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Excerpt
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1 Introduction

In 2003, Canadian Northland Resources started to explore an iron ore deposit close to the Finnish–Swedish border. The company was listed on the Oslo Stock Exchange in 2006, and moved from Canada to Luxembourg in 2010. Total capital investment for an iron ore mine producing 5 million tonnes a year was estimated at US $694 million in September 2010,[1] and the payback period of the mine was projected to be 4.9 years, or a net present value after interest and taxes of US $463 million at a discount rate of 8 per cent. Less than a year later, in May 2011,[2] these figures were updated to a net present value of US $934 million.

Plenty of investors were found, and Northland Resources started to construct the mine, but costs began to grow. In 2013, the company announced[3] that the total cost had increased by US $425 million. More money was needed to finish the project and the company had to ask for an out-of-court restructuring. An agreement was reached with debtors and creditors, and an injection of new capital made it possible to continue the project, but by June 2014 the company had to stop all payments and propose an informal reconstruction.[4] In October of the same year, the company had to seek permission to continue the reorganization[5]. But it was too late. Declining iron ore prices forced the company to file for bankruptcy[6] on 8 December 2014. The venture, which had begun in 2010 needing an estimated capital investment of US $694 million, ended with an open mine shaft and the receiver estimating total liabilities minus assets at more than US $1.5 billion.[7] However, this sum does not include losses accrued on public sector investments in roads, housing, and other forms of supporting infrastructure, nor any other private investments that had been made as a result of the project.

New mines have a tendency to exceed their budget. Another major new iron ore mine, the British[8] Anglo American's Minas-Rio project in Brazil, had a cost overrun that resulted in Anglo American recording an impairment charge of US $4 billion[9] in its 2012 earnings. A coincidence? Unlikely. A study of 63 international mining projects recorded an average cost overrun of 25 per cent.[10] Mining projects tend to become more expensive than anticipated.

We have all heard of projects that exceeded their initial cost estimates. The rising costs of large public projects, such as new roads and railways, public buildings, new military aircraft and naval vessels, and events such as the Olympic Games, often feature in the press. Olympic Games between 1968 and 2012 show an average cost overrun of more than 300 per cent, with a median of 150 per cent.[11] The Channel Tunnel incurred a cost overrun of 80 per cent, the Trans-Alaska oil pipeline was 12 times more expensive than originally estimated, and the Sydney Opera House 14 times more costly than initially expected. More recently, the US Air Force F22 Raptor aircraft became so expensive that the number to be built was reduced from 650 to 187 and substituted with the cheaper F35 Lightning II aircraft, which itself has been delayed and costs increased by more than 50 per cent.

Delays and cost overruns affect both public and private sector projects, although the latter rarely come to the public's attention. A review of 35 studies[12] of major projects did not find a single study where major projects had not, on average, exceeded their budget. Other studies have shown that cost overrun is no smaller today than 100 years ago.[13] We do not seem to learn. Still others have shown that cost overrun varies by type of project and the organization planning and implementing the project. Technology and management matter. Anyhow, as Table 1.1 illustrates, cost overrun is the norm.

Delays and cost overruns are endemic. Still, there are plenty of questions to be answered. Where and when do cost overruns tend to occur? Are certain types of project more prone to cost overrun than others? Are larger projects more likely to increase in cost than smaller ones? Does the length of the construction period affect cost overrun? Is cost overrun less of a problem today than in the past? What are the drivers of time and cost overrun? Are they to be found in the technology, in behavioural biases, in politics, or in the control system and the way projects are organized? Does deviation in cost appear at random, or can the logic behind deviations be modelled and foreseen? What happens in projects and firms when costs increase? What are the consequences of overrun on firms and society, and are there perhaps both negative and positive effects of overrun? These are some of the questions we will try to answer in this book.

