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Cost overruns of infrastructure projects – distributions, causes and remedies

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Abstract

This paper analyses the accuracy of cost estimates for Swedish transport infrastructure projects 2004-2022, discusses causes of cost overruns, and suggests remedies. Cost estimates for all projects in the national investment plans 2010-2022 are tracked from early planning to completion. Final costs for all projects finished 2004-2022 are compared to decision-to-build cost estimates. Results show considerable cost escalation during the planning stages, on average, while cost estimates at the decision-to-build are close to final costs, on average. Cost escalations during the planning stage are not uniform, however: the distribution of cost changes is highly skewed with a long right tail. The reason that final costs tend to exceed early cost estimates is that project decisions are effectively locked in before projects' costs and benefits have been thoroughly assessed. Lock-in of premature decisions does not only cause cost overruns; even worse, it distorts project selection and design, reduces incentives to search for more cost-efficient designs, and increases opportunities and incentives for project beneficiaries to underestimate costs and overestimate benefits. Several ways to tackle these problems are suggested.

Keywords: cost overruns, transport infrastructure, project management, decision processes, transport policy.

1 Introduction

Cost overruns of transport infrastructure projects is a common problem all over the world, and there is an extensive literature about magnitudes, frequencies, causes and possible remedies. The contribution of the present paper is twofold. First, it analyses how costs evolve from the initial planning stage to project completion for all projects in the Swedish twelve-year national investment plans established from 2010 to 2022, and compares decision-stage cost estimates to final costs for all projects finalized between 2004 and 2022. Following all projects in the investment plans reduces the problems of selection and attrition bias common in cost overrun studies. Second, based on these results, interviews with planners and projects managers and systematic case studies and classifications of the causes of cost overruns, the paper discusses the root causes of cost overruns, and suggests how infrastructure planning processes can be designed to overcome these.

The results show that, on average, almost all of the average cost escalation occurs during the planning stage, from projects' first inclusion in the national investment plan to start of construction. The distribution of cost changes from first plan to start-of-construction is highly skewed with a fat tail to the right, but with a mode (most common value) around zero. In other words, the problem with cost overruns is not that all projects' costs increase more or less uniformly, but that a subset of projects' costs increase extremely.

The paper's most important message is that the fundamental problem of cost overruns is linked to a failure or inability to reconsider earlier decisions about project selection and design, even when project costs increase considerably compared to earlier estimates. In early stages, costs and benefits are inherently uncertain, partly because project design is not yet determined, partly because necessary data for estimating costs (e.g. soil conditions) are not yet available. The Swedish infrastructure planning process is intended to have several decision tollgates, where decisions are made to either proceed with the project or to cancel it. However, projects are rarely cancelled once they have been included the national investment plan, even if their costs increase or benefits decrease.

Several kinds of problems arise when effectively irrevocable decisions are based on early, inherently uncertain estimates of costs and benefits. First and most important, it distorts project selection and design, since a subset of the chosen projects will turn out to be more costly or less beneficial than anticipated. Had true costs and benefits been known, other decisions might have been made, and more benefits might then have been realized for the same budget. Second, it increases the risk for scope creep, and reduces incentives to search for more cost-efficient designs in the planning stage. Third, it gives incentives for stakeholders benefitting from the project to underestimate costs and overestimate benefits. Finally, it gives unwarranted bargaining power to stakeholders whose cooperation is necessary for the project (e.g. land owners or municipalities), enabling them to effectively blackmail the project manager for various advantages in return for their cooperation. All these mechanisms may contribute to further cost escalations. The root cause of all of these mechanisms is that project selection is determined too early in the planning process.

Using general uplifts of early cost estimates does not solve the problems above. Eliminating the systematic bias in cost estimates by general uplifts can, in principle, eliminate cost overruns on average, which is of course worthwhile; one problem caused by cost overruns is that other projects are postponed or pushed out of the project portfolio. But applying a general uplift on cost estimates does not eliminate the even more serious problems with distorted project selection and distorted incentives in the planning process. The root problem of cost overruns is not really that early cost estimates are uncertain, which is unavoidable. The root problem is not even that early cost estimates are downward biased on average, which can be solved by general uplifts or contingencies. The root problem is that making (effectively) irrevocable decisions prematurely distorts the selection and design process, meaning that society gets less benefits for a given budget than had been possible.

Hence, it is of fundamental importance to avoid making irrevocable decisions before true costs and benefits are known as well as possible. However, this is easier said than done, for several reasons: political incentives, long planning processes, linkages to other long-term planning processes (e.g. for housing and industries), and psychological and institutional biases causing resistance against cancelling projects once planning has begun. The paper concludes by discussing these difficulties and what can be done to overcome them, facilitating a planning and decision process where final decisions are not made until costs and benefits have been properly investigated.

2 Literature

A large international literature has documented that costs of infrastructure projects tend to be underestimated on average, and that differences between estimated and final costs (positive or negative) is often very large (Catalão et al., 2019, 2021; Cavalieri et al., 2019b, 2019a; Chong & Hopkins, 2016; Flyvbjerg et al., 2002; Gao & Touran, 2020; Love et al., 2022; Lundberg et al., 2011; Merrow et al., 1988; Odeck, 2004, 2019; Odeck & Welde, 2021). The magnitudes of average cost overruns vary considerably between studies, however. For example, Odeck (2004) find a modest 8 percent average cost overrun for Norwegian road projects (comparing final cost estimates before contracting to final costs), while Chong and Hopkins (2016) report average cost overruns of 135 percent for road projects funded by US development aid (comparing cost estimates at funding authorization to final costs). A useful summary and comparison of studies is given in Odeck and Welde (2021).

The literature on cost overruns is dominated by a series of papers by Bent Flyvbjerg and coauthors, stressing that the problem is common and arguing that it cannot be solved by merely improving methods for cost calculation or project management. Instead, Flyvbjerg argues that psychological biases (e.g. optimism bias) and political biases (or “strategic misrepresentation”) are the main causes of cost overruns (Flyvbjerg, 2014, 2021; Flyvbjerg et al., 2002, 2018). It is sometimes claimed (by Flyvbjerg and others) that the fact that costs tend to be higher and benefits lower than anticipated, on average, proves the existence of optimism bias and stakeholder misrepresentation. The claim is that cost overruns cannot be caused simply by "honest errors" in the ex-ante cost estimates. In the words of Flyvbjerg (2009, p. 350): "*If misleading forecasts were truly caused by technical inadequacies, simple mistakes, and inherent problems with predicting the future, we would expect a less biased distribution of errors in forecasts around zero.*"

This is not true, however, because of a statistical phenomenon called "winner's curse" or selection bias. As shown in Eliasson & Fosgerau (2013), if projects are selected based on uncertain ex-ante estimates of their true costs, the true costs of the selected projects will turn out be higher than the ex-ante estimates, on average, *even if* the ex-ante estimates of all project candidates are unbiased. A bias in a *selected* sample can hence arise *purely* due to the selection process. In other words, observing a bias in a selected set of projects does not prove that there was a bias in the original choice set from which the selected projects we chosen. And much less, of course, does observing such a bias prove the influence of psychological or political biases. It is uncontroversial, on the other hand, that psychological, cognitive and political biases exist; what is not clear is how large their contribution to cost overruns is, through what mechanisms they contribute, and most importantly how their effects can be mitigated. These issues are discussed in more detail in section 4 of the present paper.

