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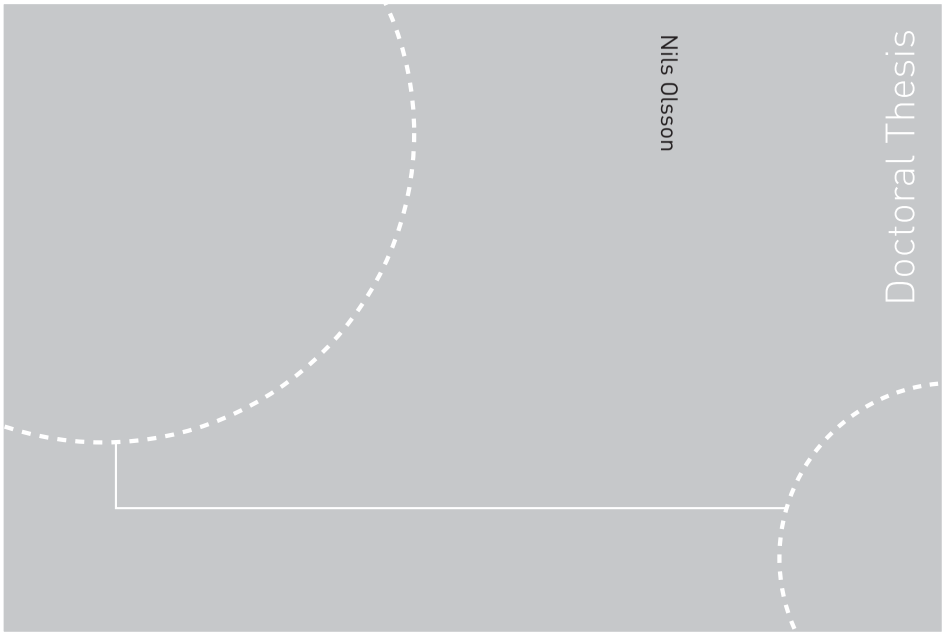

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Nils Olsson

Project Flexibility in Large Engineering Projects

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Thesis for the degree of doktor ingeniør

Trondheim, September 2006

Norwegian University of
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NTNU
Innovation and Creativity

Preface and Acknowledgements

The work presented in this thesis has been carried out at Department of Civil and Transport Engineering at NTNU. I would like to express my sincere thanks for the supportive and inspiring guidance that I have received from my supervisor Professor Knut Samset. He has always supported my choices and believed that this could be done.

During my work on several large projects, project flexibility has emerged as a key issue. I have frequently observed it to be a critical success factor, major risk and conflict topic, but rarely as an issue that was subject to a common understanding and a structured approach for handling. It appeared to be an area where it was possible to make a research contribution. Consequently, the topic became the 'glue' in the thesis.

Both scientifically and financially, this research has benefited from the Concept research programme. Concept focuses on front-end management of major investment projects. Funded by the Norwegian Ministry of Finance, the programme aims to develop know-how to make more efficient use of resources and improve the effectiveness of major public investments. In addition, I have received financial and scientific support from the Department of Civil and Transport Engineering at NTNU. This research has also been carried out in co-ordination with railway related research involving NSB AS, the Norwegian National Rail Administration and the Norwegian Research council.

Throughout the work on the thesis, I have enjoyed the discussions with my fellow Ph.D. candidates Ola Lædre, Ole Morten Magnussen, Andreas Seim, Mads Veiseth and Alexander Langlo. I have also appreciated the valuable co-operation with Per T. Eikeland, Ole Jonny Klakegg and Agnar Johansen.

My warmest thanks and love go to my wife, Rønnaug, and sons, Erland, Einar and Henrik, who have supported me all the way. According to the boys, the work on this thesis has made me more like a 'nerd' than ever before. My parents and sister have also been supportive. They have all personally illustrated what lifelong learning really means. Thanks to my father for proof reading.

And warm thanks to all my friends and colleagues at NTNU and SINTEF; it has been a pleasure working with you.

Trondheim, September 18, 2006

Nils Olsson

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Magnussen, O.M. & Olsson, N.O.E. 2006. Comparative analysis of cost estimates of major public investment projects. *International Journal of Project Management* 24:4, 281–288.

Paper 3.
Olsson, N.O.E. & Magnussen, O.M. 2006. 'Projects trapped in their freedom: Flexibility aspects of front-end quality assurance of major projects'. Paper submitted to *Project Management Journal.*

Paper 4.
Olsson, N.O.E. 2004. 'Flexibility in Engineering Projects: Blessing or Curse?' Paper presented at the NORDNET 2004 International PM Conference, 29 September – 1 October 2004, Helsinki, Finland.

Paper 5.
Olsson, N.O.E. 2006. 'Impact analysis of railway projects in a flexibility perspective'. *Transport Reviews* 26:5, 557-569.

Paper 6.
Henriksen, B., Olsson, N. & Seim, A. 2006. 'Adjustments, effectiveness and efficiency in Norwegian hospital construction projects'. Proceedings CIB W70 Trondheim International Symposium. Changing User Demands on Buildings, 12–14 June 2006, Trondheim, Norway.

Paper 7.
Olsson, N.O.E. & Samset, K. 2006. 'Front-End Management, Flexibility and Project Success'. Paper presented at PMI Conference, 17-19 July 2006, Montreal, Canada.

Paper 8.
Olsson, N.O.E. 2006.'Flexibility and Front-End Management; Key to Project Success and failure' Paper accepted for presentation by ProMAC International Conference on Project Management, 27-29 September 2006, Sydney, Australia.

