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Cost and schedule performance in large government projects

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Abstract. This paper uses data from 111 large government projects in Norway. We compare their final cost to the formal budget set by the parliament in their formal funding decision. We use standard statistical measures to illustrate their cost performance and whether the projects have been completed within the agreed schedule. We also examine the proportion of projects that have been fully successful from an operational perspective, that is, how many have been completed without either cost overruns or delays. The results are encouraging and better than most reported in the international research literature. On average, Norwegian government projects are completed 5% below budget. Three of four projects experience cost underrun. Schedule performance is weaker as the average completion is ten months after planned completion. Only about a third of the projects can be considered fully successful according to the performance targets for both time and cost. Despite these somewhat positive results, we warn against the implications of large projects currently under construction and which are experiencing challenges concerning costs and schedule.

1. Introduction

Public investment projects are crucial to societal development, encompassing a broad range of initiatives from important infrastructure like roads, power plants, and public transport to more sophisticated endeavours such as digitalisation efforts and defence procurements. The successful delivery of these projects, irrespective of their nature and perceived advantages, necessitates governmental commitment to efficiency, ensuring that the outcomes align with the best interests of society.

While "The Iron Triangle" of time, cost, and quality has traditionally defined project success, there's an emerging agreement on the need for a broader evaluation approach ([1] [2] [3]). This extended perspective not only assesses immediate project outcomes but also considers the wider impacts, such as environmental, social, and socio-economic effects ([4] [5]), advocating for a more nuanced understanding of project success. This shift in perspective is crucial for policymakers and researchers alike, as it provides a more comprehensive view of project performance and can guide future decision-making.

This study examines the empirical cost and schedule performance of completed government projects in Norway, recognising that while efficiency is not the sole measure of success, it is crucial

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for effective governance. Timely and budget-compliant project completion is vital for delivering intended benefits. Moreover, adhering to budgets ensures the judicious use of public funds, allowing for the reallocation of savings to other projects or societal needs, thus maximising public resource utilisation.

The research presented in this paper originates from the Concept Research Programme, tasked by the Norwegian Ministry of Finance to research large government investment projects from different sectors. The projects have in common that they have been subjected to the prerequisites set out by the so-called state project model. The model is a standardised arrangement of projects into stages with requirements for documentation produced by the ministries and agencies responsible for the appraisal and planning of the projects. It was initiated in 2000 and covers projects above a threshold of NOK 1 billion (app. EUR 90 million); it involves two external reviews that cover the early choice of concept and the cost estimate before the parliament can make a final investment decision [6]. This rigorous process is designed to align projects with strategic goals and ensure realistic planning and budgeting to improve their chances of successful completion within established budgets and time frames. A standardised governance regime across sectors that sets out requirements necessary for projects to be funded by taxpayers' money has the advantage of ensuring that projects are subjected to political control in the early stages of project development. This may reduce the risk of locking planners and decision-makers into an inefficient course of action that may be difficult to stop once a project has gained momentum [7]. A final advantage is that projects are comparable across sectors and time. Paired with a research programme that collects data and follows projects over a long time, this allows for a more robust assessment of project performance than studies that use data from disparate sources worldwide [8].

Despite the heterogeneity of project success, cost performance remains at the heart of the Norwegian state project model. While success may be multi-dimensional, a project can't be fully successful unless completed within budget. This paper aims to assess the effectiveness of project delivery measured by two metrics: cost and time. Although this issue has been the subject of many other studies, it is imperative that researchers collect data and monitor results so that the organisations responsible for the planning and delivery of the projects can implement measures to combat poor performance, should that be necessary. Our analysis is confined to assessing project efficiency within our dataset and discussing possible future outcomes. It's important to note that this study does not delve into the specific causes of significant cost overruns or underruns, as such an examination would exceed the scope of our quantitative methodology.

2. Theoretical background

Professor Bent Flyvbjerg from the University of Oxford has articulated an "iron law" of project management: "Over budget, over time, under benefits, over and over again". Based on a sample of 16,000 projects from 136 countries, Flyvbjerg and Gardner [9] found that 47.6% were completed within budget, and a mere 8.5% avoided both cost overruns and delays.

Although it is unclear whether Norwegian projects were included in this sample, the findings resonate with a broader pattern observed in various international studies across different countries and sectors, indicating a widespread challenge in achieving project efficiency. Numerous studies from different sectors such as ICT[10], mega-sporting events ([11][12]), defence acquisition [13] and transport [14] have documented that cost overruns are more common than underruns.

In Norway, studies of cost performance have found more positive results than those reported from other countries. Odeck ([15][16]) studied cost performance in road projects varying in size from very small (< EUR 2 million) to larger (> EUR 10 million). In the two samples (n = 620 and n = 1,045), he found average overruns of 8 and 10%, respectively. In a study of large road projects (n = 40), Odeck et al. [17] found that the mean overrun was 0% and that projects subject to the state project model (n = 22) had a mean underrun of 11%. Welde and Klakegg [8] looked at the cost performance in 96 projects from five different sectors, all part of the state project model, and found a mean underrun of 4%, while only 25% of projects experienced a cost overrun.