A number of studies into the causes of cost overruns in the development of new military aircraft and missiles were carried out in the 1950s in the USA. These studies emphasized the process of developing new knowledge. The number of publications on cost overrun expanded quickly thereafter, especially during the 1970s when inflation reached

Table 1.1 *Average cost overrun according to a few studies of cost overrun*

Year of study	Type of project	Number of projects	Average cost overrun in %
1971[14]	R&D projects in two US pharmaceutical firms	75, 69	78, 111
1983[15]	US public sector military projects	244	127
	US public sector civilian projects	200	92
1985[16]	Turkish public sector construction projects	394	44
1990[17]	Indian public sector projects	133	82
1990[18]	R&D projects in Swedish engineering firms	91	80
1992[19]	Canadian computer software projects	89	33
2002[20]	Transportation infrastructure projects	258	(27.6)
2008[21]	Mining and smelting projects	63	25 (14)
2008[22]	Korean road projects	138	28.6 (10.7)
2011[23]	Swedish rail projects	65	(21.1)
2014[24]	Norwegian road projects	434	10.06
2014[25]	Nuclear reactors	180	(117)
	Hydroelectric dams	61	(71)
	Thermal power plants	36	(13)
	Wind farms	35	(8)
	Electricity transmission projects	50	(8)
	Solar farms	39	(1)
2014[26]	Major oil and gas projects	205	59

Note: Figures within parentheses are in estimated constant money value.

double digits. Today, there are many studies across a wide range of sectors, including electric power, road, mining, major public sector infrastructure, construction projects in both the private and public sectors, new industrial plants and processes, product development projects in pharmaceutical and engineering companies, computer software projects, and new weapons system programmes. There are case studies of problem-ridden projects, postal surveys mapping managers' theories and attitudes to cost overrun, laboratory experiments with managers acting on cost data, theoretical papers, and statistical studies of groups of projects. The study methods vary, but the causes of cost overrun identified are generic.

Many studies argue for or test whether a single variable can explain cost overrun. They claim, for example, that projects overrun their budget due to the estimators being overoptimistic, or not being entirely truthful in order to get their project approved, or the fact that the lowest tender is most likely to have underestimated the real cost. These single variable causes often advanced in academic journal articles are certainly relevant explanations in experimental situations and for specific projects, but many of these studies disregard the fact that major projects involve many actors, several sub-processes, and stretch over many years, as well as the importance of control systems for project cost estimation and implementation. Projects are planned and implemented in a context.

An important factor is that major projects and programmes are not planned in detail at approval, and that project planning is a learning process. It begins with a vague vision that must be specified before it can be realized. This requires testing of ideas and alternative solutions, and inevitably means that the plans will change, sometimes radically. When an investment project that was estimated to cost $100 million turns out to cost $150 million five years later, the two projects being compared are almost certainly not exactly the same, as important changes will have been made as the project progressed.

There has also been a tendency to disregard earlier studies by claiming that they do not apply to the type of project being studied currently, and references are only made to studies of similar projects. However, as we will show, experiences from different types of projects are very similar. There is a logic behind cost growth and cost overrun.

The ability to predict future costs is a prerequisite for meaningful investment planning and appraisal. If the cost of certain types of project tends to increase more than others, then we will allocate more funding to such investments than intended. Cost overruns affect the direction of investment, and possibly also the volume. This is a fundamental bias that is not mentioned in textbooks on capital budgeting, corporate finance, and corporate governance, where estimates are usually taken for granted. How to calculate the payback, net present value, and internal rate of return of an investment has become a compulsory subject at all business schools and in engineering management. We teach the pros and cons of various capital budgeting techniques and supply figures for students to exercise their numeracy. It is seldom mentioned that costs tends to increase and market goals take longer than anticipated to achieve, but if we cannot make reasonably good estimates how can we make the right investments?

We need to know more about where, when, and why deviations tend to occur, what the consequences are, and how to deal with deviations.