Abstract

Traditionally, projects tend to strive for increased predictability by managing details and attempting to bring all variables under control. However, experience shows that the chance of realising a plan without major amendments decreases with an increasing time horizon, which points to a need for flexible projects. A number of scholars argue that flexibility is necessary to face changes and uncertainty in the business environment. On the other hand, flexible projects are generally not described as desirable in project management literature. These conflicting approaches to flexibility have justified an analysis of the dynamics related to project flexibility, both from a theoretical and an empirical perspective. Such an analysis is presented in this thesis, based on analyses of large engineering projects in Norway. Most of the projects are governmental investments.

This thesis aims at structuring knowledge on project flexibility. Two types of results have emerged; the first related to how to analyse project flexibility, and the second related to how to manage flexible projects. Based on studies of different parts of the life cycle of projects, the research provides indications as to how flexibility can be addressed in the front-end phase of large public investments. A framework for analysing project flexibility is also proposed.

Chapter 1 discusses flexibility in a project management perspective, and raises key research questions. The research presented in this thesis addresses the dynamics between utilising benefits from flexible approaches and avoiding drawbacks. Being flexible is characterised by a capability to adapt to new, different or changing requirements.

Flexibility is used in a rather wide sense in the thesis, but is always related to the managing effects of uncertainty. Project flexibility includes adjustments and preparations in response to both internal and contextual uncertainty, such as for example, scope change management, iterative decision process and adjustments related to uncertain funding. Chapter 1 ends with two key research questions related to how to analyse and manage project flexibility.

Chapter 2 presents the research design. The thesis is based on nine papers. These papers are summarised in part one of the thesis. Three main data sources have been used, along with complementary information. First, project evaluations and summaries of 18 Norwegian investment projects have been analysed. Second, this research has benefited from access to an established database for major governmental investments, including results from 48 front-end assessments of large governmental projects. Third, a wider range of data has been collected in a multi-case study of four Norwegian railway projects.

The research is based on an inductive-deductive approach, using a combination of qualitative and quantitative information. Validity and reliability associated with the data used in this thesis are not sufficient to provide solid answers, taken in isolation. As is common in project management research, the small samples in the studies generally do not support statistical analysis of the data, particularly when subgroups of the material are subject to analysis. However, the research has taken previous

studies of related issues into account. The results presented in the thesis support many of the findings from other studies, but also indicate some nuances to common understanding of project flexibility. Further research is needed to clarify to what extent these indications are of a general nature or project-specific.

Chapter 3 discusses project flexibility in different project phases. A distinction is made between three project phases: front-end, planning and execution. Both this thesis and previous research point to a flexible front-end phase as the least controversial aspect of project flexibility. Low flexibility after the front-end phase increases the likelihood of projects being completed on time, within budget and according to specifications. Some models and measures of project flexibility in a time perspective are also presented in this chapter.

Chapter 4 analyses project flexibility from a stakeholder perspective. Project *stakeholders* are actively involved in a project, or their interests may be positively or negatively affected by the project. Project flexibility is perceived differently by different stakeholders. Flexibility for one project stakeholder can be another stakeholder's risk.

An analysis of flexibility in stakeholder perspective called for a distinction between internal and external project flexibility. Project internal flexibility relates to flexibility within defined scope – *how* requirements are to be met. External flexibility refers to adjustments of project scope – *what* requirements are to be met. Project internal flexibility appears to be particularly desirable to project managers and contractors. Project external flexibility is more likely to be looked upon favourably by users and project owners. Incentives open to stakeholders affect their approaches to project flexibility. In general, flexible projects have a value for stakeholders which benefit from adjustments and come at a cost for those who have to adapt.

Chapter 5 highlights the relevance of efficiency and effectiveness when discussing flexible projects. In general, efficiency is related to producing direct project outputs, often measured in terms of cost, time and quality. Effectiveness is related to added value for owners and users. The case in favour of flexibility emphasises the possibility to increase a project's effectiveness. The case against project flexibility highlights the negative effects on efficiency due to changes and the possibilities for frustration due to lack of decisions and commitments.

Analyses presented in this thesis indicate challenges in materialising the expected benefits of flexible projects. On the other hand, the expected decrease in efficiency in flexible projects has been frequently observed throughout the analysis. Chapter 5 also addresses redundancy as an enabler for project flexibility. Redundancy is created when more resources than strictly necessary are available. The logic behind redundancy is that a project with redundant resources will be efficient because it can be executed as planned, compared to a project with no redundancy that turns out to be error-prone in reality.

Chapter 6 discusses flexibility related to modularity, flexible decision processes and flexible final products. Flexibility in the decision process means that decisions and commitments in projects are made sequentially over phases. Flexibility in the product is achieved when the final product that a project is to produce is prepared for

alternative use. There are indications that flexible projects utilise both flexible products and flexible decision processes, rather than emphasising one of these dimensions at the expense of the other. When analysing flexibility in decision processes, there was a need to make a distinction between planned and actual approaches to flexibility. Actual approaches turn out to be different from planned ones.

Modularity can be an enabler for flexible project management. On a macro level, modularity means that projects are divided into independent sub-units. Decision makers can then make incremental commitments to each sub-unit at a time. In the studied projects, macro modularisation was associated with cost control but also with lower benefit realisation than planned. On a micro level, modularisation means a decomposition of a product into modules with specified interfaces. Such modularisation can reduce the 'knock-on' effects of design changes.