One potential reason Norwegian results are seemingly better than those reported in the international literature may be because Norwegian projects are typically approved at a relatively mature stage, with a well-defined project basis. By this stage, while not all project delivery details may be finalised, key aspects such as the location, concept, and scope are usually established, providing a framework for setting robust budgets. The maturity of budgets at the final investment decision stage may vary between countries. Still, Welde and Klakegg [8] argued that Norwegian cost estimates that are prepared for the final investment decision are similar in maturity to those used in final business cases in the U.K. [18] and to Class 3 estimates in the AACE Cost Estimate Classification System [19].

Throughout their development, which can span several years, Norwegian projects undergo extensive planning and quality assurance reviews, during which both costs and scope are refined. Studies have indicated that project costs generally increase up to the final investment decision, with significant escalations often occurring from the initial stages ([20][21]). However, these early-stage increases should not, in our opinion, be regarded as cost overruns since no official budget has been set. Reasons for escalations can include new legal requirements, changes in conceptual solutions, and shifts in political goals, among others. Not all projects with early cost increases proceed to implementation, suggesting a filtering process through planning and quality assurance.

The extent of delays has been far less studied. In Norway, Welde and Bukkestein [22] are the only study that has looked at delays in projects that have been through external quality assurance. In a sample of 113 projects, they found that large government projects are delayed by, on average, 11 months.

A recurring observation in international research is the persistent challenge of managing cost overruns, with no single explanation for this trend. The literature proposes multiple theoretical reasons:

- **Lack of learning transfer**: Highlighted by Cooper et al. [23], there's a notable difficulty in extracting and disseminating management lessons across projects and managing portfolios effectively.
- **Increased project size and complexity**: Söderlund et al. [24] note that new projects' escalating size and complexity contribute to this issue.
- **Inadequate planning and scheduling**: Thamhain [25] identified that poor planning and scheduling practices lead to cost overruns.
- **Scope and design changes**: Durdyev and Hosseini [26] and Durdyev [27] note that project scope and design changes are significant factors.
- **Project delivery and contract strategies**: Creedy et al. [28] suggest that the choice of project delivery method and contract strategy can impact cost control.
- **Inaccurate cost estimations due to unconscious or deliberate bias:** Flyvbjerg et al. [29] highlight the issue of cost estimates not aligning with actual expenses.

Additionally, external factors such as price inflation and market conditions, often not fully considered in project risk analyses, also contribute to cost overruns.

The enduring stability of the Norwegian state project model is a key advantage, providing a solid foundation for project evaluation, trend identification, and knowledge development. This creates a basis for various studies but also emphasises the need for updates to ensure the scheme remains relevant and informative at both portfolio and project levels. Although the issues of cost overrun and project control are well-studied topics in the literature, new quantitative data offers timely insights, serving as a contemporary record of current and historical practices. In other words, regularly conducted studies fulfil a dual purpose as they both provide an understanding of practice until the time of the study while also contributing to a long-term historical record. The publication of these findings is invaluable to researchers and practitioners, establishing a standard for evaluation and **comparison**. While this paper focuses on Norwegian projects, the generated knowledge also supports wider comparisons, aiding in identifying best practices and highlighting areas needing attention.

3. Data and methodology

This study measures how large government investment projects have complied with targets for cost and schedule. The study is based on projects subject to the state project model, which ensures consistency and comparability concerning cost estimates, risk analysis, and project maturity. The study uses data from 111 projects, with the distribution of project types shown in Figure 1.

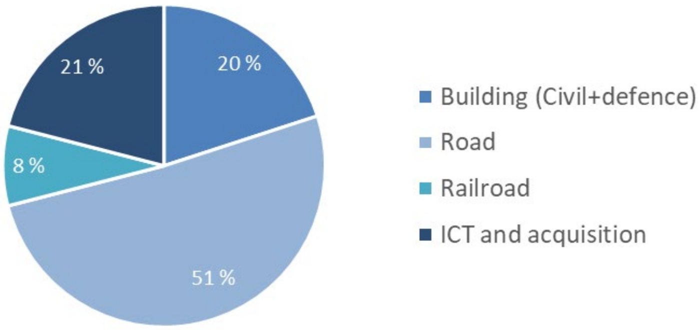

Figure 1: The distribution of project types in our sample

The predominance of road projects in the sample is attributed to the relatively easier access to their cost data, especially from the Norwegian Public Roads Administration, and their significant share of large government projects. There is a prevalence of relatively older projects, which may mean that the results do not necessarily provide as precise a picture of projects being implemented today. The projects have a total final cost of NOK 263 billion (EUR 24 billion), measured in 2023 prices. The size of the projects (measured in final cost in 2023 prices) varies from NOK 260 million to NOK 10,700 million (EUR 25–975 million). The data were collected by the Concept Research Programme, which the Ministry of Finance tasks with researching large government projects. The organisations responsible for the projects must submit accurate cost information to the programme following Ministry of Finance directives. All the projects in the sample have been subject to the so-called state project model, which requires that cost estimates be subjected to rigorous scrutiny by external consultants before the parliament can approve a formal budget. This ensures consistency in planning, methodology, and project maturity before the parliament can formally approve a budget.

