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Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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To cite this article: Hans Lind & Fredrik Brunes (2015) Explaining cost overruns in infrastructure projects: a new framework with applications to Sweden, Construction Management and Economics, 33:7, 554-568, DOI: 10.1080/01446193.2015.1064983

To link to this article: https://doi.org/10.1080/01446193.2015.1064983

Construction Management and Economics, 2015
Vol. 33, No. 7, 554–568, http://dx.doi.org/10.1080/01446193.2015.1064983

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Explaining cost overruns in infrastructure projects: a new framework with applications to Sweden

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Received 3 November 2014; accepted 17 June 2015

The aim is to both develop a new theory-based framework for analysing cost overruns, and to use this for an empirical study of cost overruns in infrastructure projects in Sweden. The conceptual part is based on a literature review and the empirical part is primarily based on a questionnaire to project managers. The framework has a descriptive part comprising two dimensions: when, during the process, the cost overrun arose and what part of the cost function was responsible: change in the product, change in quantities of the inputs and change in price of inputs. The explanatory part is a development of Flyvbjerg's theories and identifies four possible explanations: political/strategic aspects, psychological aspects, competence-related aspects and bad luck. The result from the empirical study is that most cost overruns occur in the initiation and planning stages up to the final design and are related to design changes and increases in the amount of inputs needed because of technical and administrative problems. Of the explanatory factors, there is most support for lack of competence and optimism bias.

Keywords: Construction costs, infrastructure, Sweden, cost overruns.

Introduction

Cost overruns have been observed in a large proportion of infrastructure projects, which here primarily cover roads and railways. Ansar *et al.* (2014) show, however, that there are similar problems in dam projects. Flyvbjerg *et al.* (2003) present results from a database of over 250 large road and rail projects from a number of countries and from different time periods. The results can be summarized in the following points:

- 86% of the projects had cost overruns compared to forecasted costs. The average overrun was 28%.
- The overruns were highest in rail projects, with cost overruns of 45%. For road projects it was 20%.
- Cost overruns were somewhat lower in Europe compared to North America and 'other geographical areas'.
- There were no historical trends. Cost overruns in recent periods have the same magnitude as in earlier periods. This point can be further substantiated by a recent Swedish dissertation showing large cost overruns in almost all major infrastructure projects in Sweden during the last decade (Lundman, 2011).

The basic definition of 'cost overrun' is that the final cost is higher than was budgeted in an earlier stage. In the literature, cost overruns are described as problems, and this convention will be followed here, but it could be argued that what really matters is the absolute level of the final cost. However, underestimation of costs in earlier stages could lead to the selection of the wrong projects if the underestimation is not the same across all the projects available.

A number of approaches to the explanation of cost overruns can be found in the literature. In Flyvbjerg's work, three basic explanatory factors are typically mentioned (technical, psychological and political), while others present very long lists of explanatory factors. Memon *et al.* (2011), for example, list 78 explanatory factors. One starting point is the belief that it is important to find a way to structure possible explanations, and that this could be done by starting from basic microeconomic theories about what determines cost. The first, conceptual, part of this paper presents a framework and this framework is also related to the explanations that can be found in Flyvbjerg's works.

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In the second part of this paper, the framework is used in an investigation of the causes of cost overruns in recent Swedish infrastructure projects. In an article about cost overruns in the Netherlands (Cantarelli *et al.*, 2012b, p. 55) it is underlined that it is important to study individual countries, as the mechanism behind cost overruns may depend on the institutional structure of the country. The aim of the second part of this paper is therefore also to add one more national study that can be used for future international comparisons.

The main contribution here is therefore twofold. From a theoretical perspective the contribution is an attempt to create more structure in explanations of cost overruns, and then it will be seen, for example, that Flyvbjerg's three explanatory factors are not on the same 'level'. From an empirical perspective the contribution adds information about the causes of cost overruns in Sweden.

The focus is only on cost overruns. Several recent studies have pointed out that there might be similar problems with the revenue predictions (e.g. Nicolaisen, 2012; Flyvbjerg, 2013); this is not discussed here, as it would require a different descriptive framework than the one presented below, even if the more fundamental explanatory factors are similar.

Method

The conceptual part

The first part of the paper is conceptual and based on a literature review, with a focus on the works of Bent Flyvbjerg and on studies published in academic journals since 2010. The choice of Flyvbjerg should be uncontroversial given his large number of publications in the area of cost overruns and how often his work is referred to. As there is so much written on cost overruns, it was decided to limit the analysis of other literature to the most recent studies. The reasoning is that if new ideas have been presented, they should be found in the most recent literature, including the works of Flyvbjerg. The literature has been found through searching scientific databases available through the university library and also through the reference lists of articles found. A special comparison has been made between Flyvbjerg's earlier work and his latest works to see whether there has been any development over time.

The new framework for analysing cost overruns is based on microeconomic production theory and the concept of a cost function in that theory. There are competing theories in all scientific areas, but it is hardly controversial to argue that microeconomic theory is the dominating fundamental theory in economics today. Investigating cost overruns starting with this established theory of cost determinants should therefore be both interesting and important. Arguing that one conceptual framework is better than another is not easy, and it is similar to problems encountered when comparing paradigms; see, for example, Kuhn (1962). In the end it is up to the reader to evaluate whether the framework presented below makes things clearer and the analysis of cost overruns simpler.