Chapter 7 summarises a framework for analysing project flexibility and indicates guidelines for managing flexible projects. The framework for analysis consists of project flexibility categorisations, perspectives of analysis, and flexibility drivers and enablers. Approaches for the management of project flexibility are also suggested in Chapter 7. Successful strategies for project flexibility either aim at avoiding flexibility or at enabling projects to be flexible. Projects can avoid adjustments or live with them. One key to successful flexibility management in projects lies in the transition from an initial open-minded environment to the subsequent focused phases. Based on the results in the thesis, an attempt is made to list approaches to project flexibility management.

Even though the results are based on studies of only a few projects, there are indications that the drawbacks of flexible projects are largest when projects do not prepare for future adjustments. This notion is consistent with previous works on flexibility, which highlight that flexible decisions require a structural framework of strategies and guidelines. The suggested approaches and categorisations related to project flexibility are intended as an input to such a structural framework.

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1. Introduction

This chapter discusses different approaches to project management from a flexibility perspective. One purpose of the chapter is to define how project flexibility is understood in this thesis, but also to give some illustrations of how others have used the concept of flexibility. Key research questions related to project flexibility are stated in this chapter. These questions have in common that they address the dynamics between utilising benefits from flexible approaches and avoiding drawbacks. The thesis is designed to address these questions.

A number of scholars have argued that flexibility is necessary to face the changes and uncertainty in the business environment. On the other hand, a wide range of studies indicate that a clear project definition and minimisation of changes also are critical factors for the success of projects. These approaches to project flexibility, which can appear as conflicting, have justified the study of the dynamics related to project flexibility that is presented in this thesis. The subject is analysed both from a theoretical and an empirical perspective.

1.1 Perspectives on project management

In a wide sense, projects include any activity that meets the characteristics of projects listed by the PMI (Project Management Institute) (2004: 5): 'A project is a temporary endeavour undertaken to create a unique product or service'. Common characteristics of projects include: finite budgets and schedule constraints, complex and interrelated activities, clearly defined goals, and uniqueness (PMI 2004).

Projects are traditionally seen as temporary organisations designed for unique tasks (Cleland 2004), often in contrast to the mass producing core activities of organisations. Projects are initiated to solve tasks of almost any type (Engwall 2003) to such an extent that Western society seems to be heading towards a *projectified society* (Lundin & Söderholm 1998, Gareis 2004). A major benefit of organising a task as a project is the freedom to create an organisation more or less from scratch. While uniqueness is the competitive advantage of projects as a way of organising, changes and lack of predictability are commonly seen as the major pitfalls of projects. Successful projects are often claimed to be characterised by control and governance (Hall 1980, Morris & Hough 1987, Miller & Lessard 2000).

Söderlund (2004) discusses two main theoretical traditions in project management research. The first tradition has its roots in engineering science. Planning techniques and methods of project management, including the recent emphasis on uncertainty quantification and risk management, have been the major focus. This is in accordance with Packendorff (1995), who claims that a number of writers trace the intellectual roots of project management research and knowledge to various types of planning techniques, such as PERT (program evaluation and review technique) and CPM (critical path method). The other tradition has its intellectual roots in the social sciences and focuses especially on the organisational and behavioural aspects of projects. Söderlund (2004) terms these *the engineering tradition* and *the social science tradition*, respectively. In a similar distinction between project management traditions, Crawford & Pollack (2004) use the terms 'hard' and 'soft'. Crawford &

Pollack relate 'hard' project management approaches to objectivist, scientific approaches and that have parallels to Söderlund's (2004) engineering tradition. The 'soft' project management approaches stem from interpretivist and constructivist schools of thought, and share similarities with Söderlund's (2004) social science tradition.

1.2 Uncertainty

The *uncertainty* of a decision in a project can be described as 'the gap between the amount of information needed to perform at task and the amount of information already possessed by the organisation' (Galbraith 1973: 5). Christensen & Kreiner (1991) make a distinction between *operational* and *contextual* uncertainty. They relate operational uncertainty to uncertainty within the defined scope of a project, and contextual uncertainty to the project context. Karlsen (1998) discusses *environmental uncertainty*, which represents uncertainty generated by factors outside a project's system boundaries, and *task uncertainty* which relates to factors within project boundaries. Jensen et al. (2006) divide environmental uncertainty into two categories: *institutional* and *interactional* uncertainty. The purpose is to identify interactional uncertainty as representing environmental explanations necessary for understanding the circumstances of a project without including everything outside the projects.

This thesis does not aim at covering the issue of uncertainty in a broad perspective. However, the distinction between the two types of uncertainty that Karlsen (1998) and Christensen & Kreiner (1991), among others, discuss has implications for the analysis of project flexibility. This thesis uses the terms *contextual uncertainty* and *internal uncertainty*. Internal uncertainty is related to operational uncertainty (Christensen & Kreiner 1991) or task uncertainty (Karlsen 1998).

1.3 Flexibility

The term *flexibility* is used in a rather wide meaning in this thesis, but generally related to managing effects of uncertainty. Bahrami & Evans (2005) list 11 concepts related to flexibility: adaptability, agility, elasticity, hedging, liquidity, malleability, mobility, modularity, robustness, resilience, and versatility. According to the Merriam-Webster Online Dictionary (2006), being *flexible* is '*characterised by a ready capability to adapt to new, different, or changing requirements*', a definition of flexibility which is also used in this thesis. With such a wide definition, project flexibility includes preparations to manage both internal and contextual uncertainty, such as scope change management, iterative decision process, and adjustments related to uncertain funding in general.