The literature was selected based on our knowledge and engagement with the field, supplemented by targeted searches to provide context for our study. These searches were primarily conducted on Google Scholar using search strings such as 'project cost performance,' 'project (time OR schedule) performance,' and additional queries on explanations for cost and time overruns.

3.1 Analysis

Large government projects employ a stochastic method for cost estimation, acknowledging input parameters' uncertainty and modelling the impact of varying external conditions on costs. This approach yields an outcome space representing a range of potential costs and their associated probabilities ([8] [30]). Cost estimates are centred around the median estimate (P50) and the total budget. The P50 acts as a target for the responsible agency, while the added contingency makes up the difference up to the total budget. The total budget is normally set at the P85 level and determined by the parliament. Ideally, this setup aims for most projects (about 85%) to conclude within the total budget.

To measure overruns/underruns, we use the measures most used in the literature on cost overruns, namely the percentage cost overrun (PCO) and the mean percentage cost overrun (MPCO)[31]:

$$PCO_i = \left(\frac{Y_i - F_i}{F_i}\right) \times 100$$

Project $i's$ cost performance is thus a function of its final cost, Y_i, and its estimated/budgeted cost, F_i.

The MPCO is defined as:

$$MPCO = \frac{1}{n}\sum_{i=1}^{n} PCO_i$$

It is simply the average of overruns across projects, regardless of project size, i.e., the arithmetic mean.

As a quantifiable metric, time is another benchmark for assessing project performance. Yet, pinpointing the precise conclusion of a project often presents a challenge, as project deadlines are frequently defined by broader timeframes, such as "by the end of year x" or "during the first half of year x," rather than specific dates. In this context, our approach to determining time delays hinges on whether a project extends beyond the stipulated time interval. If a project is delayed by a more definite deadline, any delay is measured from that specified date. This methodology acknowledges the variability in project timelines and aims to establish a clear criterion for identifying delays, facilitating a more structured evaluation of project timeliness and overall efficiency. Furthermore, the table below depicts our definition of completed projects according to type.

Table 1: Our definition of completed projects according to type. Based on Welde and Bukkestein [22].

Type of project	Viewed as completed
Road	Traffic opening
Railroad	Trains in regular service
Buildings	Official move-in
Defence acquisition	The acquisition has been transferred to the user
ICT	The results of the project have been put to use

Ideally, schedule performance should also be measured as a percentage, as we do for costs. However, this would require us to know the exact planned duration of the implementation phase, which is unknown. That leaves us with deviation from completion time as the metric for assessing schedule performance.

3.2 Research limitations and delimitations

This paper entails some important delimitations. First, it is geographically restricted to Norway and specifically to projects that have undergone the state project model. The projects in our sample were approved by the parliament from 2001 to 2017 and completed from 2004 to 2021. Consequently, all projects exceeded a threshold value (currently NOK 1 billion). Second, the study sample is limited to sectors included in the state model, such as public buildings, public infrastructure, ICT, and defence acquisitions; notably, oil and gas and offshore projects are excluded from the state model. Methodologically, this paper focuses on the dimensions of cost and time. The methodological approach is further discussed in Section 3.1.

While seemingly straightforward, registering the final costs and completion times for projects entails a range of challenges that can complicate the process. First, determining when a project is officially "finished" is often unclear. Infrastructure like roads or buildings may take years from completion to finalising the project accounts. During this interim, costs may accumulate, making any stated cost at a given time merely a temporary figure in an evolving financial landscape. Second, there is a lack of access to and transparency in cost data worldwide, not just in Norway. This issue hampers the ability to conduct thorough and accurate analyses of project costs. Third, comparing initial budget limits and final costs necessitates indexing amounts to a common reference year. However, various agencies employ disparate price adjustment methods, complicating direct comparisons. The methodologies used for price conversion are often not transparent and can be perplexing for those not intimately familiar with the specific practices of each agency. Researchers typically must rely on summaries from project accounts and seek clarification from the involved agencies to interpret final costs accurately. Fourth, after the parliamentary investment decision, some projects encounter unforeseen cost increases, necessitating adjustments to the total budget. These projects may still be considered "within budget" despite significant overruns relative to the original budget sanctioned by parliament. In such cases, the approach used in this study is to compare to the original, and not the adjusted, budget. Last, the time of completion details vary, and few projects include a specific date. Instead, goals are often open to interpretation due to formulations such as "by the end of year x" or "during the first quarter of year x". This may contribute to a source of error.

The challenges presented above result in a paradox, namely that comparing final costs to budgets and completion date to schedule requires research. Therefore, the complexities in studying cost and schedule performance should not be underestimated. Caution should thus be taken when interpreting and comparing the results between countries, as practices concerning the point of reference, indexing, and project account issues may vary ([8] [32] [33]).