Case studies of cost overruns in Sweden have been carried out by Lundman (2011), among others. There have also been general reports about the persistence of cost overruns in Sweden (e.g. Riksrevisionen, 2010, 2011a, 2011b). The aim was, however, to get a more general picture of the causes of cost overruns and it was concluded that the best way to do this was to present a questionnaire to a number of experienced project managers. They should have a broad experience of infrastructure projects and therefore have a well-founded view on how common the various possible causes of overruns are. The questions were structured in the same way as the theoretical framework developed in the first part of the article. Cost calculations are also made by a number of consultancy companies in Sweden, but these consultancies are not following the project over time in the same way as the project managers and therefore they were not judged to be as knowledgeable about the causes of cost overruns.

The questionnaire was sent to two groups: project managers working for the Swedish Transport Administration (STA, Trafikverket) and to project managers employed by the three largest contractor companies in Sweden (Skanska, PEAB and NCC). These companies dominate the market for larger projects, even though some foreign contractors also have been active in this market in recent years. The first group was found by going through current projects on the STA website. The second group was found by asking leading staff in each company to recommend competent and experienced project managers that could participate in a questionnaire about cost overruns in infrastructure projects. There is of course always a risk of some bias when the company makes the selection of respondents, but it was difficult to see that the company would have any interest in selecting persons with a specific view on the issue of cost overruns.

It is therefore a strategic sample and not a stochastic sample, and this has limitations when generalizing the view of cost overruns for the whole population of project managers in Sweden. The advantage with this strategic sample is that it was possible to choose competent and experienced project managers, many of whom had worked on both the contractor and the client side. Almost all of them had worked for more than 10 years in the industry. With this level of competence it was assumed that the respondents would give better information about cost overruns than a stochastic sample of

project managers would have given. The Student's *t*-test was used to see whether there was any significant difference in the answers from the project managers from the client side and the contactor side.

A total of 230 questionnaires were sent out, of which 97 were returned fully completed, giving a total response rate of 42%. As shown in Table 1, the total number of partially completed questionnaires was 106; as some respondents did not answer every question the number of responses differs a little in the tables presented later in the article.

We have checked the difference between respondents and non-respondents according to background (regions among the STA staff and company among the contractor staff) where possible, and the response rates were roughly the same. Compared to other questionnaire-based studies on cost overruns (see literature review below) the response rate is high and the risk of bias should therefore be lower.

The survey was constructed following some general principles. There were five possible answers concerning to what extent the respondents agreed with the statements made. It was believed that it would be difficult for the respondents to distinguish between more alternatives. We used a neutral 'maybe' and also added a 'don't know' option in order to have an exhaustive list of possible answers. The complete questionnaire is presented in Appendix 1.

Limitations

As with all research methods there are limitations with questionnaires; see for instance Wärneryd (1990). The limitations are primarily on three levels: bias in observation by the individual, bias in the structure of the questionnaire and bias in the sample.

Bias in observation by the individual

Are the project managers really neutral in their observation about the extent (frequency) of cost overruns and what causes cost overruns? According to the research field of behavioural economics (e.g. Kahneman, 2011), frequencies can, among other things, be influenced by the availability bias. The project manager thinks an event has happened often because it was easy to remember, compared to a project that did not run over budget and therefore might be more difficult to remember.

Kahneman (2011, p. 207) also points out that individuals have a tendency to see causality when there isn't any. A change might only be due to stochastic events. One famous bias is the confirmation bias: if the project manager has decided that there are cost overruns he/she will ignore information suggesting the opposite.

In general it is difficult to prevent the above biases; what can be done is to be aware of them when drawing conclusions from a questionnaire.

Bias in structure of the questionnaire

A questionnaire relies on communication between the researcher and the respondent. There are a couple of limitations, which will be mentioned here. First is the problem with definitions, as a questionnaire does not make it possible for the respondent to ask questions of the researcher if things seem unclear. One example in this paper might be the definition of cost overruns and especially at what point the *ex ante* estimation should be compared to the *ex post* cost. To reduce this problem a definition of cost overruns was presented at the beginning of the questionnaire. This definition reads as follows: 'In this text "cost overruns" means a notable difference (10 per cent or more above inflation) between the client's final cost and the budgeted cost early in the project. It can also be seen from a contractor's perspective where "cost overruns" means the actual cost is higher than the budget that was the basis for the offer.'

Another problem that is discussed in the literature is how respondents answer a question depending on which order the questions are presented in. It could be the case that statements presented first are given a higher positive response rate than those presented later in the questionnaire.

Bias in the sample

Another limitation is of course external validity; can the results be generalized to construction managers and projects in general? The questionnaire was sent out to project managers found on the Swedish Transport Administration's website and even though they were

Table 1 The number of survey participants and the response rate

	Sent out	Total started	Completed	Response rate
STA staff	190	81	74	39%
Contractor staff	40	25	23	58%
Total	230	106	97	42%

not a random sample, they should be representative of the population of project managers working for the STA. The project managers on the contractor side were chosen for their experience and even though they are not representative of project managers in general, they should be the best informants concerning the causes of cost overruns. As mentioned above, there might be some risk of bias with some questions and this will be revisited when the results are presented below.

It should finally be mentioned that the focus is on cost estimation and that typically the cost is formulated as a specific amount without an interval of uncertainty. Analysis of risk, in the sense of how large the probability is that the final number ends up in a certain interval around the estimated cost, will not be covered. The argument for this is that, at least in Sweden, such probability intervals are not published. One method used in Sweden to analyse risk, the successive approach, is critically evaluated in Brunes (2014).