Flyvbjerg is also famous for formulating his "iron law of megaprojects": "over budget, over time, over and over again" (Flyvbjerg, 2014, p. 6). However, whether this is true depends on whether final costs are compared to early-stage or late-stage cost estimates. Welde and Odeck (2017) and Lind and Brunes (2015) find that most of cost escalations occur before start of construction, i.e. during the planning and design stages, a finding which is repeated in the present paper[1]. A similar conclusion was reached by the UK National Audit Office (2007). Similarly, Chapman (2024b) show that late-stage cost estimates of Swedish infrastructure projects do not deviate systematically from final costs, and Chapman (2024a) shows the same for major English road projects. Hence, when assessing the magnitudes of cost overruns, it matters greatly whether final costs are compared to early-stage or late-stage estimates (Odeck & Welde, 2021). For example, the study of Chong and Hopkins (2016) find a mean cost overrun of +135% when comparing cost estimates at funding authorization to final costs, but they also note that most of this cost escalation (100 percentage points) occur between funding authorization and the final "engineer's estimate", implying a more moderate cost increase of 18% between the "engineer's estimate" and final costs. Another difference is between final cost estimates, contract costs and final costs. Chong and Hopkins (2016) and Makovšek (2014) find that contract costs are lower, on average, than final cost estimates, so the difference between contract costs and final costs is larger than than between final cost estimates and final costs. Nilsson et al. (2019) compare contract costs to final costs for Swedish infrastructure projects, finding a larger cost increase for road projects (+20%) than for railway projects (+32%). Part of the debate surrounding magnitude and causes of cost overruns seems to be caused by some papers using data which are not publicly available;

[1] Interestingly, Cavalieri et al. (2019a) find an opposite pattern in a study of Italian infrastructure projects, where large cost overruns occur in the project execution stage, while the contracting authorities on the other hand tend to overestimate the financial needs' of projects. One possible explanation is that the contracting authorities are risk averse with respect to cost overruns, and thus add (too) big contingencies to cost estimates, which leaves room for opportunistic behaviours in the execution phase.

the works by Flyvbjerg are notorious in this respect. McLeod (2023, p. 10) argues that the lack of data transparency is an obstacle for research in the area to proceed forward: "the limited availability of reference class data (and the ongoing absence of any established open data practices in megaproject studies) inhibits the kinds of reproducible and iterative examination of the evidence which might disprove or substantiate the many diverse and uncertain benefits that might arise from public infrastructure megaprojects".

Projects change intentionally during the planning and design phase, a point stressed by e.g. Love and Ahiaga-Dagbui (2018), and hence it is not unexpected that final costs deviate from early cost estimates. The relevant cost estimate to which the final cost should be compared is the one used at the time of decision, a point stressed by e.g. Flyvbjerg et al. (2018) and Odeck and Welde (2021; 2017). However, it is often difficult to determine when a decision to execute a project is effectively irrevocable. Moreover, a large number of decisions regarding scope, design and implementation are made during the entire planning and execution lifecycle. That projects change during the planning and design phase is not a bad thing per se; the real problem is if early decisions cannot be reconsidered even if one would like to, or are not reconsidered even if they should. Cantarelli et al. (2010) call this "lock-in" or "escalation of commitment", and argue that this mechanism contributes to cost overruns (although their evidence for this is limited to two Dutch case studies). This is also one of the main conclusions of the present paper. Identifying precisely when a decision to carry out an infrastructure project is actually made is often difficult in practice. There is usually a formal decision point at the end of a long planning stage, but it is common that several kinds of momentums build up during the planning stage, for example through links to other planning process or through political promises, making the formal decision point effectively moot. This means that decisions may become effectively irrevocable before the formal decision has actually been made. That it is so difficult to identify when the "point of no return" has passed is one reason that studies of cost overruns can come to very different results regarding magnitudes and frequencies of cost ocerruns. For example, the Swedish Audit Office argued in a series of reports (Riksrevisionen, 2010, 2011) that final costs of infrastructure projects should be compared to the cost estimate made when a project was first included in the national investment plan. The Transport Administration, on the other hand, argued that final costs should be compared to the cost estimate made at the final decision-to-build. Using the Audit Office's comparison makes cost overruns become substantially larger and more common than if the Transport Administration's comparison is used. It is not obvious which is the most correct. On the one hand, it is rare that projects are cancelled once they are included in the national investment plan; on the other hand, the final decision to build an infrastructure project is in fact made when the government makes its final go-ahead decision. The risk of "lock-in" in planning processes is discussed further in sections 4.1 and 5.

Flyvbjerg's quip "over time, over budget, over and over again" risks drawing attention from a crucial observation: cost escalations and cost overruns[2] vary considerably across projects. In

[2] In line with several previous authors (e.g. Odeck and Welde, 2017), this paper generally uses the term "cost escalation" when cost estimates increase during the planning and design phase, and the term "cost overrun" when final costs are higher than the cost estimate decided at the decision-to-build. To avoid

other words, it is *not* the case that cost escalations and overruns are more or less similar for all projects, even projects of the same kind. If this had been the case, the solution would be simple: add an uplift to cost estimates based on comparisons between past projects' ex-ante estimates and final costs. This is the basic idea of so-called "reference class forecasts", a remedy suggested by Flyvbjerg and used by e.g. the UK Department for Transport (2021, 2024). The problem is that while this can eliminate the average difference between ex-ante estimates and final costs, it does not solve the problem of distorted selection – that other projects or designs might have been selected if true costs had been known. This distinction between "doing projects right" (e.g. keeping budgets and time plans) and "doing the right projects" is emphasized by e.g. Cooke-Davis (2004) and Williams and Samset (2010). Williams et al. (2019) stress that the "front-end" of projects (including project selection, scoping and design) is crucial for the success of projects, and provide a literature review of research on the front-end phase of projects (see also Samset and Volden (2016), Aubry et al. (2025) and Berg et al. (2025)). The reference class forecast approach has also been criticized for not attacking the root causes of biases in cost estimation (Love et al., 2024).

Despite the large literature on cost overruns and their determinants, there is still no consensus about what the most important causes and the most effective remedies are. Ahiaga-Dagbui et al. (2017) argue that this is because large parts of the literature suffer from various methodological weaknesses. Chapman and Quang (2021) distinguish two schools of thought regarding the causes and remedies of cost overruns, one school focusing on the complexity of large projects as a root cause and hence emphasizing e.g. better project management as a remedy, and one school focusing on cognitive and political biases as a root cause, emphasizing that such biases should be mitigated by using uplifts on cost estimates. Chapman and Quang stress that these explanations and remedies are not mutually exclusive, but the two streams of literature have largely evolved separately. Chapman and Quang conclude that the two schools of thought need to be reconciled. In a sense, the present paper is an attempt at such a reconciliation; the conclusion here is that cost overruns is caused by the combination of (often unavoidable) project complexity *and* political, psychological and institutional biases causing resistance against reconsidering or cancelling projects which turn out to be more expensive than anticipated.

At least from an engineering perspective, causes of cost overruns in the execution phase can be grouped (somewhat loosely) into three categories: scope increase (the project did more things or with higher standards than planned), increased unit costs (some or all parts of the projects became more expensive than foreseen), and unrealistic or low-quality pre-execution cost estimates (for example neglecting necessary parts of the project, or not having realistic risk margins even for foreseeable risks). Obviously, the borders between these can be fuzzy, but they can still be useful for categorizing factors causing cost overruns. Various studies have reached different conclusions regarding which factors are the biggest culprits. Lind and Brunes (2015) report a survey among experienced project managers, finding that the respondents thought that the most important causes were changes in project scope and design, and unexpected technical problems (65% of project managers thought that these factors "definitely" or "probably" often

overly long sentences, however, "cost overruns" is sometimes used as a general term, in line with large parts of the literature.

caused cost overruns). Less important causes were optimism bias in early stages (44% thought that this often caused cost overruns), lack of competence among technical or budgetary staff (33%), changes in input prices (21%) and intentionally setting budgets too low (16%). The authors noted that most cost overruns occured in the initiation and planning stages up to the final design. The Transport Administration (Trafikverket, 2018) followed up 21 projects completed 2015-2017 (which are also part of the data set in this paper), with an average cost increase of 17% from first inclusion in the national plan to completion. The most common documented causes for cost changes were ”Uncertain cost estimate in first plan", "Major changes in content or design", "Changes in input prices" and "Changes in laws and regulations", but it was not possible to quantify their relative constributions. Welde and Endre (2021) compare contract costs to final costs, finding that increases in scope was the most important cause of cost overruns.