4. Results

In this section, we report on project efficiency within our sample, starting with an analysis of cost performance. Following this, we will examine the time aspect, assessing how projects fare in terms of meeting their schedule target. The following discussion will combine these two dimensions and discuss the outlook for ongoing and future projects.

4.1 Costs

Table 4 shows the budget and deviation from the P50 estimate for our sample. As expected, the deviation from the total budget (P85) is negative, with an average cost underrun of -5 % compared to the parliament-approved budget. Still, the proportion of projects exceeding the budget is higher than desired. Ideally, if estimates and budgets had been perfectly calibrated to the performance of the projects, no more than c. 15% should exceed the budget and 50% the P50 estimate. The modal value is -2%, suggesting that a typical project in the sample is completed slightly under budget. Notably, there is a significant range in performance, with 10% of projects underrunning by more than 26% and 10% overrunning the budget by more than 16%. The ten projects with the highest overruns have an average overrun of 32%. Excluding these ten projects, the average budget underrun for the sample would improve to -8 %.

Table 2: Deviation from budget and the P50 estimate

	N	Average (between projects)	Weight. avg.	Median dev.	Mode	Std. dev.	Min.	P10	P25	P75	P90	Max.	Prop. above
Total budget	111	-5%	-5%	-6%	-2%	18%	-48%	-26%	-14%	2%	16 %	84%	27%
P50 estimate	106	5%	6%	1%	0%	20%	-39%	-18%	-5%	14 %	29 %	116%	58%

The research literature is divided on whether large projects are more prone to overruns than small ones. While larger projects, in most cases, come with increased complexity and implementation challenges, they contain several elements that can provide greater flexibility in implementation. Figure 2 illustrates the relationship between project size (measured in million NOK in 2023 prices) and deviation from the P50 estimate. The positive relationship indicates a greater risk of overruns in larger projects. The average deviation in projects below and above an estimated cost of NOK 2,500 million is small, though (4 and 6%, respectively). The difference is not statistically significant ($t(101) = -0{,}34$, $p = .488$), so we cannot conclude that larger projects have a higher risk of overruns than smaller ones.

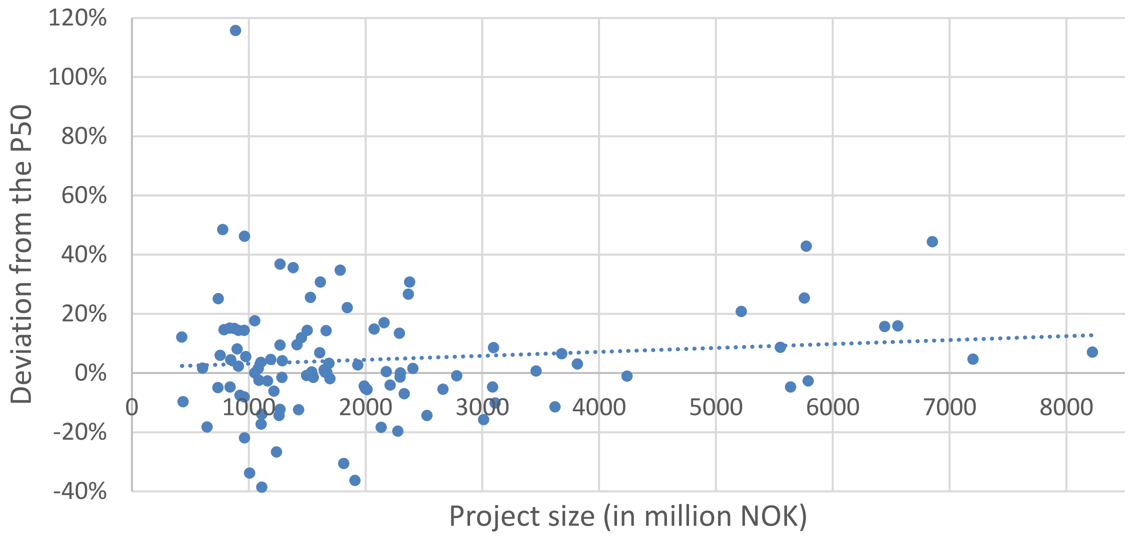

Figure 2: Relationship between deviations from budget and the approved budget

4.2 Time

Table 5 shows the extent to which the projects have been completed within schedule. On average, projects are delayed ten months compared to the target for completion.

Table 3: Extent of delays (number of months)

N	Average delay	Median	Mode	St.dev.	Min.	P10	P25	P75	P90	Max	Prop. delayed
111	10	2	0	21	-35	0	0	12	38	105	53%

The distribution of project delays is skewed, evidenced by the average delay being notably higher than the median delay of just two months. This skewness arises from a substantial number of projects experiencing significant delays. Despite this, only a slight majority of projects, 53%, encounter delays. The distribution mode is zero, indicating that the most common outcome for a project is to experience no delay at all. Thus, while delays are not uncommon, the most frequent scenario for a project is to be completed on time.

