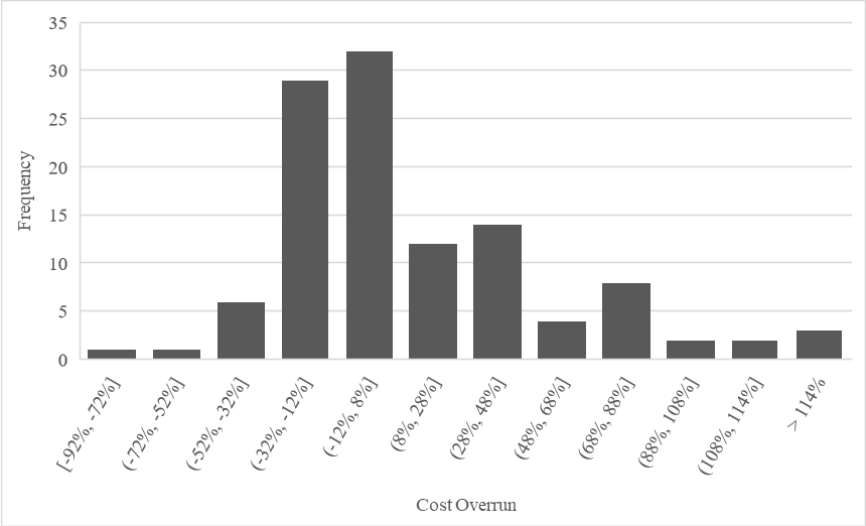
Appendix 2 – Breusch-Pagan test for heteroskedasticity

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of Cost_overrun

H0: Constant variance

chi2(1) = 65.68
Prob > chi2 = 0.0000

Appendix 3 – Distribution of cost overrun



Appendix 4 – Frequency of cost overrun