Earlier studies of causes of cost overruns

The literature on cost overruns is enormous so it is necessary to be selective. It is undisputed that Bent Flyvbjerg is the leading researcher in this area, so the natural starting point is the work of Flyvbjerg and his collaborators, see e.g. Flyvbjerg *et al.* (2003), Flyvbjerg (2005, 2007, 2008), Flyvbjerg *et al.* (2009) and Cantarelli *et al.* (2010). In the first subsection below, the explanations proposed in these works are presented, as well as whether there are any changes in explanations in the most recent works available (Flyvbjerg, 2013; Ansar *et al.*, 2014; Flyvbjerg, 2014). In the second subsection, the focus is on studies presented since 2010 and how the recent literature relates to various dimensions of Flyvbjerg's theories. In the third subsection, recent studies of cost overruns in Sweden are presented.

Flyvbjerg's explanatory frameworks

Flyvbjerg divides the possible explanations of cost overruns in somewhat different ways in different articles. In Flyvbjerg (2008) three main groups of explanations are presented, and these seem to be the most common explanations in his work.

- *Technical explanations*: These explain cost overruns in terms of inaccurate and unreliable data. Technical complications of some kind may have arisen during the project and led to increased costs.
- *Psychological explanations*: These centre on theories from behavioural studies, primarily optimism bias. Actors who are working with a specific project tend to be over-optimistic about the implementation of the project: 'to judge future events in a more positive light than is warranted by actual experience' (Flyvbjerg, 2008, p. 6).
- *Political-economic explanations*: Here, cost overruns are explained by strategic misrepresentation: 'Here, when forecasting the outcomes of projects, forecasters and planners deliberately and strategically overestimate benefits and underestimate costs in order to increase the likelihood that it is their projects … that gain approval and funding' (Flyvbjerg, 2008, p. 6).

In Flyvbjerg *et al.* (2009), the explanations are divided into 'delusion' and 'deception', where the first covers psychological explanations (actors take an 'inside view'), and the second 'accounts for flawed planning in decision-making in terms of politics and agency issues' (p. 173).

In Cantarelli *et al.* (2010), the explanations are divided into four groups and the division seems to be based primarily on what type of theories the explanations are based on or related to. It is argued 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' (p. 13).

The first group is *technical explanations* and this includes, for example, forecasting errors (including price rises, poor project design, and incompleteness of estimations), scope changes and inadequate organizational structures and processes. Forecasting theory and planning theory are the fundamental theories behind this type of explanation.

The second group of explanations is *economic* and is exemplified by deliberate underestimation due to lack of incentives, lack of resources, strategic behaviour, and poor financing/contract management. The background theories mentioned here are neoclassical economics and rational choice theory.

The third type is *psychological explanations*, exemplified by optimism bias among local officials, cognitive bias of people involved in the project and a cautious attitude towards risk. Prospect theory and rational choice theory are mentioned as the relevant theories in this area.

The fourth and final type of explanation is *political* and includes deliberate cost underestimation and manipulation of forecasts based on private information. Here, Machiavellianism and agency theory are mentioned as relevant.

Looking at Flyvbjerg's work as a whole, the tripartite structure of explanatory factors seems to be the most relevant: *technical*, *political* and *psychological*. The *economic* explanations mentioned above can be covered by the technical and the political.

In a number of recent studies Flyvbjerg and collaborators have examined cost overruns in the Netherlands. Cantarelli *et al.* (2012b) come to the conclusion that 'The main problem with cost-overruns lies in the pre-construction phase' (p. 90).

They have not collected any direct material concerning explanations but they write: 'Considering the three main explanations for cost overruns – technical, psychological and political-economical explanations – the latter seems the most likely' (p. 90).

Cantarelli *et al.* (2012a) also look at the Netherlands, but focus on the geographical variation and relationships with studies from other countries about different project types. They find that cost overruns seem largest in fixed-link projects and also argue (p. 329) that such projects might be more prestigious and therefore more prone to strategic behaviour from central actors.

In Flyvbjerg's most recent work, similar explanatory structures are used. Ansar *et al.* (2014, p. 44) divide the explanations into delusion and deception as discussed above. Flyvbjerg (2013, p. 761) focuses on the 'inside view' and the psychological explanations, but writes 'two types of explanation best account for forecasting inaccuracy: optimism bias and strategic misrepresentation' (p. 762). Flyvbjerg (2014) also mentions strategic misrepresentation (p. 15) and the psychological dimensions are also implicit in the arguments presented (see, for example, pp. 12–13). Two observations can be made from these recent works: the first is that the 'technical explanations' are excluded and this is especially interesting in terms of the framework presented below, where the technological factors belong to the descriptive part while the others belong to the explanatory part. A second observation is that there is a change in focus in the recent works, where discussions about what can be done to reduce cost overruns are given much more space.

Other recent literature on cost overruns

Some of the recent studies reviewed (Cantarelli *et al.*, 2012c; Love *et al.*, 2013) are primarily interested in finding a statistical pattern in cost overruns and whether or not this pattern differs between procurement types and project types. As these studies do not directly concern explanations of cost overruns, they will be put aside here.

Some recent studies start with a very long list of factors and then try to find out which of these are the most important by sending out a questionnaire and letting actors in the sector rank the factors on the list. Through the use of more or less advanced statistical methods, the most important factors are identified. Rahman *et al.* (2013) and Doloi (2013) are examples of this. There are several problems with these studies. The first is that there are problems with overlaps between the factors and that some factors might cover the same underlying factors. This can be illustrated by Rahman *et al.* (2013, p. 1965), where one factor listed is 'Design and Documentation-related factors' and another is 'Information and Communication-related factors': but isn't it likely that problems with information lead to problems with design? Asking people to rank factors that are not clearly defined and that are overlapping seems very problematic from a methodological point of view. A common problem in these studies is also the quality of the answers, particularly when the respondents have to answer so many questions. The conclusion (p. 1970) that site management factors were major factors contributing to cost overruns is therefore not convincing. As will be returned to in our framework below, it is important to determine the question of *when* in the process a cost overrun occurs and *why* it occurs (in a certain part of the process).