The high standard deviation of nearly two years highlights the uncertainty in expected project execution at the decision-making stage, with 10% of projects experiencing delays exceeding three years. If we exclude these extreme cases, the average delay is reduced to four months and the median delay to zero. Despite this variability, a substantial portion of projects adhere to their scheduled completion times, with the distribution mode being no delay, representing 38% of all projects. This suggests a dichotomy where, while many projects are finished on schedule, a notable number diverge significantly from their intended timelines.

Interestingly, half of the projects face no or only minor delays, which typically suggests a normal distribution with an average delay close to zero. However, extreme delays in the upper quartile skew the average. Analysing delays by project type reveals that ICT/ERP and defence materiel procurement projects incur more delays than building and infrastructure projects. A contributing factor could be the larger sample size of building and construction projects, totalling 86, which may dilute the impact of extreme delays. ICT/ERP and material procurement projects show significant variability in delays, with standard deviations of 33 and 34 months, respectively (though these categories are based on smaller samples). Figure 3 illustrates this trend, indicating that building and construction projects are more likely to be completed on schedule or with minor delays, with 93% finishing within six months of their deadlines.

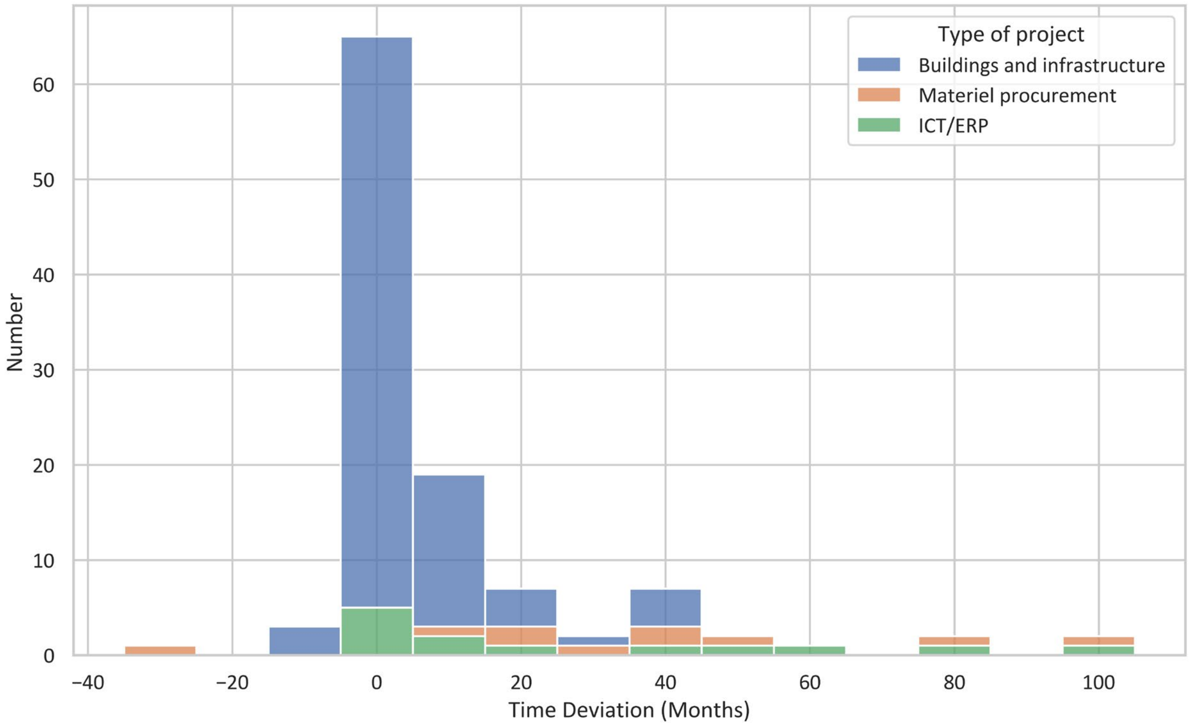

Figure 3: Distribution of time variances categorised by type of project

5. Discussion and conclusions

The results in the preceding findings chapter show that cost performance in large government projects in Norway is relatively good. Cost underruns are more common than overruns, which stands in contrast to most of the results reported in the international research literature [9-14]. The achievement of the performance target for time is somewhat weaker, and even if a typically large government project is carried out according to the schedule, many projects are significantly delayed. Figure 4 shows the share of projects without cost overruns and delays.

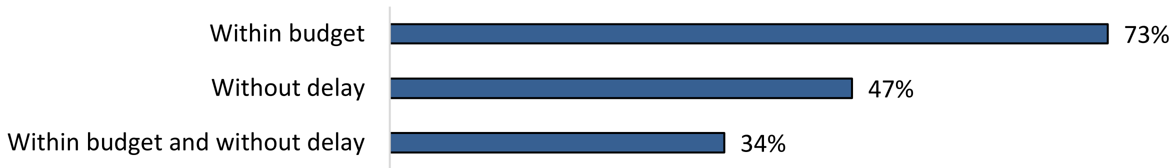

Figure 4: Share of projects without delays or cost overruns

Figure 4 illustrates that projects have generally been more effective in managing costs than adhering to schedules, with only about a third (34%) avoiding both cost overruns and delays. This performance is, however, better than the outcomes referenced by Flyvbjerg and Gardner [9], and it may appear that their "iron law" does not apply to Norway. This demonstrates that good cost estimation and risk analysis practices, as well as external quality assurance, might be a powerful remedy for cost overruns. Countries struggling with poor project performance should thus look to examples of good practice rather than viewing failure as inevitable.