In a planning perspective, Sager (1994) presents flexible planning as a proper response to an environment aiming at conflict solutions, since it favours democracy in collective choice processes. Further, Sager makes a distinction between *opportunism* and *rigidity*, and places 'flexibility' in between these two extremes. Rigidity implies unwillingness or lack of ability to adjust to a changing situation. In contrast, opportunism can be described as a policy of extreme adapting to new circumstances, without being guided by any rules or overall strategy. He points out that flexibility refers to future choices among satisfactory alternatives, and that flexibility implies adjustments in accordance with principles and criteria.

Flexible projects are generally not described as desirable in project management literature. In other management disciplines, such as in strategic management, flexibility is an established enabler to manage uncertainty (see, for example, Mintzberg 1994). Flexibility is so well acknowledged as a key success factor of competitive organisations that Bahrami & Evans (2005) used the term 'super-flexibility' to describe the most flexible companies.

1.4 Project flexibility

Project flexibility is part of a fundamental dilemma in project management. On the one hand, projects need stability and control to be executed efficiently, typically measured in terms of time, cost and meeting specifications. In this perspective, flexibility should be minimised. On the other hand, important decisions in projects must be taken based on limited information in an unpredictable world, creating a need for flexibility options.

The PMI (2004: 368) defines *project management* as 'the application of knowledge, skills, tools, and techniques to project activities to meet project requirements'. In this terminology, project management is aimed at meeting project requirements, and not necessarily related to meeting the overall objectives of projects. The PMI (2004) and Bahrami & Evans (2005) argue that projects and project management are applied once an organisation has decided to escalate initial activities in a focused implementation. Other authors (e.g. Miller & Lessard 2000, Samset 2001) highlight the front-end phase in relation to project management. As discussed in Paper 7, the emphasis on the front-end phase in project management is related to how "project management" is defined by different authors. As an example, it is not entirely clear if PMI (2004) considers selecting the right project as a part of project management.

Mikkelsen & Riis (2003) have identified a dilemma in project planning: namely, that the importance of decisions is highest at the when the availability of information is at its lowest. A common way of reducing this dilemma is to increase the available knowledge about the project. A project flexibility approach to address this dilemma is to postpone irreversible decisions until more information is available.

The engineering tradition of project management, referred to by Söderlund (2004) and Crawford & Pollack (2004), focuses on stability for projects, particularly in their later phases. The social science tradition has a greater understanding of the benefits of project flexibility. Kreiner (1995) points out that the traditional focus on stability becomes challenged under conditions of uncertainty, which creates what he calls 'drifting environments'. The drifting environments of a project are not necessarily caused by actual changes but may also result when the project owners, users or other stakeholders gain a better understanding of, and ability to express, their actual needs. The results presented in Paper 4 indicate that flexible projects are generally not desirable when the unit of analysis is limited to the project itself, but can be rational when a wider context is included in the analysis.

Real options represent one approach to project flexibility (see, for example, Amram & Kulatlaka 1999, Brennan & Trigeorgis 2000). Real options illustrate the value of flexibility based on theory related to financial options. Flexibility is compared to

owning an option – the right, but not the obligation to take an action in the future (Amram & Kulatlaka 1999). The real options paradigm recognises that decisions are made sequentially over phases. Uncertainty can increase the value of a project as long as flexibility is preserved and resources are not irreversibly committed. The value of flexibility can be quantified in monetary terms. Uncertainty about the future profitability of an investment project makes it often optimal to postpone commitment to a project, compared to a situation in which there is no uncertainty (Brennan & Trigeorgis 2000).

Koskela (2000) describes how production principles, such as just-in-time, have been adopted in a theoretical framework aimed at the construction industry under the term *lean construction*. In this framework, the term 'last responsive moment' is used to achieve flexibility in projects (Ballard & Howell 2003). According to Ballard & Howell (2003), the last responsive moment means that decisions must be made within the lead time for realising alternatives and that a decision should not be made until it has to be made.

1.5 Efficiency versus effectiveness

A project's ability to produce its immediate outcome can be measured in terms of *efficiency*. It is a question of doing things right and producing project outputs in terms of the agreed scope, quality, cost, and time. It is a measure internal to the project and restricted to the project or contractor's perspective. The longer-term effects of the project can be measured in terms of *effectiveness* – or, in other words, doing the right things. It is an external measure. Eikeland (2001) relates effectiveness to how the results of a project contribute to added value for owners and users. In OECD terms, effectiveness measures the realisation of the project's objectives (OECD 2000). This is the perspective of the project owner or financing party, who in many types of projects might have a perspective similar to that of the users.

Performance measurement systems in organisations frequently strive to capture a range of performance aspects (see, for example, Sink & Tuttle 1989). Figure 1 shows that these aspects often include measures of efficiency, effectiveness and changeability. Project success is commonly measured in terms of efficiency and effectiveness. It is less common to measure changeability, or flexibility, in project management. While a high degree of flexibility is desirable to many organisations, it is more often mentioned as a threat than a key success criterion for projects.

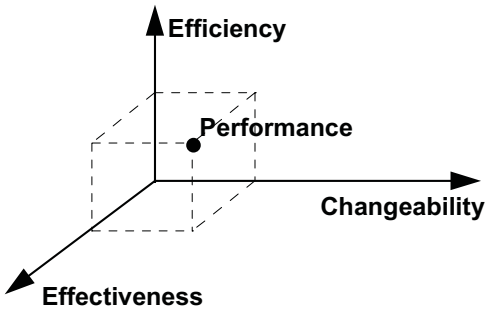

Figure 1. Performance measurement dimensions. (Moseng & Bredrup 1993)

A literature review in an early part of the work on this thesis (Paper 4) gave indications that flexible projects are primarily enablers for improvement of effectiveness rather than efficiency. This notion has served as guidance for the methodological choice of data collection and projects to be studied.