There are also papers that work with a 'data mining' approach in order to be able to find patterns and predict cost (see, for example, Ahiaga-Dagbui and Smith, 2014), but as these studies do not focus on identifying a causal mechanism they are not discussed further here.

Love (2011) is very critical of Flyvbjerg's focus on political/strategic factors and optimism bias. He presents several Australian case studies and writes in the concluding section (p. 1202):

> The association between strategic misrepresentation and optimism bias with project overruns which has been promulgated does not adequately explain why social infrastructure projects consistently under perform in terms of time and cost. The limitation in Flyvbjerg's and his colleagues' theorem is that intermediary conditions and events that lead to project overruns occurring are not examined or explained. A chronological lacuna exists between the initial event and the final outcome.

This can be interpreted as a demand for a more descriptive part ('when do cost overruns occur') and an explanatory part, and this is the basis for the framework presented below. Looking at Love's more positive results, he points to a combination of lack of competence and optimism bias in a number of respects, for example in the planning and procurement stage, where not enough time is given to various tasks and therefore the wrong types of procurement are chosen (p. 1203). There is also an element of 'bad luck' in his explanations as they point to unexpected events and special circumstances that, given certain conditions, can lead to cost overruns.

Nicolaisen (2012) presents information about cost overruns in a Danish rail project and writes (p. 143):

'Regarding costs, the majority of cost overruns for Ringbanen appear to be caused by additional project items that have been approved individually after the initial budget approval'. Jennings (2012) analyses the London 2012 Olympic Games and comes to the conclusion that cost overruns were caused by a combination of scope changes, optimism bias, and inattention to general uncertainties. There were also external changes, especially related to security, that led to large cost increases. Jennings' approach is close to the approach used by Love (2011).

An interesting recent theoretical contribution can be found in Cantarelli *et al.* (2013), where they show how cost overruns can occur by using a 'signalling game' where the client cannot distinguish between competent and less competent contractors, and whether a low offered price reflects high efficiency or lack of contractor competence. The effect of this will be that in some cases a less competent contractor is chosen and in the end this leads to cost overruns. As a comment it can be said that this mainly concerns cost overruns during the construction stage.[1]

Recent studies of cost overruns in Sweden

Several government investigations (Riksrevisionen, 2010, 2011a, 2011b) have documented that cost overruns are still a problem in the Swedish infrastructure sector. The reports do not discuss causes in a systematic way, but they do make the point that data is not registered in such a way that makes it easy to analyse what has really happened during the process and when and where cost overruns have occurred.

Two recent Swedish studies question some more fundamental points in cost-overrun literature. Mandell and Brunes (2014) analyse quantity choice in unit price contracts in a theoretical model and conclude that 'deliberately procuring low quantities, and thereby facing a high risk of cost overruns, is sometimes optimal, as it minimizes the expected total cost' (p. 483). This result, however, only concerns cost overruns in the construction stage and when unit price contracts are used. Eliasson and Fosgerau (2013) show that cost overruns can be a reflection of selection bias. The idea is that there are random factors affecting cost calculations, so that costs are sometimes underestimated and sometimes overestimated. If the project with the highest expected surplus is selected, then there will be a bias that leads to an overrepresentation of projects with underestimated costs. Even if this mechanism is at work, the question of what led to the underestimated cost in the first place still remains, so Flyvbjerg's explanatory factors might still be relevant. Eliasson and Fosgerau's (2013) paper is called 'Cost overruns and demand shortfalls – deception or selection?' but our point is that there might be deception even if there also is a selection bias.

The most comprehensive study of Swedish cost overruns in recent years is that by Lundman (2011). This is primarily a case study of the Bothnia railway line, but he also studied eight other large infrastructure projects in Sweden. The most striking result, in line with, for example, Cantarelli *et al.* (2012b) is that most of the cost overruns in the nine projects occurred during the early planning stages. There were only minor cost overruns in the procurement and construction stages. Another interesting result was that 85% of the cost overruns were due to indirect costs such as administration, detailed design, purchase of land and preparatory work including cost for delays caused by appeals. A similar result for the Bothnia line can be found in Cars *et al.* (2009). The arguments are actually much in line with those in Love (2011): unexpected events and circumstances occur and it is not obvious that they are related to either optimism bias or political/strategic factors. In the framework presented below, there are two factors related to this that are not explicit in Flyvbjerg's frameworks: cost overruns related to lack of competence and to bad luck.

A conceptual framework for understanding cost overruns

The core idea in the framework presented here is that 'explaining' cost overruns is a question that can be interpreted in different ways. Therefore, there is first a more *descriptive part* that concerns observable things like when during the process did the cost overrun occur and what cost component increased. The descriptive part gives results in the form of *frequencies/correlations*, like 'cost overruns mostly arise early in the process' or 'cost overruns often arise because more work (or material) is needed'. It could also be argued that unless it is known *when* during the process the cost overrun occurred, or *what component* of the cost function (price, quantity, etc.) changed, we do not really know what to explain. The descriptive part lays the foundation for the explanatory part and simplifies the search for explanations of cost overruns.

The explanatory part then consists of finding more fundamental causal factors and the framework presented below tries to give a systematic overview of possible explanations. The starting point is that cost overruns are caused by human behaviour and that a rational person can be 'mistaken' for a number of different reasons. This proposed framework is also compared to Flyvbjerg's framework presented above.