There are comparatively few studies that have demonstrated empirically effective remedies against cost overruns. Two exceptions are Odeck (2014), who shows that cost overruns and project delays were reduced following the reorganization of the Norwegian Road Administration to introduce more competitive procurement and execution of projects, and Odeck et al. (2015), who show that the introduction of external quality assurance of initial cost estimates of Norwegian infrastructure projects radically reduced cost overruns. Welde and Klakegg (2022) show similar experiences, based on continuing Norwegian experiences. Another example is Park (2021), who shows that the UK's introduction of reference class forecasting reduced cost overruns.

3 Evolution of project costs from first decision to finished project

3.1 The Swedish infrastructure planning process

National transport infrastructure in Sweden is planned in a twelve-year multimodal investment plan, which is revised every four-year election cycle. Sweden has had multimodal infrastructure investment plans since 2010, when the Transport Administration was formed by merging the Road Administration and the Rail Administration[3]. When it is time to revise the investment plan, the government issues a directive to the Transport Administration, specifying the government's priorities. Based on the directive, the Transport Administration draws up a proposal for an investment plan for the next twelve-year period, comprising updated benefits and costs of investments already in the plan, which new investments to include, and (occasionally) which investments to exclude from the previous plan. There is no guarantee that investments in the current plan are included in the next plan proposal; investments where costs have turned out to be higher (or benefits lower) can be excluded in the new proposal. This rarely happens,

[3] Before the Transport Administration was formed, the Road Administration and Rail Administration followed planning processes broadly similar to the current one. The focus in the present paper is on the larger infrastructure investments specified in the national plan, but the plan also specifies budgets for road and railway maintenance, funds for smaller non-specified investments and various other items.

however; usually, less than a handful of investments, and often none, are excluded from the current plan in the new plan proposal. On the other hand, it is common that projects' scope, content and design change between plans. Based on the proposal, the government decides a new plan, usually making some changes compared to the Transport Administration's proposal.

Investments in the plan are categorized in three planning stages. A separate decision by the government is necessary to move an investment from one planning stage to the next, meaning that investments must pass three decision tollgates before construction starts[4]. First, an investment is included in the national plan, where it is placed in the "early planning" stage, corresponding to year 7-12 of the twelve-year plan. Once its scope, design, benefits and cost have been further investigated, it is moved to the "late planning" stage, corresponding to year 4-6 of the plan, where investments are prepared for start of construction. After further investigation of costs and benefits, and often adjustments of its scope and design, investments are moved to the "ready for construction" group, corresponding to year 1-3 of the plan. The national plan also lists projects currently under construction.

Section 3.2 analyses how project costs have evolved for all projects in the investment plans starting in 2010, 2014, 2018 and 2022. Section 3.3 compares final costs to late-stage cost estimates for all projects finished between 2004-2022.

Costs from different years have been adjusted with the Transport Administration' road/railway construction cost index[5], which measures how construction costs evolve over time. This index has increased faster than inflation for several decades, so the following cost comparisons understate the cost increases in real terms. Table 1 shows how the index has changed since 2010. Cost estimates generally refer to median (P50) costs, but cost estimates in the early planning stage (see Figure 1) usually do not quantify uncertainties, so confidence levels are not formally defined.

Table 1. Change in construction cost index between plans.

	Index increase	General inflation	Index increase excl. inflation
Plan 2010 → Plan 2014	14%	5%	9%
Plan 2014 → Plan 2018	6%	3%	3%
Plan 2018 → Plan 2022	15%	7%	8%

3.2 Changes in estimated project costs in the investment plans 2010-2022

This section follows how cost estimates have evolved for all investment projects in the twelve-year investment plans starting in 2010, 2014, 2018 and 2022. Since planning and construction of

[4] This process is not always followed to the letter, however. For example, an investment may sometimes enter the plan directly in a later planning stage (year 4-6 or even year 1-3). Occasionally, an investment is postponed and moved back to an earlier planning stage.

[5] There are several kinds of such indices. The one used here is a weighted average between the road and railway investment indices.

infrastructure projects usually takes more than four years, most projects occur in two or more subsequent plans. This makes it possible to follow a large number of cost estimates for all projects from when they were first included in the national plan up to the present date (including projects which are still not finished, or started before 2010). The analyses presented here are built on all investments which are present in at least two subsequent plans. In total, the data set comprises 216 investments, with 302 corresponding cost changes between plans. Figure 1 summarizes the data material, presenting cost changes between plans, both in terms of number of projects and their total cost (billion SEK, in bracketed italics; 10 SEK ≈ 1 €). Most projects move one stage at a time between subsequent revisions of the national plan, but projects may also move several stages between one national plan and the next, since the government may decide to let projects continue from one stage to the next in the time period between revisions of the national plan. This is why projects can move from, for example, "early planning" in one plan directly to "ready to start", "under construction" or even "finished" in the next plan.

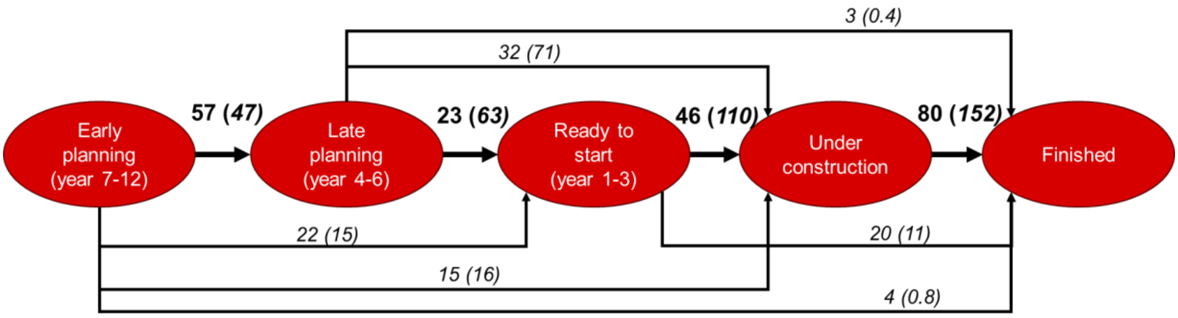


Figure 1. Overview of the data set: status changes of projects between subsequent national investment plans. Number of projects first and total cost in billion SEK (in brackets).

	All modes	Road	Railway	Multimodal or other modes
Number of projects	216	98	102	16
Average cost	168	78	261	12
Lowest cost	4	9	4	18
Highest cost	4244	1855	4244	449

Table 2. Project characteristics. Costs refer to earliest cost estimates, in million euros.

Figure 2 shows how cost estimates change, on average, depending on how projects change status from one plan to the next. For example, projects which go from the "early planning" stage in one plan to the "late planning" stage in the next increase their cost by 28% on average. As Figure 1 shows, some projects may move several stages between one plan and the next, which is why there are arrows from, for example, "early planning" directly to "ready to start" and even "finished". Clearly, estimated costs increase much more during the planning stages than during the construction stage.

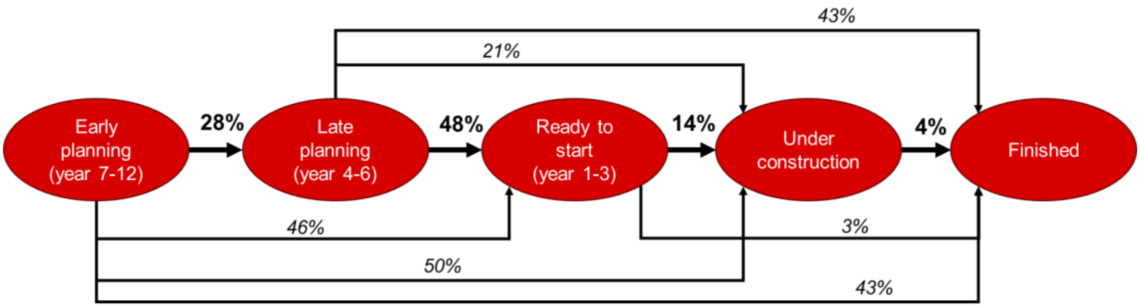


Figure 2. Changes in estimated costs between subsequent investment plans, grouped by type of project status change. (Average percent changes are unweighted, i.e. large and small projects have the same weight. Weighted average changes are presented in the Appendix.)