1.6 Structure of the thesis

The thesis consists of two parts. Part one serves three main purposes. First, it states the key research questions that the whole thesis addresses. The research questions are presented in the next section of this chapter. Second, part one discusses the applied methodology of the thesis as a whole. The studies presented in each paper are utilised with the aim of making the whole thesis more than just the sum of its individual parts. Finally, part one provides a summary of results from the research.

Part two consist of nine papers. Paper 1, 2 and 3 present results relating to studies of major engineering projects, most of them governmental. One aim of these papers is to analyse similarities and differences between projects and flexibility approaches. Paper 4 consists of a literature study on flexibility. The next paper, Paper 5, focuses on railways. Railway investment projects were chosen for in-depth studies of one particular type of governmental investment. Another sector-specific study related to hospitals is presented in Paper 6. Paper 7 and 8 benefited from the analyses presented in the preceding papers, but also contribute other aspects to the subject.

1.7 Research questions

The purpose of this research is to structure knowledge on project flexibility. Based on studies of different parts of the life cycle of projects, the research aims at providing indications as to how flexibility can be addressed in the front-end phase of large public investments.

The following two key research questions are addressed in the thesis:

How can different aspects of flexibility in projects be analysed?
Flexibility is discussed as a blessing and a curse. Flexibility for one stakeholder is often viewed as another stakeholder's risk. The thesis also aims at identifying other aspects of flexibility which can contribute to an analysis of the issue. These aspects will be summarised as an analytical framework for project flexibility.

After studying project flexibility, what are the implications for project front-end management?
The thesis aims at identifying characteristics of successful project flexibility management. Such knowledge may prove valuable in the preparations of future projects. The results will be summarised as generic approaches for flexibility management.

2. Study design

The research design of the thesis as a whole is presented in this chapter. Empirical evidence used in the thesis is also presented, including how it was obtained and why this particular information was chosen. Based on the empirical evidence and the design of the study, there is also a discussion of the quality of the data and how the evidence may be interpreted. In addition, the applied methodology in each study is presented in more detail for each of the included papers.

2.1 Research approach

In this thesis, one phenomenon – flexibility – is analysed in a complex environment with several influencing factors. Investigating project flexibility from different angles has provided a multidimensional view of the subject. A combination of qualitative and quantitative information has been used. The thesis provides opportunities for triangulation, as described by Fellows & Liu (2003). An advantage of using multiple sources of information lies in the development of converging lines of evidence. To achieve a triangulation effect, information from two or more sources has been used to address the same research questions.

The research is based on an inductive-deductive approach, described by Fellows & Liu (2003). Inductive research explores an issue through observation. The aim is to establish explanatory principles or hypotheses. In deductive research, hypotheses are tested against observations.

Case studies included in the thesis apply a research methodology based on the works of Yin (2003). Three important principles in the research have been: (a) multiple sources of information, (b) use of case study databases to assemble evidence related to the cases, and (c) maintaining a chain of evidence with links between the questions asked, data collected and conclusions drawn.

2.2 Empirical evidence

Several different information sources have been used. The main sources are:

1. Evaluations of Norwegian public investments
2. Ex-ante uncertainty analyses of major governmental investments
3. Case studies of Norwegian railway projects

In addition, the thesis benefits from case studies of the effects of the quality assurance of major governmental investment, railway traffic analyses and experiences from hospital projects.

To analyse project flexibility, information was needed to cover both efficiency and effectiveness aspects of projects. As the prime source of information regarding efficiency, major governmental investments were chosen. Work related to preparations and execution of the Norwegian quality-at-entry regime provided data that covered enough projects to justify some quantitative analysis. The quality-at entry

regime was introduced in 2000 by the Norwegian Ministry of Finance. It calls for mandatory quality assurance and uncertainty analysis of all governmental investments in Norway exceeding NOK 500 million (*c*.60 million USD). To achieve a wider perspective, the same type of information was also obtained for a limited number of non-governmental projects. Analysing effectiveness required a different approach regarding the number of projects as well as type of information. Railway projects were chosen because of the possibilities to gather information for a number of years.

In the following, the main information sources are described. Each of the papers in the annexes gives additional details.

Evaluations of Norwegian public investments
A set of independent project evaluation reports was collected. Personal experience from projects was also utilised. To analyse the information related to the projects, codified data were entered into a database. This included information on the general characteristics of the project. On the basis of the descriptive information, an assessment was made of approaches to project flexibility. This was based on subjective assessments made by the researcher.

Ex-ante uncertainty analyses of major governmental investments
The thesis has befitted from access to reports from assessments made under the Norwegian quality-at-entry regime. These assessments are made by consultants prior to the parliament's appropriation of the projects. Information from the quality assurance reports has been entered into a database. The information is relatively detailed, but limited to the situation at the time of approval of the project investments in parliament. Transportation infrastructure includes roads, bridges and tunnels, and railways account for more than one-third of these projects. Defence-related projects also represents more than one-third. The remaining group of projects includes public buildings, hospitals and IT systems.

Case studies of Norwegian railway projects
The benefits of projects materialise after the projects have been commissioned, calling for a rather long time perspective of the analysis. Railway projects were chosen because of the possibilities to gather information for fairly long time spans. The availability of timetables means that it is possible to measure key benefit elements such as travel time and frequency based on documentation. In addition, data on number of travellers and punctuality were included in the analyses. Being a multi-case study in the terminology used by Yin (2003), the analysis of four railway projects is based on multiple information sources. The most important sources are:

- Documents from the involved organisations, as well as publicly available information. This includes reports, evaluations and quantitative information, such as timetables and statistics.
- Interviews
- Participant observation in meetings and other arenas where the projects have been discussed.