There are, as we will see, systematic biases in estimates. For instance, comparisons between budget and outcome of investment projects show that deviation in cost varies more for small than for large projects, and correlates with the length of the construction period, project complexity, advances in new technical knowledge, and changes in the project. There are also systematic biases in the way costs are estimated and how organizations handle cost overrun, and major public sector projects often have multiple goals and are initiated, planned, and implemented in a highly politicized environment. There are significant differences between private and public sector projects. A better understanding of these factors is important for investors, project managers, corporate finance, and the allocation of resources in organizations and society.

Investments in fixed assets are designed and have their costs estimated by engineers. They have the technical knowledge to make the choices that determine the economy of the investment, which is why their knowledge is of course essential to the quality of cost estimates. However, deviations between plan and outcome are also studied by accountants, economists, sociologists, psychologists, and political scientists. This book builds on research from several of these disciplines, so our first task is to define the terms used, as their interpretation differs somewhat from discipline to discipline.

When we talk about *cost overrun* we mean that the cost has exceeded a budget or contract, and we measure this *budget overrun* as the difference between approved budget and final cost. A *cost underrun* is the opposite. In this context, we can also talk about *time overrun*, and *time underrun* relative to a time schedule. The term 'overrun' is used differently in industry and in studies of public sector projects. While a cost increase prior to an approved budget would not be labelled a cost overrun in private industry, many studies of public sector projects use the term cost overrun to denote a difference between early cost estimates, sometimes the very first estimate, and final cost.

We will also talk about *cost increase* or *cost growth*, with the opposite being *cost decrease*; here, we mean an increase in cost between two estimates where the first estimate is not necessarily an approved budget or a figure stated in a contract. The term *cost growth* is used in the project management literature.[27] A term used in social science to denote an unanticipated increase in cost between two estimates is *cost escalation*,[28] and its opposite is *cost de-escalation*. However, as 'cost escalation' in project management literature is used to denote a price increase in specific goods or services (i.e. a relative price change), we will not use that term to avoid confusion.

While traditional project management literature focuses on planning and implementing projects to approved budget and goals, we will view cost overrun from the perspective of the firm and society. Thus, an investment project becomes only one of many investment options open to an investor, and what is of interest is the cost of a project to the firm or society as a whole. We term this a *business economist perspective*.

This book consists of six chapters and three appendices. In Chapter 2, we discuss the problem of measuring cost overrun and define our variables. Chapter 3 deals with what happens when cost increases above budget, and the negative and positive consequences of cost overruns to organizations and society. In Chapter 4 we present a model of cost overrun and growth based on results from earlier studies of the subject, and the assumption that estimators base their estimates on facts and update their estimates as new information becomes available. Cost growth becomes a consequence of the way project cost estimators and planners resolve economic-technical uncertainty. We further develop this model in Chapter 5 by adding on the dimension of political decision making and the resolution of political uncertainty versus economic-technical uncertainty. The results and conclusions of our analysis are summarized in Chapter 6. For a review of the literature, see Appendices A to C.

Chapter 2: We start our venture into the realm of cost estimates and deviations using four examples to illustrate the many problems of estimating the correct cost of an investment project, the appearance of cost overrun, and actions taken when cost increases. The first example, an investment in a new press section in a paper machine, shows that it is not always a simple task to estimate the correct cost even when a tender offer exists. The next two examples involve investments in a paperboard machine and two nuclear reactors, and illustrate how the cost of individual budget items can increase even though the total budget does not.

When costs increase, the first thing project management does is to search for savings to meet the budget. The paperboard machine example illustrates how savings can often be made by postponing parts of the investment or by selling and leasing back parts of the project, savings that usually become future operating and investment costs. The final example deals with one of the largest construction projects being undertaken currently: the management of nuclear waste. This project is planned and cost estimated in a highly politicized environment, and our example shows how costs and assumptions made in the costing process can be affected by political decisions. We will use these examples to illustrate problems associated with establishing the size of a cost overrun, and how important it is to avoid comparing apples and oranges. We will return to these examples and the problem of measuring deviations later on in the book.