Figure 2 contains so much information that it is not easy to interpret, since some projects bypass some stages, for example going from "early planning" in one plan to "ready for construction" in the next plan. Figure 3 summarizes the information by calculating average changes between each stage, weighting the cost changes in Figure 2 with the number of projects in Figure 1.

Figure 3. Average changes in estimated costs between subsequent investment plans, depending on change in project status.

Figure 4 presents the same information as in Figure 2-3 but visualized in a diagram. The thin lines show average cost changes for each type of project status change (also shown in Figure 2). The bold line shows the average evolution of project costs (also shown in Figure 3).

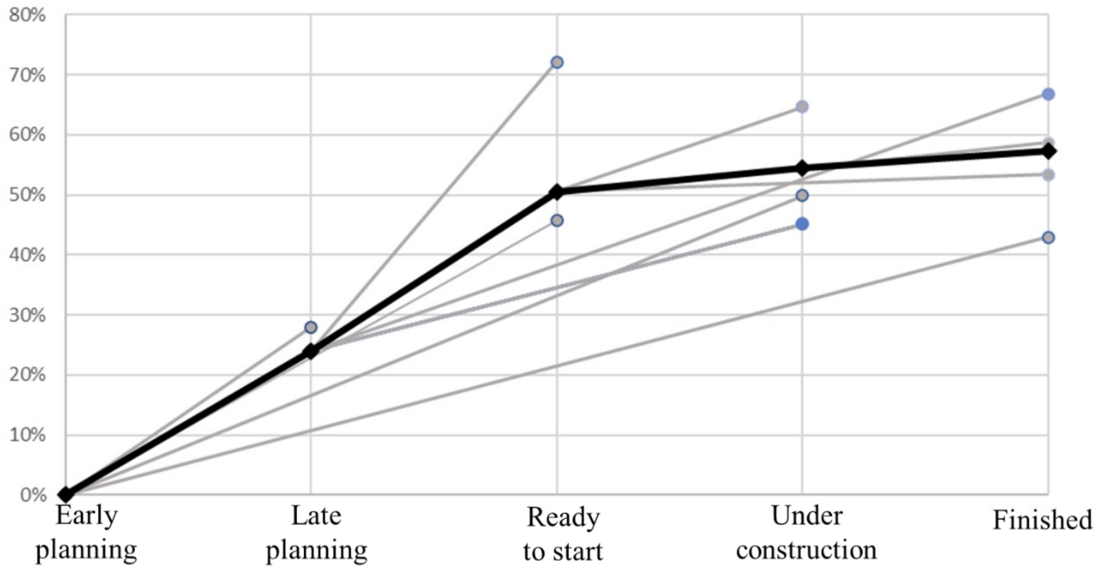


Figure 4. Graphic representation of cost changes from early planning to finished project. Thin lines show average cost changes for each kind of project status change; the bold line is the weighted average.

Evidently, average costs increase primarily during the planning stages, up until projects are ready to start. From the go-ahead decision, costs still increase somewhat on average, but only with a relatively modest 7 percent from go-ahead decision to final cost.

Figures 2-4 show cost changes for all projects appearing in the national plans from 2010 to 2022. If we only consider the projects have both been initiated (first included in the plan) and completed between 2010 and 2022, the sample is reduced to 41 projects. As expected, the average cost escalation for this sample is smaller: the cost escalation from first cost estimate to final cost is 28%, or 15% if weighted by project cost. This is natural, since these are projects which could go from initiation to completion in at most 12 years, meaning that that these are relatively successful and less complicated projects; projects with long planning or execution times are excluded. The causality between planning and execution times and cost escalation works in both directions: complex projects tend to have long planning and execution times and higher risk for cost escalations, *and* projects which turn out to be more expensive than anticipated tend to be postponed for reconsideration, rescoping or redesign. This can also be seen in Figure 4: projects which proceed fast, moving several stages between subsequent national plans, tend to have lower cost escalations than average.

However, the changes in Figure 2-4 are *average* changes – but not all projects experience cost overruns of the same magnitude; in fact, there is a considerable variation across projects. A relatively small share of projects experience large cost increases between plans, while the majority of projects only suffer modest cost changes or none at all. In other words, the increase in average costs during the planning stages are mostly driven by a minority of projects with very large cost increases.

Figure 5 shows the distribution of cost changes from when projects are first included in the plan to the “ready to start” stage, for road and rail projects respectively. The top figure shows the raw data in a cumulative distribution, while (for ease of interpretation) the bottom figure shows the corresponding density function (smoothed using a kernel estimator). Figure 6 shows the distribution of cost changes from “ready to start” to final cost.

As seen in Figure 5, the distribution of cost changes from first plan to the ready-to-start stage is wide and highly skewed, with a long tail to the right. Cost estimates increase for around 70 percent of projects, but most projects have relatively modest (in this context) increases in cost; half of the projects have cost increases of 20 percent or less, and three quarters of projects increase less than 50 percent. Considering that the average cost increase is almost 60 percent, this illustrates how skewed the distribution is.

Figure 5. Distribution of cost changes from first inclusion in national plan to the "ready to start" stage. Top diagram is cumulative distribution (raw data), bottom figure is density function (smoothed with a kernel estimator).

It is interesting to note that the modes of the distribution (the most likely values, i.e. the peaks of the distributions) are close to zero. This suggests that early cost estimates reflect the *most likely* cost, rather than the average or median cost of a project. For symmetric distributions, i.e. when cost overruns are as large as cost underruns, the mode, median and average coincide – but this is not the case for skewed distributions.