Figure 5, which plots time deviations (in months) against cost deviations (as percentages), segmented by sector and project size, reveals no apparent correlation between time and cost deviations. This is particularly noticeable in clusters of projects with similar time deviations but wide variations in cost deviations, suggesting that project size, in terms of final cost, does not strongly influence the likelihood of adhering to budgetary or scheduling targets. This indicates that larger projects do not inherently face greater difficulty maintaining schedules or budgets.

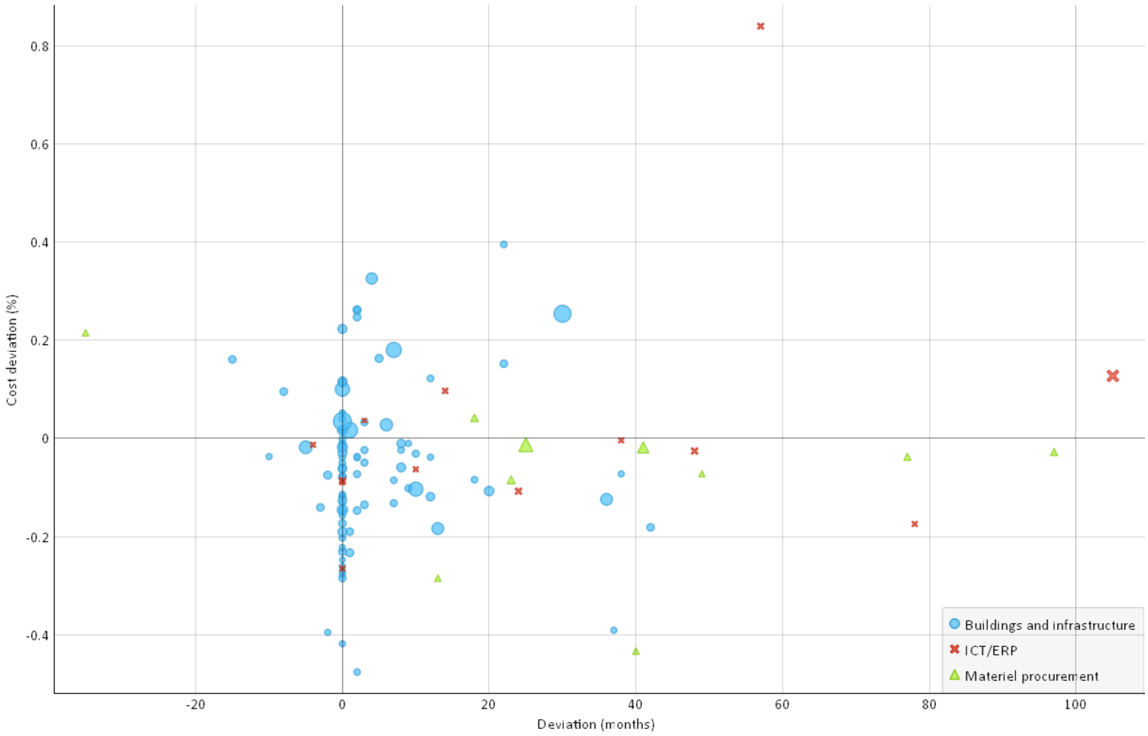

Figure 5: The relationship between time deviations (months) and cost deviations (%) for the sample

Overall, our findings indicate a generally satisfactory performance among projects. The literature is divided on whether large projects are more prone to overruns than small ones, with, for example, Söderlund et al. [24] noting that increasing size and complexity contribute to this issue. We found a slight positive relationship between project size and deviation from the P50 estimate, but it is not sufficient to conclude that larger projects have a higher risk of overruns than smaller ones. Still, when considering a portfolio containing varying-size projects, there's a risk that significant overruns in a few large projects could lead to the collective final cost surpassing the aggregate budget limit. Figure 6 demonstrates that the portfolio-level outcome aligns closely with the average project performance, with the final cost being 4% less than the cumulative budget in 2023 NOK.