Descriptive framework

Infrastructural projects are complex and take many years to complete, so it seems important to describe when the cost overruns occur more in detail before one tries to explain them using, for example, the kinds of factors that Flyvbjerg discusses. The descriptive framework here consists of two parts. The first is *when* in the process the cost overrun occurs, and the second is in *which part of the cost-function* the cost overrun occurs; see Lundman (2011) for a similar approach, although there are no explicit references to production and cost theory in his work.

Descriptive framework 1: when in the process?

The first part of the descriptive framework concerns *when during the process cost increases occur*. Even if the exact process differs from country to country, it is possible to identify a number of stages in the process where costs are estimated or measured; see Figure 1.

Stage 1. The cost estimate when the project has just started is the first base for measuring cost overruns. This is *the initiation stage*. Lundman (2011) uses the terms 'idea-study' and 'pre-study' (p. 13) when this part of the Swedish process is described. When cost overruns are measured it is typically in relation to the cost estimate at the end of this first stage, when a preliminary 'go ahead' decision is taken.

Stage 2. When the process continues, the more detailed design, or detailed specifications or functional demands, are determined in order to procure the project. Here, this is called *detailed design stage* and it is assumed that new cost estimations are made before the decision is made to continue and procure the project. The first cost increases can occur between the end of the initiation stage and the end of the detailed design stage.

Stage 3. *Procurement* of the construction works. Cost increases in this stage mean that the bids from contractors are higher than the estimated cost at the end of the detailed design stage.

Stage 4. *Construction* then starts and the final cost is the actual cost when construction works are complete. It should be underlined that in this article cost overruns are primarily seen from the client's perspective. With a fixed price contract there might be cost overruns from a contractor's perspective during stage 4, which simply means that the actual profit for the contractor is lower than the expected profit.[2]

Descriptive framework 2: which part of the cost function?

The second part of the descriptive framework concerns the different components in a standard cost function in microeconomic theory. In that theory the cost is determined by three factors: the goods produced, the amount of the inputs needed to produce the specific goods and finally the price per unit of each of the inputs. This means that cost overruns can be related to one or more of these factors. When discussing cost functions it is typically assumed that the firms are efficient and do not use more inputs than technologically necessary, but in reality waste might occur and explain cost overruns. This is the fourth factor below.

Factor 1. Design (the goods produced): Cost overruns can occur because there is a change in the produced goods. In Flyvbjerg's categorisation described above, 'scope changes' are mentioned (Cantarelli *et al.*, 2010, p. 11) and this means that the characteristics and qualities of the project change between different stages in the planning and construction process. The project has changed content and the new design has led to increased costs. This also covers changes in quality in some dimension.

Factor 2. Input quantities: This can be described as a *change in the production function.* The planned quantities of the inputs are simply not enough to accomplish the planned project. During the development of the project it is found that higher quantities of the factors of production are needed to produce a given project. For example, geotechnical conditions may have been worse than believed, which created a need for more man-hours and more material than expected in order to produce the given object.

Factor 3. Prices (real): A change in *the price of the inputs, including materials.* Cost overruns can be caused by inputs becoming more expensive than estimated. Here there are some interesting complications concerning how to take inflation into account. When cost overruns are seen as a problem it is natural to assume that the 'real cost' has increased and not only the nominal

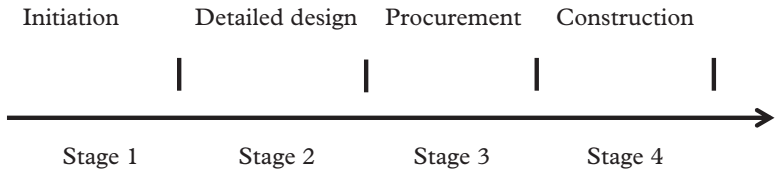

Figure 1 The different stages in a project

price. This comes back to the question of how the estimated costs are presented. Are they explicitly presented as the cost in current prices at the time of the calculation, or at the time when the project is expected to be undertaken? If a bridge to be built in five years' time is said to cost 500 million SEK (without any specific statement of the value of money) our interpretation is that it then is expected to cost 500 million SEK adjusted for the predicted general inflation. Any increase above that would be cost overrun, for example because prices increased more than the expected inflation.

Riksrevisionen (2010, 2011a) discuss the possibility that the responsible authorities have hidden some cost overruns by presenting figures that have been deflated using a special road or rail construction index that has increased much more than inflation. These reports criticize the responsible authorities for underestimating the 'true' cost overrun by using this deflation procedure. The lesson learned from this is that it is important to be very clear about what kind of prices the cost estimation and the final cost are based on.

Factor 4. Waste: This means that production is not efficient and that more inputs are used than necessary. In Flyvbjerg's framework above, 'inefficient use of resources' is mentioned (Cantarelli *et al.*, 2010, p. 11), and this can be interpreted as meaning more resources are used than is necessary according to the production function. Leibenstein's concept of X-inefficiency is a term for such inefficiencies (see for example Leibenstein, 1966). As in practice it is difficult to know how great these inefficiencies are, in the rest of this paper cost overruns related to waste will be included in category 2 above: cost increase related to higher input quantities than expected.

Descriptive framework: overview

If the two descriptive dimensions are put together (see Table 2), it can be seen that there are nine different combinations concerning when and where cost overruns might occur. A first step in analysing cost overruns would be, according to this proposed framework, to find out how the design, the estimated quantities of the inputs and the estimated price of these inputs have changed during the planning and construction process.

Explanatory framework

The descriptive framework can lead to a large number of more specific questions, such as: Why was design changed during the detailed design stage? Why was the estimated cost changed even if the design was not changed? Why were there extra costs during construction that led to a higher final cost than the procured amount? Why were the price predictions for specific components changed during the process, etc.?