Chapter 3: When costs increase, project management first uses up the contingencies built into the budget, then tries to make savings by choosing cheaper solutions and/or refraining from implementing some of the plans. They may also postpone parts of the investment or let somebody else finance parts of it and lease these back. Not all postponed parts will be implemented in the future, but postponement typically means that the investment outlay is reduced by increasing future investments and leasing fees. Choosing cheaper technical solutions can also mean higher future operating and maintenance costs, but may not, as the trade-offs between investment and operating cost made when choosing technical solutions is mostly driven by technical standards and practice. The budget can be met more easily if the project is divisible and can be implemented in stages, resources are reversible, and goals and ambitions can be re-negotiated.

The ultimate consequence of cost overrun is bankruptcy, but this is rare. Much more common is that the cost overrun places a financial burden on the firm that reduces the firm's financial flexibility and ability to take advantage of future profitable investments opportunities, acquisitions, and business deals when these appear. It can of course also threaten jobs and affect a firm's image and reputation.

There are also positive effects. Cost overrun might, under some conditions, increase total investments and savings. It makes us invest more in categories of investments that are more prone to exceed their estimates than initially planned, and less in projects that are less likely to exceed their cost estimate. This reallocates investment funds from investments in maintaining towards renewing existing product portfolios. Cost overrun can thus contribute to renewing firms and society, and this is probably the most important positive effect of underestimating the true cost.

We will also identify four types of investment project where there is a tendency to underinvest if we know the real cost of implementation at too early a stage, namely infrastructure projects with the potential to open up new markets for exploitation; radical innovations creating business opportunities for exploitation; new ventures opening up new products and markets for exploitation; and projects benefiting from changing value systems. These are all types of projects where underestimating their real investment outlay can sometimes be balanced by similarly underestimating their true long-term benefits. A key question here is to what extent the firm can appropriate profit from its investments, or whether other firms and the economy at large will reap the benefits. There is a considerable knowledge spillover, especially from R&D and intangible investments.

Chapter 4: In this chapter we show that cost growth can be explained by how we make estimates and resolve uncertainty as the planning and implementation process proceeds and we receive more accurate information. The outcome of the process depends on the technology, prior knowledge, the learning during planning and implementation of those involved, and the way the process is organized.

When project planners launch an idea they cannot specify in detail exactly what has to be done to implement their idea. The learning process as the project develops means that they might discover additional works that have to be carried out, and therefore have to make changes to the original design. The project can increase in scope, and its design can be altered. The cost of making such changes increases with the amount of resources spent, as resources already spent on the earlier design cannot be fully recovered. It does not cost much to make design changes while the project is still in the planning process, but when the project is being implemented it becomes increasingly expensive. The need for such unanticipated changes drives cost.

Implementing an idea is a process of learning. The idea always comes first. Then a plan has to be formed showing how this idea can be implemented. Based on that initial plan, a cost estimate can be made, and this will gradually become more reliable as the project planners form a more precise image of the project and what is needed to implement it. Changes in the original plan and additional work will often be necessary as uncertainties are resolved, and some types of project require more changes than others, depending on previous knowledge and the need to develop new skills and knowledge.

These observations make it possible to formulate a model based on the way uncertainty can be resolved. Therein, we distinguish between uncertainty that will be resolved during the planning process, termed dynamic uncertainty, and static uncertainty, which is always present and will not necessarily be resolved. Uncertainty associated with standard houses and other projects which can be planned in detail and implemented can be resolved using existing knowledge; R&D projects require the acquisition and development of new knowledge for uncertainty to be resolved. Static uncertainty derives from things we cannot control, such as changes in market prices, or what other actors in a development or production chain do, and we must remember that what is resolvable uncertainty for one actor might not be so for another.