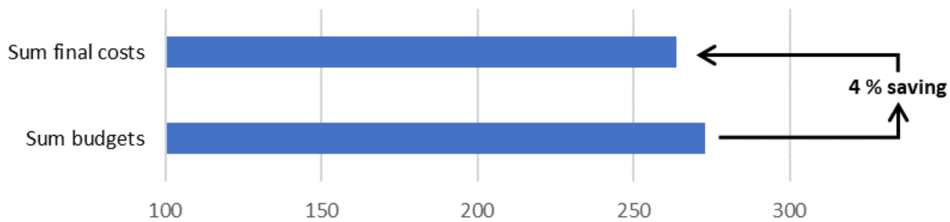

Figure 6: Total final cost and sum of budget in NOK billions (2023 prices)

This suggests that, despite the potential risks posed by larger projects, the portfolio has remained within budgetary confines. This should provide some assurance to policymakers despite potential areas for improvement. However, it's important to note that past performance does not guarantee future results, especially considering all potential factors that influence projects [23-29], in addition to external factors such as price inflation and market conditions. And also, future projects may face different challenges, which could impact outcomes. While our dataset includes some of the largest projects in their sectors, ongoing projects are consistently larger than past projects. For example, the average anticipated cost (P50) for road projects in our analysis was NOK 1.3 billion. In contrast, today's major road projects frequently surpass this figure, potentially leading to an increased risk of cost overruns due to their greater complexity. While it's uncertain if larger projects carry a higher risk of cost overruns, their potential financial impact is undoubtedly more significant.

Currently, multiple projects with estimated costs exceeding NOK 10 billion are either in the planning stage or under construction. These may introduce risks that are difficult for project owners and contractors to mitigate, thus adding uncertainty to individual projects and the overall portfolio. These projects are unfolding under demanding macroeconomic conditions. Some have already required parliamentary intervention for budget increases. Figure 7 highlights the escalating cost issues facing active projects, demonstrating the revisions made to the budget after initial parliamentary decisions.

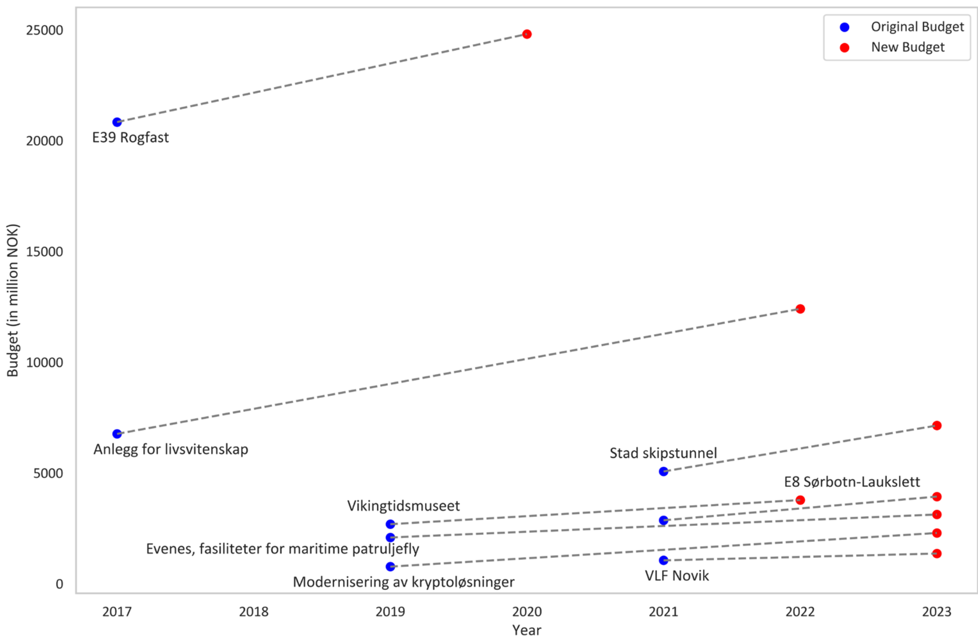

Figure 7: Change in budget for ongoing projects

The difficulty in keeping within budgets, coupled with the necessity for adjustments due to changing project demands or unexpected challenges, highlights the complexity of project management. The likelihood of other projects exceeding their budgets is a valid concern, especially considering the eight projects shown in Figure 7, whose budgets have already escalated by nearly NOK 17 billion. Should these increases be reflected in the final costs, the government's portfolio could face a net negative outcome, with overall expenses exceeding the budgets. The study reflects mostly smaller projects (under NOK 2 billion), while larger, even megaprojects (over ≈ EUR 1 billion, [34]) are underway.

It remains unclear whether larger projects are more prone to cost overruns. Still, with the current landscape where larger and even megaprojects are in progress, the financial ramifications of such overruns are significantly more impactful, accentuating the need for robust project management and oversight in large-scale projects.