The explanatory framework below is based on the idea that there can be a number of different mechanisms behind 'mistakes' like these:

(1) The calculations are *consciously manipulated*. The design is initially made in a cheap but infeasible way, and the quantities of the inputs are known to be below what is really needed, etc. This is what Flyvbjerg (2005) calls political explanation or deception.
(2) The calculations are not consciously manipulated, but there are *psychological/behavioural factors* that make the involved persons underestimate the cost. Optimism bias is one example mentioned by Flyvbjerg *et al.* (2009), among others, and he also calls this kind of explanation 'psychological delusions'. The characteristic feature is that the involved persons actually believe that they have made the best possible estimation, but an outside observer would see that it was biased.
(3) A third possible explanation for 'mistaken' estimations is *lack of competence*. This is not explicitly included in Flyvbjerg's framework, but can of course be an explanation for initially proposing a design that later will be found not to work, or the explanation for mistakes in a procurement document that later leads to extra cost, or an explanation for why geotechnical investigations

Table 2 Cost overruns related to stages and proximate causes

		When in the process		
		2. Detailed design (compared to initiation stage)	*3. Cost according to procurement contract (compared to 2)*	*4. Final cost (compared to 3)*
Which part of the production function	*Design*	??	??	??
	Input quantity	??	??	??
	Prices of inputs	??	??	??

were not carried out in a satisfactory way. There is currently a discussion about the importance of knowledge management in organizations (see, for example, Warsame *et al.*, 2013) and this indicates that lack of competence can be an explanation for cost overruns in a specific project.

(4) Finally, there can in any project be *genuinely unexpected events*, and cost overruns can then be seen as caused by *bad luck*. Everything was done in the correct way and the cost estimation actually showed the most probable cost, but events that it was not reasonable to expect actually happened and led to higher costs. There might, for example, be unexpected changes in rules and regulations. Note that if these changes were fairly easy to predict but not accounted for, then the explanation for the cost overrun could be attributed to lack of competence or conscious manipulation.

The complete framework

The descriptive and the explanatory frameworks are combined in Table 3. The hypothesis is that by using this framework, the understanding of cost overruns can increase. It would also be helpful when comparing cost overruns in different countries – do they occur in the same stages, in the same part of the production function and for the same reasons? The framework also shows that Flyvbjerg's traditional explanatory structure (technical, psychological and political) is not logical as the technical aspects belong to the descriptive part while the others belong to the explanatory part. The later works, where delusion versus deception is the focus, are therefore more logical even if lack of competence and bad luck should be added.

Explaining cost overruns in infrastructure projects in Sweden: results from a questionnaire

Link between the framework and the survey questions

The descriptive part of the conceptual framework contains two dimensions: which part of the production function changed and when during the process did the cost increase occur? In order to simplify the questionnaire and not put too high demands on the memory of the respondents, it was decided to focus only on the dimension concerning the production function and of course also on the explanatory factors. The results related to the descriptive framework are presented in first subsection below, and the results concerning the explanatory factors are shown in the subsection after, but first some background information.

A statistically significant[3] proportion of the population of project managers had experienced cost overruns; see Table 4. Cost overruns had in the introduction of the questionnaire been defined as significant increases in costs compared to expected (budgeted) costs. The majority said that cost overruns occur often.

A total of 89% of the project managers from the Swedish Traffic Administration (STA) and 96% of the project managers on the contractor side had experience

Table 3 Why have design, quantity and price changed at different stages?

		When in the process		
Framework for analysing cost overruns		*2. Planning stage (compared to idea stage 1)*	*3. Cost according to procurement contract (compared to 2)*	*4. Final cost (compared to 3)*
Which part of the production function	*Design changes* *Changes in quantity of input* *Changes in input prices*		*Why?* Political/strategic, Psychological Competence related Bad luck	

Table 4 Question: What is your view on the prevalence of cost overruns in infrastructure projects?

	STA staff	Contractor staff	Total
Occurs often	41 (52%)	13 (52%)	54 (52%)
Occurs sometimes	34 (43%)	12 (48%)	46 (44%)
Occurs rarely	3 (4%)	0	3 (3%)
Do not know	1 (1%)	0	1 (1%)
Number of answers	79	25	104

participating in projects where there had been cost overruns.

The descriptive part of the framework

Design changes

The first question dealt with design changes, and the results are presented in Table 5. It can be seen that design changes are seen as common in projects with cost overruns. This opinion was more common among the contractor staff.

Price changes

The result dealing with price changes is presented in Table 6, and price changes were not seen as very common in projects with cost overruns. The difference between the two respondent groups was smaller in this case.

Changes in input quantities

The next question dealt with input quantities in the form of unexpected technical problems; see Table 7. We interpret this as meaning that when there are technical problems, there will be a need for extra material, extra work hours, etc., which in turn lead to cost overruns. As can be seen in the table, the answers indicated that changes in input quantities were not as common as design changes, but more common than price changes. On this question there were also only small differences in the answers.