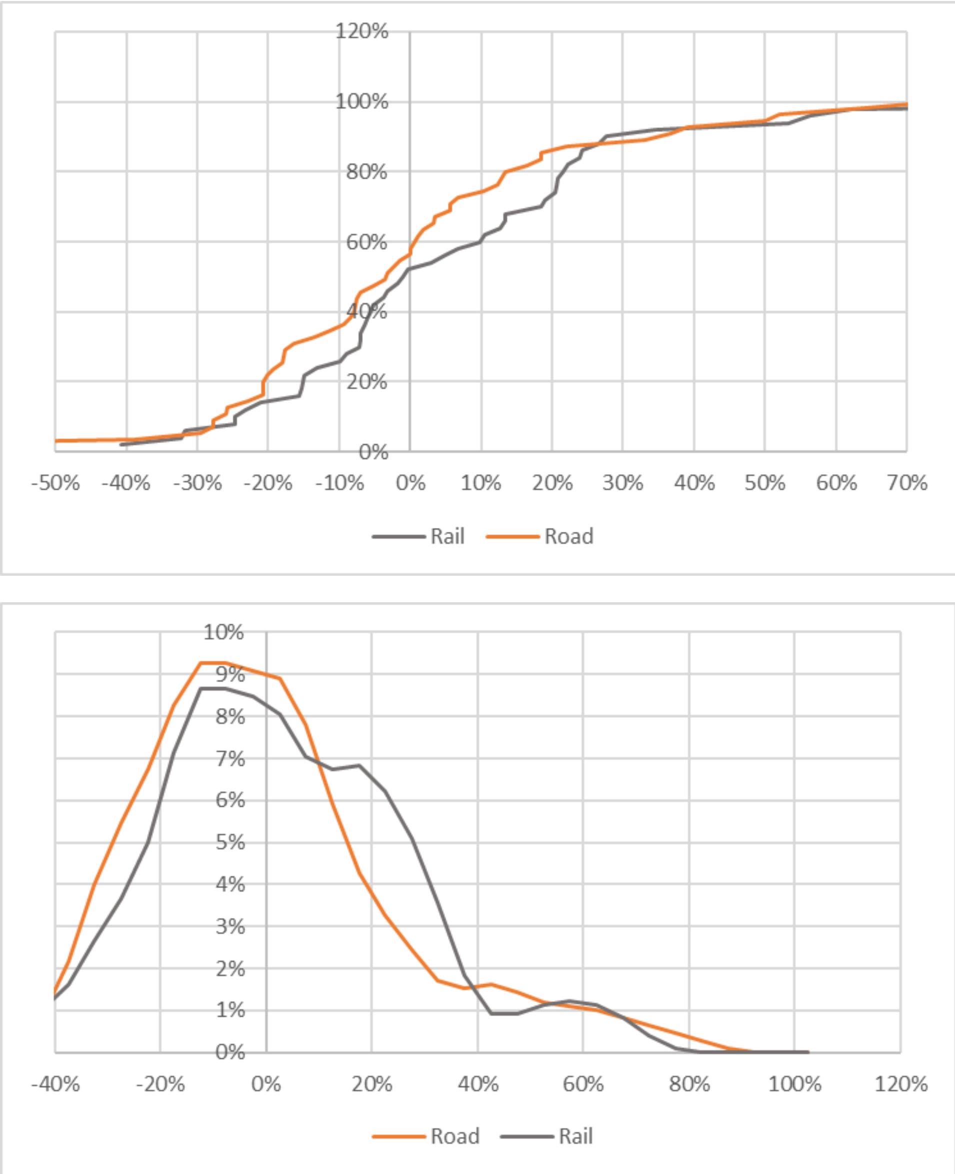


Figure 6. Distribution of cost changes from "ready to start" to final cost. Top diagram is cumulative distribution (raw data), bottom figure is density function (smoothed with a kernel estimator).

Figure 6 shows that the distribution of cost changes from ready-to-start to final cost is much narrower, and centred almost at zero.

Table 3. Descriptive statistics of the cost changes presented in Figure 5 and Figure 6.

	From first plan to "ready to start"			From "ready to start" to completion		
	All	Road	Railway	All	Road	Railway
Number of projects	134	75	56	101	51	49
Average cost change	42%	46%	40%	4%	1%	7%
Median cost change	18%	22%	18%	-1%	-2%	-1%
Std.dev. of cost change	82%	87%	78%	27%	24%	30%
Mode (of kernel distr.)	11%	11%	12%	9%	9%	9%
Cost change >0	69%	67%	73%	48%	45%	49%
Cost change <0	31%	32%	27%	54%	57%	53%
Cost change > 25%	43%	45%	43%	13%	13%	14%
Cost change < -25%	4%	1%	9%	9%	11%	6%

3.3 Late-stage cost estimates compared to final costs, 2004-2022

The analyses in section 3.2 used all projects first included in the national plans 2010 or later. Another (partly overlapping) data material comprises the costs of all 276 projects finished 2004-2022.[6] For these projects, we have final costs and two late-stage cost estimates: the estimate from the last national plan before the ready-to-start decision, and the cost estimate presented at the government's ready-to-start decision. These two cost estimates are the ones used by the government for its final project decisions; the first is used when the national plan is approved, and the second when the final go-ahead decision is made.

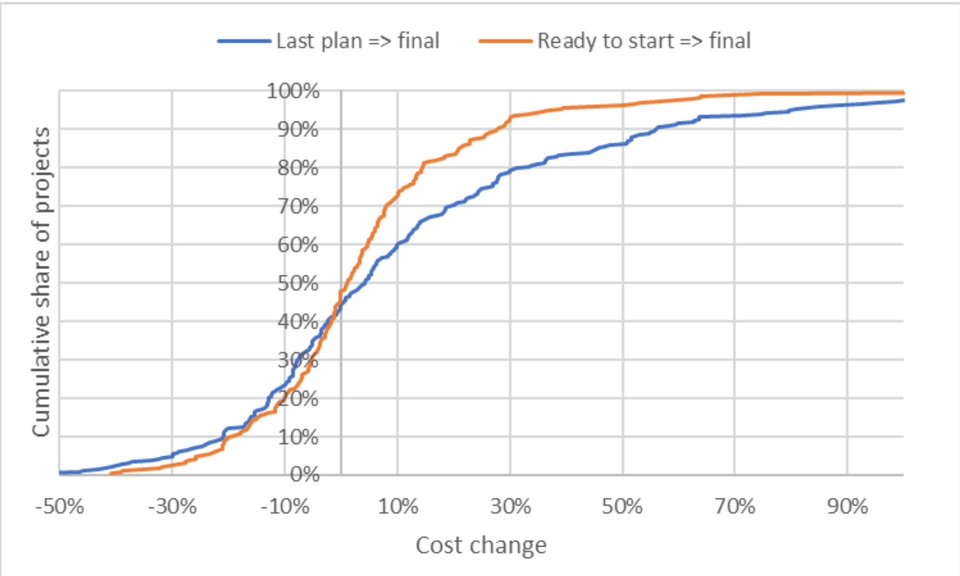
Table 4 compares these two cost estimates to final project costs. On average, final costs exceed the late-stage cost estimates, but relatively little; the average cost overrun with respect to the go-ahead decision is 4 percent, and the median is 1 percent. Cost overruns are larger when compared to the earlier cost estimate presented in the last national plan before the go-ahead decision. The conclusion coincides with the findings in the preceding section: the precision of cost estimates improves during the planning process, and the cost estimates used for the final go-ahead decision are fairly to final costs, on average.

[6] I am grateful to Ulf Magnusson from the Transport Administration for collecting this dataset from the yearly reports of the Transport Administration and the preceding Road Administration and Rail Administration.

Table 4. Descriptive statistics of the cost changes from late planning stages to completion. See also Figure 7.

	From last national plan to completion			From "ready to start" decision to completion		
	All	Road	Railway	All	Road	Railway
Number of projects	263	165	97	234	151	83
Mean cost change	12%	10%	15%	4%	4%	5%
Median cost change	4%	4%	4%	1%	1%	0%
Stddev. cost change	35%	30%	43%	22%	20%	25%
Cost change >0	56%	56%	54%	52%	54%	49%
Cost change <0	43%	42%	46%	49%	43%	48%
Cost change > 25%	25%	22%	32%	29%	13%	12%
Cost change < -25%	5%	7%	9%	5%	5%	5%

However, as Table 4 shows, the standard deviation of the cost difference is considerable. Figure 7 shows the distribution of cost changes. Just as in the previous analyses, the distributions are skewed, with most projects having final costs close to estimates, but a minority of projects have substantial cost increases.



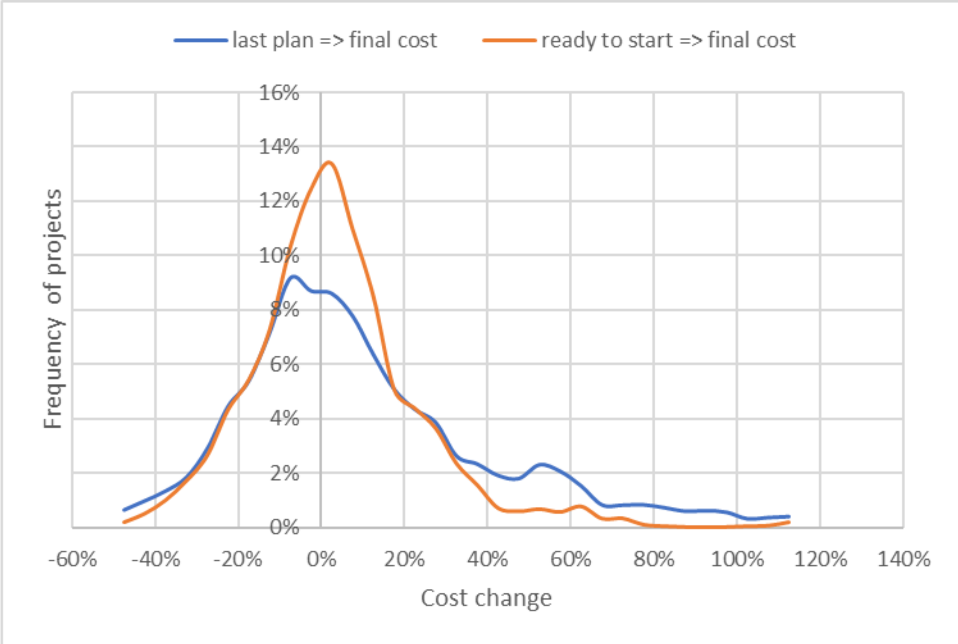


Figure 7. Relative difference between final cost and late-stage cost estimates, all projects finished 2004-2022. Top diagram is cumulative distribution (raw data), bottom figure is density function (smoothed with a kernel estimator).