We then take a closer look at cost overrun as a consequence of static uncertainty such as price changes, and the importance of regulation, standardization, and utilizing economies of scale. The cost difference between standardized and unique projects has been widened, and it seems that estimators tend to underestimate the long-term above-inflation cost growth that some types of projects experience.

Finally, we study the trade-offs between expected risk, return, and the cost of resolving uncertainty, and show that there are situations in which it is not optimal to resolve uncertainty prior to the decision to invest, either because the expected return is so high and so dependent on early operation that it is risky to wait, or because the cost of resolving uncertainty is too high in relation to expected return.

Chapter 5: Profit-maximizing organizations seek economic efficiency, and are governed by the logic of economics. Politics is partly governed by another logic, as politicians have to align their decisions and acts to the norms and values of voters and society. We therefore review the consequences of these two different logics for estimates and cost overrun.

Our original model concerns the resolution of economic-technical uncertainty. While economic-technical uncertainty derives from lack of information, political uncertainty derives from disagreement among stakeholders. The solution to political uncertainty is to form plans that are acceptable to a large enough majority of stakeholders so that the decision can be approved. Good decisions have to satisfy both the logic of economics and the logic of politics. In extending our model in Chapter 5, we discuss alternative ways of resolving political uncertainty, and show that political uncertainty has to be resolved before economic-technical uncertainty can be fully resolved.

The control systems by which proposals and estimates for new projects are reviewed before they are approved, and then monitored during implementation, are important for the accuracy of cost estimates. All organizations, private as well as public, have such control systems, and when project estimates turn out to be too low, this indicates that the system has not worked as intended. We therefore compare the way major companies control investment cost estimates with the control systems found in the public sector. In principle, there are many similarities, but the preconditions for these means of control to function well differ in many respects, and we will analyse the consequences of this.

Chapter 6: In this chapter we draw together the pieces of our endeavour in the land of estimates and deviations. We do that by first discussing situations in which the cost of the project becomes less important due to the compromises that have to be made to secure funding, or because a project exhibits symbolic power or is the result of a strong personal goal. Decisions to spend resources on projects may not be motivated solely by economic reasons, but by emotions and instincts, such as an individual's need to boost their self-esteem in the face of death. We then briefly discuss explanations for cost overrun, summarize what we have learnt and return to the issue of the effects of cost overrun on the return on investments.

Appendix A: The study builds on an extensive review of the literature and what we can learn from earlier studies of cost overrun and growth. Appendix A gives an overview of studies in this research area. There are a great number of studies into time and cost growth and budget overrun, the most common being case studies and statistical studies of groups of projects, and these demonstrate that cost overrun is the norm. There are projects that are implemented to, or below, estimated cost, but taken as a group it is difficult to find a study showing that the final cost on average is not underestimated. There are a few examples, but they all derive from one single organization. We will also see that this applies to a range of projects, including construction, R&D, and computer software projects, to older studies and newer ones, and to public and private sector projects.

Appendix B: In Appendix B, we formulate the conclusions from earlier studies, conclusions which led to the development of the model in Chapter 4. We show that estimates tend to rise over time, that they tend to increase more in the beginning of the planning process than later on, and that the outcome of smaller projects tends to vary more than for larger projects. We will also learn that estimates become less reliable the longer the time between two estimates, that cost overrun co-varies with time overrun and external and internal changes, and that some organizations are better at estimating costs than others.

Appendix C: The model in Chapter 4 assumes that the estimator has access to gradually more accurate information, and the ability to identify and choose the alternative that maximizes his utility. In Appendix C, we relax these assumptions and assume that estimators are limited in terms of information, cognitive ability, and time to process information. Decisions are based not only on reasons, but on a mixture of emotions and reasons.

There are a great number of explanations in the literature emphasizing the importance of emotions in cost growth and overrun – for instance, that investors appropriating funding are overoptimistic, do not consider what is spent as sunk cost, and know less than those requesting funding. We will review the more prominent of these explanations: optimistic bias, self-serving bias and anchoring bias, path dependence, and information asymmetry.