Table 5 Question: Cost overruns often depend on changes in the design of the project

	STA staff	Contractor staff
Yes, definitely	18 (23%)	12 (50%)
Yes, probably	29 (38%)	7 (29%)
Maybe	21 (27%)	4 (17%)
No, probably not	9 (12%)	1 (4%
No, definitely not	0	0
Do not know	0	0
Number of answers	77	24

Table 6 Question: Cost overruns often depend on misjudged price changes

	STA staff	Contractor staff
Yes, definitely	3 (4%)	1 (4%)
Yes, probably	15 (20%)	2 (8%)
Maybe	26 (34%)	6 (25%)
No, probably not	31 (40%)	8 (33%)
No, definitely not	2 (2%)	7 (30%)
Do not know	0	0
Number of answers	77	24

Table 7 Question: Cost overruns often depend on unexpected technical problems that were difficult to predict

	STA staff	Contractor staff
Yes, definitely	8 (11%)	2 (8%)
Yes, probably	39 (51%)	15 (62%)
Maybe	24 (32%)	5 (21%)
No, probably not	5 (7%)	2 (8%)
No, definitely not	0	0
Do not know	0	0
Number of answers	76	24

Overview and conclusion

To get an overview and make a statistical test possible given the small sample, counts for both of the 'yes' answers and for both of the 'no' answers were added together; see Table 8. These answers also indicate that the project managers consider design and technical problems as a source of cost overruns. The results also show that project managers do not consider price increases as a source of cost overruns.[4]

Explanatory analysis

In this section of the questionnaire the aim was to see which of the explanatory factors described in the framework got most support.

In Table 9 below the results concerning the deception explanation are presented. This hypothesis gets some support but it is not very strong. Even though it is not

Table 8 Result with aggregated answers

Factor	Yes	No	Maybe	Number of respondent
Design changes	65%	10%	25%	101
Changes in input prices	20%	48%	32%	101
Technical problems (increase in quantity of factors of production)	64%	7%	29%	100

Table 9 Question: Cost overruns often depend on a budget that consciously was set too low

	STA staff	Contractor staff
Yes, definitely	5 (7%)	0
Yes, probably	10 (13%)	4 (17%)
Maybe	22 (29%)	4 (17%)
No, probably not	28 (37%)	13 (56%)
No, definitely not	11 (14%)	0
Do not know	0	2 (9%)
Number of answers	76	23

possible to test statistically because the numbers are too small, it is interesting to note that all 'yes, definitely' answers come from the client side. This is interesting as we thought that maybe the answers to this question would be biased from the client side, as they might want to underestimate deceptive practices.

As mentioned above, there might be incentives to be too optimistic in order to get your favoured projects on the list (or get more projects squeezed into the budget). The results presented in Table 10 show more support for this hypothesis compared to the previous one. It can be noted that also in this case there seems to be somewhat more support from the client side.

Two questions relate to lack of client competence. The answers are presented in Tables 11 and 12. These statements get considerable support, especially from the contractors' side, which is as expected: there is a strong risk of bias in the answers from the client side to a question like this.

Table 10 Question: Cost overruns often depend on too optimistic judgments

	STA staff	Contractor staff
Yes, definitely	5 (7%)	0
Yes, probably	32 (42%)	7 (29%)
Maybe	27 (35%)	9 (38%)
No, probably not	10 (13%)	6 (25%)
No, definitely not	3 (4%)	2 (8%)
Number of answers	76	23

Table 11 Question: Cost overruns often depend on lack of client competence

	STA staff	Contractor staff
Yes, definitely	2 (3%)	5 (21%
Yes, probably	13 (17%)	10 (42%)
Maybe	31 (40%)	2 (8%)
No, probably not	26 (37%)	6 (25%)
No, definitely not	4 (5%)	1 (4%)
Do not know	1 (1%)	0
Number of answers	77	23

Table 12 Question: Cost overruns often depend on lack of competence among the staff that sets budgets

	STA staff	Contractor staff
Yes, definitely	4 (5%)	6 (25%)
Yes, probably	21 (27%)	5 (21%)
Maybe	34 (44%)	10 (42%)
No, probably not	15 (20%)	2 (8%)
No, definitely not	1 (1%)	0
Do not know	2 (3%)	0
Number of answers	77	23

Table 13 Question: Cost overruns often depend on bad luck

	STA staff	Contractor staff
Yes, definitely	0	0
Yes, probably	0	0
Maybe	11 (14%)	1 (4%)
No, probably not	43 (56%)	11 (50%)
No, definitely not	23 (30%)	10 (42%)
Do not know	0	1 (4%)
Number of answers	77	23

The final question concerned the role of (bad) luck and it can be seen that 'bad luck' is not something that the respondents believe in; see Table 13. This should mean that they think that there is always a specific cause and that the cost overruns could have been avoided if everything had been done in the right way.

At the end of the part in the questionnaire about explanations there was room to add further explanations. Among the STA staff 42% said that they had nothing to add and among the contractors this share was 30%. Many of the answers were more concrete examples of the factors already covered. For example, the STA staff mentioned changes in the views of leading politicians, poor project documents, communication problems and changing regulations. Contractor staff mentioned poor documents, and appeals.

As a summary of the explanatory part, the four possible explanations identified in the framework can be ranked in the following way for infrastructure projects in Sweden in recent years. The explanation that is ranked number 1 got most support:

(1) Lack of competence
(2) Psychological bias (optimism bias)
(3) Strategic behaviour
(4) Bad luck

Conclusions and policy implications

The contribution in this paper is on two levels. The first is the development of a better theory-based framework for analysing cost overruns. The core of this framework is the division into a descriptive part and an explanatory part. The descriptive part covers two dimensions, where the first is *when* during the process the cost overrun occurs and the second is *which part of the cost function* has changed: is it changes in the product (scope changes, quality changes), changes in the amount of inputs needed or changes in the price of the inputs.

The descriptive part will give important information about possible explanations. For example, if the cost overruns occur during the construction stage because of increased input prices, the likelihood of political manipulation is perhaps not so high. Scope changes and changed estimations of input amounts would on the other hand increase the likelihood of possible political manipulations.