4 Causes of cost overruns

With the quantitative analyses presented above as background, this section summarizes and discusses sources and causes of cost overruns. In addition to the observations in the preceding section, the discussion here builds on and consolidates findings from several sources, including interviews with planners and project managers, case studies carried out at the Transport Administration, and several previous Swedish reports (Eliasson, 2023; Riksrevisionen, 2021, 2023; Trafikverket, 2018, 2021a, 2021b, 2024).

4.1 The fundamental problem is "lock-in" of premature decisions

A key takeaway from the analyses in section 3 is that early cost estimates are not only downward biased, but that they are very uncertain. This is effectively unavoidable; when projects are first included in the national investment plan, projects' scope and design are still not determined, and data crucial for cost calculations (such as soil conditions) are not yet available (Trafikverket, 2018, 2021b). This means that costs and benefits are *inherently* uncertain at the early planning stage. One of the purposes of the planning process is to gather data about costs and benefits of different options, and find the most efficient and feasible project design. This inherent uncertainty is why the Swedish infrastructure planning process is designed to have multiple decision tollgates. At each tollgate, better estimates of costs and benefits are available, and a decision to either cancel or proceed with the project can be made. Formally, the final go-ahead decision is not made until the project design is determined in detail, and costs and benefits are reasonably well known. Indeed, as the analyses in the preceding section show, cost estimates at the final decision tollgate are fairly close to final costs, on average.

The problem is that in practice, the planning process does not work as intended. Projects are rarely cancelled once they have entered the national investment plan, even if costs turn out to be higher than anticipated, or benefits lower (Riksrevisionen, 2010, 2011, 2021). This means that projects are in effect selected based on the early, uncertain estimates of costs and benefits.

The fundamental problem with early decisions being locked in is that it distorts project selection and design, (as discussed in e.g. Cantarelli et al. (2010)). Had true costs and benefits been known, other projects and designs might have been selected, and more net benefits might then have been realized for the same budget. The root problem of cost overruns is hence not really that early cost estimates are uncertain, which is unavoidable. The root problem is not even that early cost estimates are downward biased on average, which can be solved by general uplifts or contingencies. The root problem is that making (effectively) irrevocable decisions distorts the selection and design process, meaning that society gets less benefits for a given budget than had been possible.

Deciding to carry out an infrastructure investment based on early-stage information is akin to the proverbial buying of a pig in a poke: there is no way to know for certain what's in the bag. The only solution to this conundrum is to avoid making irrevocable decisions based on incomplete information. When buying pigs in pokes, make sure that you can get a refund if the bag turns out to contain something else than a pig.

It is worth stressing that this pig-in-a-poke problem is not solved by using general uplifts of early cost estimates, for example by using so-called reference class forecasts as suggested by Flyvbjerg and coauthors in several papers (2021; 2018). Reference-class forecasts (and similar uplifts) can improve budget planning by making cost estimates right on average; but they do not solve the problem of distorted project selection, since they do not change the ranking of project candidates (of the same type or "reference class") (Eliasson & Fosgerau, 2013).

It is also worth stressing that the *inherent* uncertainties in the early stages cannot be solved by improving methods for calculating costs (even if that is important too, as discussed further below). No cost calculation method, regardless of how advanced it is, how much past experience it builds on, and what risk analyses are brought in, can accurately calculate the cost of a project that is still only vaguely defined, and where crucial data is still not collected (Lind & Brunes, 2014, 2015).

The only way to solve this is to gather more information about projects before final decisions are made. This means that more projects need to be investigated than will eventually be carried out; the best ones are selected, and the rest are cancelled. This is in fact how the Swedish infrastructure planning process is supposed to work, with its multiple decision tollgates (Riksrevisionen, 2023). However, projects included in the national plan are rarely cancelled, because ccancelling projects is easier said than done. The political, institutional and psychological resistance to cancelling a project, or reducing it in scope, increases the longer the planning process has been going on. This is for several reasons, for example that "national investment programs are seen as promises by other parts of society, irrespective of whether project costs increase during the process toward procurement and implementation" (Nilsson, 2022, p. 224). This will be discussed in the final section, where ways to reduce this resistance are also suggested.

4.2 Other mechanisms contributing to cost overruns

As noted in section 2, selection under uncertainty is enough to create cost overruns purely due to selection bias or "winner's curse" (Eliasson & Fosgerau, 2013). But several other factors may also contribute to cost overruns, some of which are discussed below. Several of them are linked to the same root cause – that project selection is rarely reconsidered, so once project planning starts in earnest, the likelihood that the project is cancelled is small. This means that the focus of the planning process often shifts from finding the most cost-effective project to "getting the project done" (Jäderholm, 2020; Nilsson, 2022).

Scope creep and lack of thrift

As noted above, projects' scope and design change during the planning stage. This is not a bad thing per se; indeed, the planning stage is intended to find the most cost-efficient project scope and design (Williams & Samset, 2010). But the results in section 3, that cost increases during the planning stage are so much more common than cost decreases, suggest structural problems. Apparently, there are incentives and structures which makes it comparatively uncommon for projects to be downsized in scope and cost during the planning process.

Scope creep refers to this tendency of projects to increase in size once they are decided, for example by adding more content or increasing design standards. Lind and Brunes (2015) found that project managers cited this as the most common reason for why final costs exceeded earlier cost estimates. Naturally, there may be additions to a project which are well motivated and worth the additional cost. But every addition to a project's scope or standard needs to be judged on its marginal benefit and its marginal cost compared to the *alternative* use of funds. Interviews with planners and project managers suggest that the problem with scope creep is that the here-and-now benefits of project additions are often more salient, and have stronger stakeholder backing, than the abstract opportunity cost of forgoing some unspecified project somewhere else (Eliasson, 2023; Riksrevisionen, 2021). This makes it psychologically and politically difficult to say no to suggested additions to a project.

The fact that projects are rarely cancelled, especially in later stages, means that incentives for cost efficiency decrease as soon as a project enters the plan, and decreases more and more the further in the planning process a project gets. For project managers, the most important priority is often to get the project done (Jäderholm, 2020). As long as the cost is below the cost estimate, there is little incentive for project managers to be thrifty, i.e. to look for cheaper, slimmed-down designs with a higher benefit-to-cost ratio, especially if this risks delaying the project. Prioritizing getting the project done also means that it is often considered more acceptable to accept a higher cost than to cancel the project (Eliasson, 2023; Riksrevisionen, 2021). Taken together, these planning incentives create an upwards pressure on project costs, contributing to the asymmetric distribution of cost outcomes.

Stakeholder blackmailing

The resistance to canceling projects gives an outsized bargaining power to stakeholders whose cooperation is necessary to execute the projects, such as landowners and municipalities (in Sweden, municipalities have extensive power over local spatial planning). The fact that cancelling projects is so rare and politically costly means that such stakeholders can extract outsized compensating benefits, for example through additions to the projects' scope or design. Interviews with planners and project managers suggest that this also tends to contribute to an upward pressure on projects' costs.