A summary of the most important information used in this thesis is shown in Table 1.

Information	Content	N=	Paper	Type of information	Sources
Evaluations of Norwegian public investments	Public and private sector projects from different sectors. Projects initiated 1986-2000	18	Paper 1 Paper 3	Primarily qualitative	Evaluation reports; personal experience
Ex-ante uncertainty analyses of major governmental investments	Governmental investments projects approved 2000-2004	48	Paper 2 Paper 3	Primarily quantitative	Consultant reports
Case studies of Norwegian railway projects	Railway investment projects 1986-2000	4	Paper 5	Qualitative and quantitative	Interviews; statistics; evaluation reports; personal experience

Table 1. The primary information sources upon which the thesis is based.

2.3 Quality of information

Because of the design of the study, the possibilities to assert the validity or test the reliability of the findings are limited. It cannot be statistically proved that the findings are generally applicable.

Reliability is related to consistency of a measure. Information is reliable if the measurement procedures provide the same result if applied repeatedly, even by different researchers. In this type of study, reliability cannot be ensured through large, representative samples of research material. The methods to extract and codify information may be affected by judgemental subjectivity. The problem of reliability may therefore be considerable in each of the sub-studies. To compensate for this, several sets of samples of research material have been used.

Validity concerns how well a measure does in fact measure what it is intended to measure. To address validity in this thesis, several indicators are used. The combined use of indicators gives a better measure than each of the indicators independently. According to Yin (2003), case studies using multiple sources of evidence are generally rated as having a higher quality, compared to those that rely only on single sources of information.

Validity and reliability associated with the data used in this thesis are not sufficient to provide solid answers, taken in isolation. However, the research has taken previous studies on related issues into account. To a large extent, the results found in this thesis are consistent with results in previous studies. Trustworthy results can only be established through a series of replications and validations. When the number of studies with consistent results grows, the confidence in the findings should increase. The thesis has to a certain extent indicated some nuances to common understanding of project flexibility. Further research is needed to clarify to what extent these indications are of a general nature or project-specific.

3. Flexibility in different project phases

This chapter discusses project flexibility in different project phases. With efficiency in mind, both this thesis and previous research point to a flexible front-end phase as the least controversial aspect of project flexibility. From the same perspective, a flexible execution phase is generally not desired. One purpose of the chapter is to illustrate and analyse the background to these statements. In addition, an attempt is made to quantify some measures on project flexibility in a time perspective.

This thesis makes a distinction between three different project phases: front-end, planning and execution. The *front-end phase* covers the activities prior to the final decision to go ahead with the project. Even though planning is a part of the front-end phase, most projects also have a *planning phase* for more detailed preparation after the project has been decided upon. Projects are implemented in an *execution phase*, which ends when the project outputs are realised.

Authors on project management, including Morris & Hough (1987) and Miller & Lessard (2000), frequently warn against changes in projects once specifications have been established. Lundin & Söderholm (1995) describe how a project moves from relative openness at the beginning of the project, to being relatively closed in the execution phase. In the execution phase the predetermined action is supposed to be carried out according to the plans, in a '*planned isolation*'. The concept of project flexibility in the execution phase disturbs this planned isolation. In a similar way, Mahmoud-Jouini et al. (2004) characterise project management by the speed of three project phases: preparation, freezing and implementation.

In the study of 18 projects presented in Paper 1, changes and iterations were observed in all phases of the projects, but particularly during the planning phase. Highly flexible planning phases, and to a certain extent also execution phases, were pointed to as a major problem during the preparations for the quality assurance regime for major governmental investments (Berg et al. 1999).

3.1 A time perspective on projects

Many textbooks on project management present models to illustrate how project attributes change during different project phases. Figure 2 is an attempt to summarise the different models. Even though the shapes of the curves vary between different authors, they have many similarities. Uncertainty, significance of decisions and the degree of freedom to manoeuvre are typically high at the beginning of the project, and low at the end. At the same time, variables such as the accumulated cost, available information and cost of changes begin at low levels and reach high levels at the end of a project.

Even though this type of figure as shown in Figure 2 is very common and appears logical, the models are primary illustrations, and appear to a lesser extent to be based directly on empirical evidence. There are obvious challenges in quantifying and measuring the different variables. One study in Miller & Lessard (2000: 34) shows that for one particular project, regulatory, political and financial risks were at their highest during the middle of the project.

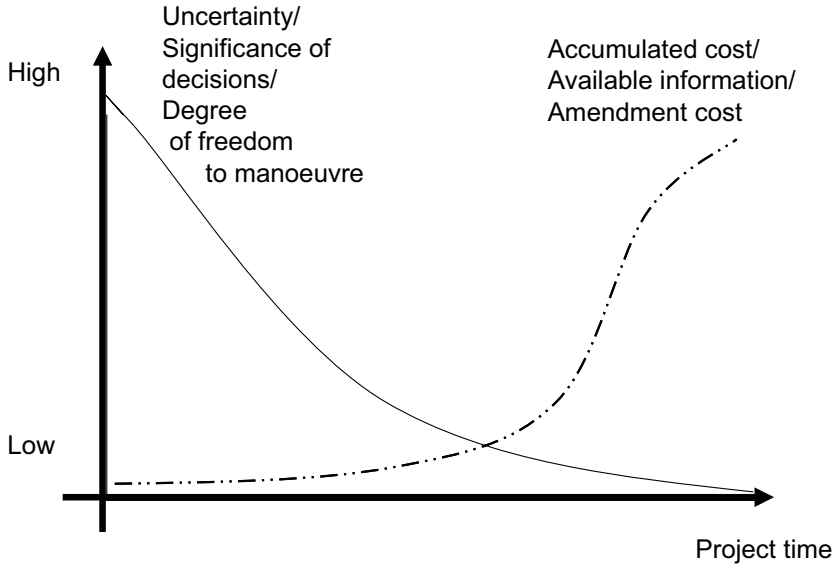

Figure 2. Development of selected project characteristics in a time perspective. (Paper 3, fig. 1. Based on Christensen & Kreiner 1991: 40, Midler 1995: 369, Samset 2001: 33, Mikkelsen & Riis 2003: 47)