References

[1] Atkinson R. Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *Int J Project Manage*. 1999;17(6):337–42.
[2] Ika LA, Pinto JK. The "re-meaning" of project success: Updating and recalibrating for a modern project management. *Int J Project Manage*. 2022;40(7):835–48.
[3] Volden GH, Welde M. Public project success? Measuring the nuances of success through ex post evaluation. *Int J Project Manage*. 2022;40(6):703–14.
[4] Turner R, Zolin R. Forecasting success on large projects: Developing reliable scales to predict multiple perspectives by multiple stakeholders over multiple time frames. *Proj Manage J*. 2012;43(5):87–99
[5] Serrador P, Turner R. The relationship between project success and project efficiency. *Proj Manage J*. 2015;46(1):30–9
[6] Samset K, Volden GH. Front-end definition of projects: Ten paradoxes and some reflections regarding project management and project governance. *Int J Project Manage*. 2016;34(2):297–313
[7] Drummond H. Escalation of commitment: When to stay the course? *Acad Manag Perspect*. 2014;28(4):430–46
[8] Welde M, Klakegg OJ. Avoiding cost overrun through stochastic cost estimation and external quality assurance. *IEEE Trans Eng Manage*. 2024;71:1984–97
[9] Flyvbjerg B, Gardner D. How big things get done: the surprising factors behind every successful project, from home renovations to space exploration. London: Macmillan; 2023.
[10] Kashiwagi, I. A global study on ICT project performance. *Journal for the Advancement of Performance Information and Value*, 2018;10(1): 8–27.
[11] Flyvbjerg B, Stewart A. The Oxford Olympics study 2016: Cost and cost overrun at the games. *SSRN Electron J*. 2016.
[12] Müller M, Gogishvili D, Wolfe SD. The structural deficit of the Olympics and the World Cup: Comparing costs against revenues over time. *Environ Plan A*. 2022;54(6):1200–18.
[13] Hofbauer J, Sanders G, Ellman J, Morrow D. Cost and Time Overruns for Major Defense Acquisition Programs. Washington DC: Center for Strategic and International Studies; 2011.
[14] Odeck J. Variation in cost overruns of transportation projects: an econometric meta-regression analysis of studies reported in the literature. *Transportation*. 2019;46(4):1345–68.
[15] Odeck J. Cost overruns in road construction—what are their sizes and determinants? *Transp Policy*. 2004;11(1):43–53.
[16] Odeck J. Do reforms reduce the magnitudes of cost overruns in road projects? Statistical evidence from Norway. *Transp Res Part A Policy Pract*. 2014;65:68–79.
[17] Odeck J, Welde M, Volden GH. The impact of external quality assurance of costs estimates on cost overruns: Empirical evidence from the Norwegian road sector. *Eur J Transp Infrastruct Res*. 2015.
[18] Infrastructure and Projects Authority, "Cost estimating guidance," 2021. [Online]. Available: https://www.gov.uk/government/publications/costestimating-guidance/cost-estimating-guidance
[19] AACE International, Morgantown, WV, USA, "Cost estimation classification system – as applied in engineering, procurement, and construction for the building and general construction industries," Rep. 56R-08, 2020.
[20] Andersen B, Samset K, Welde M. Low estimates – high stakes: underestimation of costs at the front-end of projects. *Int J Manag Proj Bus*. 2016;9(1):171–93.
[21] Welde M, Odeck J. Cost escalations in the front-end of projects – empirical evidence from Norwegian road projects. *Transp Rev*. 2017;37(5):612–30.
[22] Welde M, Bukkestein I. Over time or on time? A study of delays in large government projects. *Procedia Comput Sci*. 2022;196:772–81.
[23] Cooper KG, Lyneis JM, Bryant BJ. Learning to learn, from past to future. *Int J Project Manage*. 2002;20(3):213–9.
[24] Söderlund J, Sankaran S, Biesenthal C. The past and present of megaprojects. *Proj Manage J*. 2017;48(6):5–16
[25] Thamhain HJ. Linkages of project environment to performance: lessons for team leadership. *Int J Project Manage*. 2004;22(7):533–44.
[26] Durdyev S, Hosseini MR. Causes of delays on construction projects: a comprehensive list. *Int J Manag Proj Bus*. 2019;13(1):20–46.

[27] Durdyev, S., 2021. Review of construction journals on causes of project cost overruns. *Eng Constr Archit Manage*, 2020; 28(4): 1241-1260.
[28] Creedy GD, Skitmore M, Wong JKW. Evaluation of risk factors leading to cost overrun in delivery of highway construction projects. *J Constr Eng Manag*. 2010;136(5):528–37
[29] Flyvbjerg B, Holm MS, Buhl S. Underestimating costs in public works projects: error or lie? *J Am Plann Assoc*. 2002;68(3):279–95.
[30] Jørgensen M, Welde M, Halkjelsvik T. Evaluation of probabilistic project cost estimates. IEEE *Trans Eng Manage*. 2023;70(10):3481–96
[31] Odeck J, Welde M. Cost overruns of transportation infrastructure projects. In: International Encyclopedia of Transportation. Elsevier; 2021. p. 483–9.
[32] Love PED, Smith J, Simpson I, Regan M, Olatunji O. Understanding the landscape of overruns in transport infrastructure projects. *Environ Plann B Plann Des*. 2015;42(3):490–509
[33] Invernizzi DC, Locatelli G, Brookes NJ. Cost overruns – helping to define what they really mean. *Proc Inst Civ Eng Civ Eng*. 2018;171(2):85–90.
[34] Flyvbjerg B, editor. *The Oxford Handbook of Megaproject Management*. London, England: Oxford University Press; 2018.