Strategic misrepresentation by project beneficiaries

The tendency to decide to carry out projects based on highly uncertain estimates of costs and benefits, together with the difficulty to cancel them in later stages, increases the possibilities and incentives for stakeholders benefitting from a project to underestimate its costs and exaggerate its benefits. In earlier papers by Flyvbjerg et al. (2009; 2002, 2004), it is argued that such intentional "strategic misrepresentation" is the most important reason for cost overruns. Proving that misrepresentation is intentional is of course difficult, although there is quite a lot of evidence that it does indeed occur. In the context of the present paper, however, where the Transport Administration is responsible for planning and executing all projects, it is difficult to see what the incentives would be for the Administration to systematically misrepresent costs. It can, of course, be suspected that different parts of a large administration might use this in internal struggles for budget allocation. It is uncontroversial that *external* stakeholders promoting their favourite projects have incentives to exaggerate benefits and underestimate costs, especially in early stages. But the Transport Administration has no particular incentive to do so; its budget is not determined by cost estimates for individual projects, but by total national infrastructure grants. On the other hand, it is not uncommon that the government directly instructs the Transport Administration that certain projects must be included in the national plan, even before detailed assessments of costs and benefits have been made. This increases the potential for strategic misrepresentation by project beneficiaries.

Optimism bias

Optimism bias is the well-documented psychological tendency to overestimate the probability of success, and the difficulty of imagining all possible reasons why things might go worse than anticipated. Optimism bias can be reinforced by confirmation bias, i.e. our tendency to more easily observe and believe facts which support beliefs we already have, and the tendency to take an "inside view" which puts too much weight on subjective experience rather than taking broader perspectives and experiences into account (an "outside view").These biases occur in all contexts, but when it comes to planning, they are presumably further strengthened by a selection effect that makes particularly optimistic people more likely to become project managers, idea generators and lobbyists. In several papers by Flyvbjerg and coauthors (e.g. Flyvbjerg, 2021; Flyvbjerg et al., 2018), it is argued that optimism bias is the main cause of cost overruns. This is of course possible, but there is little conclusive evidence for this interpretation. Contrary to some arguments by Flyvbjerg, the prevalence of cost overruns does not prove that *ex-ante* cost estimates are downward biased on average. As noted before and shown by Eliasson and Fosgerau (2013), selecting projects based on uncertain cost estimates is enough on its own to generate cost overruns among the *selected* projects, even if ex-ante estimates are unbiased for *all* project candidates. We simply do not know whether optimism bias is an important contributor to the observed prevalence of cost overruns.

But whether this is the case is in fact not so important, since the solution is the same: projects must be reconsidered and, if necessary, cancelled if they turn out to be more expensive than initial estimates. Whether the initial cost underestimation is due to optimism bias, strategic misrepresentation or simply a statistical feature of the selection process is less important to know, and perhaps not even possible to know – the solution is the same regardless.

Low-quality cost calculations

Lind and Brunes (2015) interviewed experienced project managers, and concluded that a common reason for cost overruns is that the quality of initial cost estimates is too low. As explained above, this is partly because project descriptions are vague and data is not available – in such situations, better cost calculation methods will not help much. The findings in the preceding section suggest that early cost estimates tend to be close to "typical costs" – the most common values – rather than average costs.

Still, lack of data and vague project descriptions are not the only problems. It is also true that cost calculation methods need to be improved, and past experiences used more systematically. One of the recommendations from Berg et al. (2025), interviewing cost engineers about how cost estimates can be improved, is that cost calculation methods need to be continuously evaluated and improved by validating them against observations in a structured way. This needs to be done at different levels of aggregation; both at a detailed level (e.g. costs for specific project elements or construction steps) and at an aggregate level (e.g. costs for a kilometre of railway or road). Such follow-ups and validations are carried out to some extent; Chapman (2024a) concludes that learning from past experiences seem to have improved cost estimates in the UK. On the other hand, Nilsson (2022) concludes that there is very little systematic learning from experiences in Sweden, largely because comparable data is too seldom gathered and organized systematically (see also Nilsson, 2013). Comparable and structured data about costs at micro and macro levels is also a prerequisite for benchmarking costs across countries and contractors.

One of the conclusions from Trafikverket (2018) is that it is difficult to track why projects' estimated costs change from first estimates to final costs. During the planning stage, projects can change significantly in terms of scope, content and design. However, the planning documentation usually only (at best) notes what is added to or removed from the project, but rarely if ever assesses the cost consequences of these changes. Projects' final reports may state that final costs have increased or decreased for various reasons (e.g. unforeseen circumstance or content changes), but rarely, if ever, assess quantitatively how much more expensive (or cheaper) this made the project.

Structured and easily available documentation, possible to compare and aggregate, is necessary to enable systematic follow-ups of cost estimates, systematic improvement of cost calculations, and assessments of the risk for cost increases. This applies both to detailed cost estimates (costs of specific elements or steps) and aggregate estimates (benchmarking entire projects).

However, deficient cost calculation methods can in itself hardly explain why costs increase on average, since late-stage cost estimates are, on average, fairly close to final costs. Had cost calculation methods underestimated costs systematically, we would have seen systematic deviations between final costs and late-stage cost estimates as well. Still, it is clear that cost calculation methods can be improved, as evident from the large standard deviation of late-stage cost estimates compared to final costs. One way to do this, particularly useful in early planning stages, is the "outside view" approach, which can be summarized as asking "how much does this kind of projects usually cost?", drawing from previous project experience. If there is sufficient experience from more or less similar projects, then this has the clear advantage of also taking into account (to some extent) all the unexpected and perhaps unforeseeable things that may happen during a project. The "outside view" is in contrast to the "inside view", where cost estimates are produced by people familiar with the current project, building the cost estimate from the ground up, as it were, rather than taking a more abstract or comprehensive view looking at past comparable projects. Unfortunately, such data about "comparable projects" are still rare, and seldom systematically gathered; there is clearly a lot of potential in this regard.

5 Remedies: What can be done?

We can hence conclude that the fundamental problem with cost overruns is that effectively irrevocable decisions are made too early, before projects' true costs and benefits are known. Selection under uncertainty is enough in itself to generate cost overruns on average, even if ex-ante cost estimates are unbiased. The first and most obvious problem is that allocated infrastructure budgets will not be enough, causing various problems such as delayed project deliveries. But even worse is that this lock-in of early decisions distorts the planning and selection process: had true costs and benefits been known, other projects or project designs might have been chosen, possibly generating more benefits for the same budget. Moreover, as discussed above, it creates, enables or aggravates several other mechanisms causing cost overruns and reduced cost-efficiency.

To solve this, more projects need to be explored than will eventually be carried out. Projects which turn out to have higher costs or lower benefits than anticipated are then cancelled, until only the best projects remain. In effect, projects need to compete for a place in a limited budget where only the ones with the highest benefit-to-cost ratio are prioritized. This simultaneously attacks several different causes of cost overruns: decisions are not made until true costs and benefits are known; it increases the incentive to search for cost-effective projects and designs; it reduces the opportunity and incentive for strategic misrepresentations, as well as the effects of cognitive biases in early stages. Such a process may not be a sufficient solution for cost overruns on its own – but it is clearly a necessary part of a solution.

Cancelling projects is easier said than done, however. The political, institutional and psychological resistance to cancelling a project, or reducing it in scope, increases the longer the planning process has been going on. There are several reasons for this. First, status quo bias and loss aversion are well-documented psychological biases – we overvalue what we already have, compared to something we could get instead (Brown et al. (2024) provide an overview and metaanalysis). This bias is even more present in politics: cancelling a "promised" project tends to irk voters relatively more than spending the freed-up money on some other project – especially since it is often not apparent what this "other" project really will be (Nilsson, 2022). Second, infrastructure planning processes are often linked to other planning processes, such as housing or industries. If it turns out that an infrastructure project is more expensive than anticipated, it might be too late to stop or change other projects that depend on it, for example new housing or industry plants. Third, infrastructure planning processes are long and expensive. Exploring a large number of projects, or project variants, does not come cheap and takes a long time. This limits how many project ideas that can be explored.

Stating that underperforming projects should be cancelled is easy and perhaps uncontroversial. Making it happen is the hard part, since there are so many obstacles preventing it. Hence, the planning and decision process needs to be deliberately designed and structured to facilitate, and ideally force, the cancellation of underperforming projects, and provide incentives for cost control and cost efficiency. Below are seven suggestions for how this can be achieved[7].