The 'high to low' curve may represent different variables, but the underlying message is similar. Christensen & Kreiner (1991: 40) use Galbraith's (1973) definition of uncertainty as the difference between the required information and the information available. As the available information increases, the uncertainty decreases through the project. Samset (2001) uses a similar definition of uncertainty. Eikeland (2001), on the other hand, equalises '*room for manoeuvring*' with the internal uncertainty of the project, related to internal decisions that will be, but are not yet taken. A decision is within the room for manoeuvring if it does not violate the consequences of previous decisions. Midler (1995) relates the decreasing degree of freedom to manoeuvre with an increasing degree of irreversibility in project decisions. Mahmoud-Jouini et al. (2004: 361) describe the descending curve as 'possibilities of action in the project'. Mikkelsen & Riis, (2003: 47) let the 'high to low' curve represent the importance of decisions.

The 'low to high' curve usually represents either accumulated cost (Eikeland 2001), relative amount of information or knowledge available related to the project (Midler 1995, Mikkelsen & Riis 2003, Mahmoud-Jouini et al. 2004), or amendment cost (Samset 2001).

3.2 Quantifications of flexibility based on scope reduction options

In the quality assurance reports for major governmental investments, it is a part of the consultants' assignment to identify potential project *scope reductions*. These are reductions that can be carried out if other parts of the project turn out to be more costly than planned. If necessary, these parts of the scope can be taken out of the projects without threatening the fundamental functionality of the delivery. These possible reductions are summarised as reduction lists, where the potential cost

reductions are described. In the studied projects, even though it was not a formal requirement, many of the consultants chosed to add due dates for the scope reductions, to indicate when decisions had to be made to realise any cost saving from the reductions.

Reductions in quality or functionality were proposed in almost half of the studied projects. These were reductions that lowered the quality, but the volume of core deliveries from projects remained the same as planned. For road projects, the length of the new road was not changed. A common type of reduction for roads was to reduce planned improvements of existing roads, in connection with the new construction. Adjustments of ambitions related to the aesthetic quality of the project deliveries were common. Examples of this category include planting fewer trees, establishing smaller lawns and reducing the aesthetic quality of concrete walls.

Reduction lists provide an illustration of the reductions that were judged to be manageable from a project management point of view. The need for fast decisions regarding possible reductions was very commonly emphasised. As a rule of thumb, reductions in system architecture and quality standards have to be made early in the projects. It is possible to make reductions in volume and visual impression at later stages, depending on the contract structure. Another comment was that the potential volume of the reductions was so small that it did not justify setting up a system to manage the reductions. Finally, it was frequently commented that the due dates for the reductions typically came before it was realistic for project management to have updated cost estimates that could indicate any potential overruns.

A quantitative analysis of flexibility in different project phases is included in Paper 3, using data from reduction lists in quality assurance reports for major governmental investments. For about half of the projects, the reduction lists also included due dates to define when the window of opportunity closed for each item on the reduction list. Based on the reduction lists and due dates, it was possible to illustrate how the due dates of the items on the reduction list expired as time passes. This means that a part of the curve for the freedom to manoeuvre in Figure 2 could be drawn based on the empirical data presented in Paper 3.The relative size of the remaining open reductions can be seen as an illustration of the ‘room for manoeuvring’. Figure 3 shows the curve generated from the reduction lists in relation to a whole project time span. The size of reduction list is indicated by the grey area in Figure 3. At the time of parliamentary approval, the total value of all possible reductions on the reduction lists was in the range of 5–7% of total project costs. It should be noted that the size of remaining items on the reduction lists drops relatively sharply after this point. The size and shape of the grey area in Figure 3 supports the illustrative models used in many textbooks, which were referred to in relation to Figure 2.

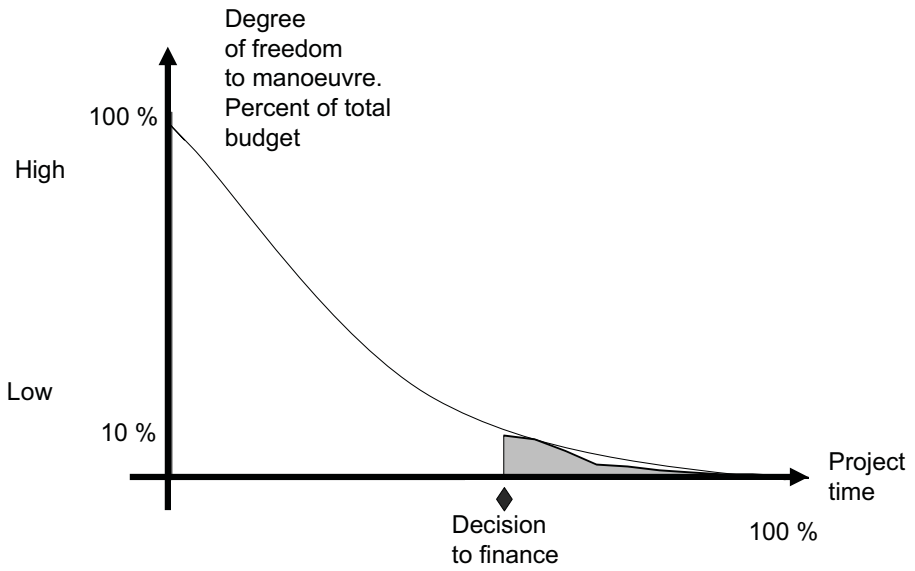

Figure 3. The relative size of the reduction lists as a percentage of the total budget at different phases of the projects. N=19