The explanatory part focuses on why someone may make a calculation that later turns out to be seriously incorrect. The person may be *forced* to do it because of political pressure, or the person may do the best they can but fail because of *optimism bias*, *lack of competence* or simply *bad luck*.

The second contribution concerns cost overruns in Swedish infrastructure projects in recent years, and if the results from Lundman (2011) are combined with the results from our questionnaire, the conclusions would be the following:

- Most cost overruns occur in the planning stages up to the final design, and are related to design changes and increases in the amount of inputs needed because of technical and administrative problems.
- Of the explanatory factors, lack of competence and optimism bias get most support.
- The most important policy implication of this work is the need to document projects in a systematic way, and the framework presented above should be very useful in this context. It will only be possible to design effective measures against cost overruns if it is known during what stage cost overruns occur, and whether the increase is due to design changes or technical complications leading to changes in the amount of inputs needed. A few examples can illustrate the point:
  - If it is found that cost overruns relate to unforeseen technical complications, then a suitable measure could be to put more resources into geotechnical investigation, for example.
  - If cost overruns occur in the earlier stages because of a combination of design changes, price changes and underestimated amounts of inputs, there might be a suspicion that a combination of strategic behaviour and optimism bias is the explanation. A possible measure could then be to systematically use independent third party reviews of plans and calculations (see Warsame *et al.*, 2013).
  - If cost overruns occur late in projects during the construction stage, then maybe the procurement documents and the type of procurement chosen should be reviewed. Here it may also be possible to use independent third parties to review the proposed documents and the chosen procurement type.
- By continuously making data about the project's development available to the public, including data presented in our proposed descriptive framework, with information about who is responsible, it is possible to reduce the risk of strategic behaviour and optimism bias. High transparency reduces the risk of this type of behaviour, as discussed more in detail in Warsame *et al.* (2013).
- Flyvbjerg (2008) proposes something called 'Reference class forecasting'. As discussed in Brunes and Lind (2014), this has several different interpretations, but one interpretation is that whenever a cost calculation is presented, there should also be information about actual costs for similar projects that have been carried out. If it is claimed that the current project will be much cheaper, clear and convincing arguments should be demanded. It is, however, not a good idea to assume that the current project will have the same percentage cost increase between stages as earlier projects, as that will create new incentives to underestimate costs in earlier stages.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. There is an interesting current example of this in Stockholm, where one large subcontractor in a tunnel project recently went bankrupt and the comment from the Swedish Traffic Authority was that this will probably lead to cost overruns.
2. A recent Swedish example is the new arena in Stockholm (Tele2 Arena), where the contractor made large losses because of a number of cost increases partly related to the bankruptcy of a subcontractor. The cost overruns were, however, limited from the perspective of the client.
3. Hypothesis testing at a 95% confidence level showed the population's opinion difference between the sum of answers 'often' and 'sometimes' and the answer 'rarely'.
4. Hypothesis testing at a 95% confidence level showed that the population of project managers regard design and changes in the input quantity as sources for cost overrun, but do not regard price as a source for cost overrun.

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Appendix 1

The questionnaire

At present there is a research project running at the Royal Institute of Technology (KTH) examining the causes of cost overruns on infrastructure projects and possible arrangements to reduce cost overruns. As part of the project a questionnaire is sent out to agents in the field to capture their experience and views about the subject. All answers will be treated confidentially.

In this text 'cost overruns' means a notable difference (10 per cent or more above inflation) between the client's final cost and the budgeted cost early in the project. It can also be seen from a contractor's perspective, where 'cost overruns' means the actual cost is higher than the budget that was the basis for the offer.

If you want to know more about the project or have other questions, contact XXX. The project leader is YYY.

Put a cross in the square that matches your judgment.

Part 1 General

1. I work with or have worked with infrastructure projects (road, railway)

□ Yes
□ No

2. I work for

□ Client organisation such as Swedish Transport Administration, municipality etc.
□ Contractor company such as NCC, PEAB etc.
□ Consultant company such as ÅF. WSP, Swecot
□ Other
Comment:

3. My working experience is (several alternatives possible)

□ I have worked both for clients and contractors/consultants.
□ I have substantial experience of employment in sectors other than the construction sector.
Comment:

4. Your experience/worked years within the business is

□ Less than three years
□ Four to 10 years
□ More than 10 years
Comment:

5. I have participated in projects that have experienced cost overruns!

□ Yes
□ No
□ Do not know
Comment:

6. What is your opinion of the occurrence of cost overruns in infrastructure projects?

□ Occur often
□ Occur sometimes
□ Occur seldom
□ Do not know
Comment:

Part 2 Causes of cost overruns

Below is a list of statements about possible causes of cost overruns. Mark the option for each which best fits your opinion.

7. 'Cost overruns are often caused by changes in the project's shape'

□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

8. 'Cost overruns are often caused by changes in prices that have been wrongly estimated'

□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

9. 'Cost overruns are often caused by unexpected technical problems which were difficult to foresee'

□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

10. 'Cost overruns are often caused by a budget that was deliberately too low'

□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

11. 'Cost overruns are often a result of overly optimistic judgments'

□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

12. 'Cost overruns are often caused by lack of competence of the client'

□ Yes, absolutely
□ Yes, probably

□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

13. 'Cost overruns are often caused by lack of competence among those who set the budget'
□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

14. 'Cost overruns are often caused by bad luck'
□ Yes, absolutely
□ Yes, probably
□ Maybe
□ No, probably not
□ No, absolutely not
□ Do not know
Comment:

15. Are there any other factors besides the above that you consider important?
□ No
□ Yes, namely….