1. ***Communication.*** A necessary prerequisite is to clearly communicate that early decisions are in fact not final. It must be made clear, to everyone and repeatedly, that including a project in the national plan is not a promise to build it; it is only a first step to explore the idea. Otherwise, other planning processes (e.g. housing, industry) tend to take infrastructure projects for granted, and make further decisions conditional on them. This creates a lock-in of premature infrastructure decisions, even if this was not the intention.
2. ***Avoid defining projects as "necessary".*** Terminology and logic implying that a project is *necessary* is pervasive, signified by statements like "investment X *is needed*" or "Y is a *problem that must be solved"*. Such terminologies and planning logics need to be avoided. Definitions of what constitutes a "problem" or "deficit" in a transport system is to a large extent arbitrary, especially when discussing aspects such as accessibility, travel times and capacity (Volden et al., 2024); but defining something as a "problem" creates a political and institutional pressure to "solve" it, regardless of the costs (Eliasson, 2015, 2023). There is unfortunately a lot of truth in the old joke: "Something must be done; this is something; ergo, this must be done".
3. ***Competition between projects.*** There needs to be competition between projects all the way to the final decision. This means that more projects need to be explored and planned than can eventually be afforded. The process should stress, publicly, that only the most cost-effective projects will be prioritized, while explored projects with too low cost efficiency will be cancelled. This is necessary to give stakeholders, project beneficiaries and project managers an incentive to look for the most cost-effective

[7] I am grateful for extensive discussions with and suggestions from many civil servants at the Transport Administration in the compilation of this list.

projects and designs possible. If all projects that are explored can eventually be afforded, there is no reason for stakeholders to search for cost-efficient designs; it makes more sense for them to argue for increasing the scope, standard and benefits of a project, regardless of the increased costs.

4. ***Transparent decision criteria.*** Transparent decision criteria facilitate reconsidering earlier decisions, since it clarifies at what point a project has become too expensive to be worth its cost. Moreover, project managers need to know what to strive for, especially in the planning and design phase, and without clear criteria for how projects will eventually be evaluated they are left to their gut feeling. For most infrastructure projects, the benefit-cost ratio (adjusted for possible additional, non-quantified effects) is a very useful ranking criterion.
5. ***Kill projects properly.*** Putting underperforming project ideas on an indefinite waiting list is a common way to avoid making the uncomfortable decision to terminate a project. This increases planning costs, since costs and benefits need to be regularly recalculated, and also increases the risk that inefficient projects are eventually carried out. If it is clear that a project idea has a low benefit-to-cost ratio compared to other candidates and to the available budget (at least for the foreseeable future), state this, and proceed to explore other ideas instead.
6. ***Explicit and salient opportunity costs.*** To stop unwarranted scope creep, suggested increases in project scope or design standards must be weighed against the opportunity cost. If a project in the investment plan is allowed to increase in cost, something else must be pushed out. This should be another specific project, because this increases the saliency of opportunity costs. If the suggested increase in project cost is worth pushing something else out of the plan, then so be it; but this must be a conscious, deliberated choice, where the increased cost is weighed against the opportunity cost.
7. ***Have an explicit "just-outside-the-plan" list.*** Having an explicit "just outside the plan" list, with candidates competing to get into the plan, also makes opportunity benefits salient. If projects in the plan are cancelled or have their costs reduced, this makes room for other, explicitly specified projects. This makes opportunity benefits salient, and creates incentives for planners and politicians to accept cost-efficient designs and to cancel underperforming projects, since there is a clear benefit of doing so.

6 Conclusions

Cost overruns of transport infrastructure projects is an endemic problem. The results in this paper shows that costs mainly increase during the planning stage, on average, while cost estimates at the ready-for-construction decision are, on average, close to final costs (although there is still a considerable variance). To some extent, it is natural and intentional that projects' content and design change during the planning process; but the fact that costs are much more likely to increase than to decrease suggests that there is a systematic problem.

It seems that the "conventional wisdom", at least in some circles, is that all projects become more expensive than estimated. The results in this paper contradict this, if the execution stage is considered: the average and median of the difference between final costs and cost estimates at decision-to-build are both small. On the other hand, the average cost escalation during the planning stage is substantial. Which perspective is the most relevant depends on whether the decision-to-build at the end of the planning stage is a real decision point, when underperforming projects run a real risk of being cancelled. If it is, then it is the difference between final cost and decision-to-build estimate that is relevant. On the other hand, if the decision-to-build is really just a formality, and the real decision has in effect been made much earlier, then the relevant comparison is between the final cost and some earlier cost estimate. Pointing out when decisions effectively become irrevocable is often difficult, and in the literature it is not always clear from which stage cost estimates are taken. This makes it difficult to compare the results in this paper to results in the literature in general; but it seems safe to say that these results suggest that cost control during the execution stage is not as bad as its reputation (this coincides with the conclusions in e.g. Odeck (2004), UK National Audit Office (2007), Lind and Brunes (2015), Welde and Odeck (2017) and Chapman (2024a)).

Cost escalations do not occur uniformly; it is not the case that all similar projects' costs increase at approximately the same rate. Had this been the case, the solution had been simple: multiply early cost estimates by an uplift factor based on past experience. While this practice can eliminate overplanning future infrastructure budgets (which is also worthwhile), it does not solve the more serious problem that the wrong projects, or the wrong project designs, may have been chosen. Had decisions been based on better estimates of true costs and benefits, other projects or project designs might have been chosen, and more social benefits might have been obtained for a given budget.

The root problem is that decisions about project selection and design are made too early in the process, before costs and benefits have been thoroughly assessed. The Swedish infrastructure planning process is designed to contain multiple decision tollgates, where planning of projects is supposed to either continue or be cancelled depending on what the planning process so far has revealed about projects' costs and benefits. But in practice, projects are rarely cancelled once they have entered the twelve-year national plan, even if the planning process reveals that some projects' costs are in fact much higher than first anticipated.

While it is certainly important to improve cost calculation methods, e.g. using benchmarks and past experiences, this alone cannot solve the inherent and asymmetric uncertainty of early-stage cost estimates. This uncertainty is unavoidable for two reasons: project design is not yet determined, and necessary data for cost calculations (e.g. soil conditions) are not yet available.

The premature lock-in of decisions also causes other problems, some of which also contribute to cost overruns: higher risk for scope creep, reduced incentives to search for more cost-efficient designs, larger incentives for project beneficiaries to underestimate costs and overestimate benefits, and increased bargaining power for involved stakeholders to extract various benefits in return for cooperation.

The only solution to these problems is to postpone real, final decisions until costs and benefits have been properly assessed. Until that point, decisions must be preliminary, and the possibility to cancel the project must still be a realistic option. That it is in fact possible to estimate costs and benefits with reasonable certainty is shown by the fact that late-stage cost estimates do not deviate systematically from final costs.

However, cancelling projects is difficult for political, psychological and institutional reasons. It is politically costly to cancel something that is viewed as a "promise". Cognitive biases such as status quo bias, loss aversion and the sunk-cost fallacy means that it is psychologically difficult to cancel a project which has been planned for a long time, and a lot of money has been spent on planning costs. Infrastructure projects are often linked to other projects, such as new housing or production plants. Hence, the planning process needs to be designed in a way that facilitates or, ideally, forces reconsideration of projects where costs increase or benefits decrease compared to the early planning stage.

This paper suggests seven ways to do this. In brief: communicate that early planning stages are only exploratory, and final decisions are made later; avoid terminology or planning logics that imply that projects are "necessary"; let projects compete for a space in a limited budget as long as possible; use transparent decision criteria that measure and stress cost-efficiency; cancel projects explicitly; make opportunity costs and benefits salient by using a ranked project list with an explicit cut-off budget line and candidates competing for a place in the investment plan.

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8 Appendix

Table 5. Average change in cost estimates by change in plan status; unweighted without brackets, weighted by project cost within brackets.

	Late planning	Ready for construction	Under construction	Finished
Early planning	28% (19%)	46% (24%)	50% (75%)	43% (47%)
Late planning		48% (34%)	21% (12%)	43% (47%)
Ready for construction			14% (33%)	3% (0%)
Under construction				4% (-1%)