Another way of quantifying the remaining flexibility options at the time of final approval of projects is to look at the reduction lists and allocated *reserves* in combination. On average, the reduction lists amounted to 6% of the total project budget. At the same time, an average of 8% of the project budgets was allocated as reserves, to cover unexpected expenses. Adding these two types of flexibility gives an approximate total remaining flexibility of 14% of the total budget at the time of parliamentary approval. The remaining flexibility options ranging between 10% and 15% of the total budget appeared to be manageable at the time of final project approval, measured by the relative size of reduction lists and allocated reserves.

The Norwegian building and civil engineering contract, NS 8405 (*Norsk bygge- og anleggskontrakt NS 8405* 2004), states that a project owner cannot demand changes exceeding 15% of the total contract value. This value corresponds fairly well with the results presented above.

3.3 Flexibility visualisations

According to Eikeland (2001), a decision is within the room for manoeuvring if it does not violate the consequences of previous decisions. As shown in Figure 4, the need for room for manoeuvring is within the actual room for manoeuvring in the early phase of projects (area A), but not during later parts of projects (area B). Eikeland (2001) also points out that a major challenge in project management is that the need for room for manoeuvring is typically at its highest when the actual freedom for manoeuvring has already decreased significantly. Area B represents situations when some stakeholders (for example, users or project owners) have a desired room for manoeuvring that is larger than the actual room. To satisfy the desire for adjustments, changes have to be made, because the adjustments violate previous decisions.

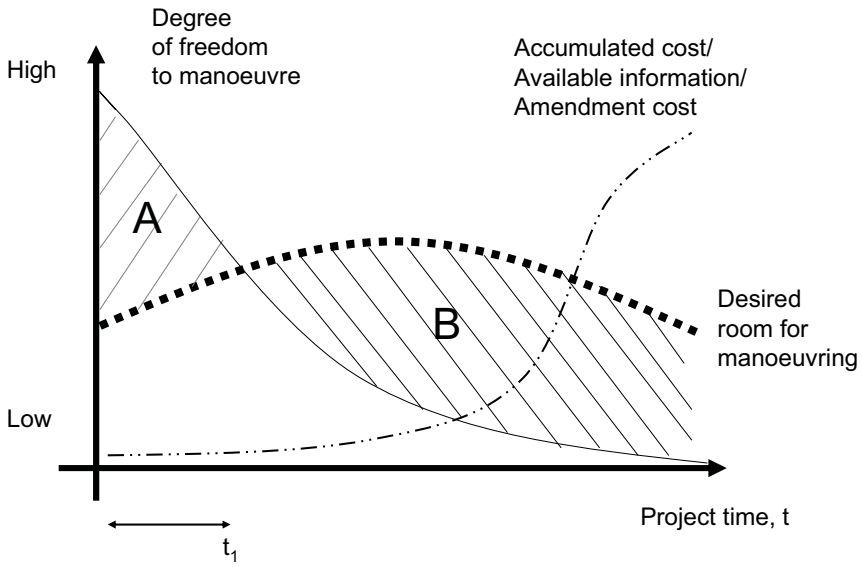

Figure 4. Consequences of different values of the uncertainty, significance of decisions and the degree of freedom to manoeuvre compared to the desired room for manoeuvring in different project phases. (Paper 7, fig. 6. Based on Eikeland 2001: 40)

With regard to Figure 4, this thesis has addressed two aspects. First, an attempt was made to quantify curves in the figure, as described earlier. Second, the work on the thesis has been a search for project management strategies that utilise the area shown as A. It should be noted that the critical measure is not necessarily the size of area A and B, but the time t_1, when the curves for actual and desired freedom to manoeuvre cross. Area A actually represents a 'flexibility surplus' and area B a 'flexibility undersupply'.

Based on product development projects, Midler (1995), Verganti (1999) and Bahrami & Evans (2005) identify strategies to increase area A and to reduce area B shown in Figure 4. The purpose is to avoid changes but to keep options open to satisfy as much as possible of the anticipated need for manoeuvring. Midler (1995) describes a management strategy for concurrent engineering projects. First, early commitment is prevented while as much information as possible is gathered on the project. In the second phase, the project is locked as precisely as possible. Finally, at the end of the project, speed is given maximum priority in order to solve the remaining technical obstacles.

Paper 1 and Paper 8 study observed flexibility in 18 projects. Most of these projects were subject to changes, extensions and iterations, i.e. they were in area B in Figure 4. When analysing project flexibility over time, there was also need to make a distinction between planned and actual approaches to flexibility. Approaches to flexibility changed during the projects and the actual approaches were not necessarily the same as the planned ones.

Earlier in this chapter, it was noted that different stakeholders have different perspectives on projects flexibility in different project phases. This leads to the next topic: project stakeholders.

4. Project stakeholders

This chapter analyses project flexibility from a stakeholder perspective. Project *stakeholders* are actively involved in a project, or their interests may be positively or negatively affected by a project. An analysis of flexibility in a stakeholder perspective called for a distinction between *internal* and *external project flexibility*. Project internal flexibility relates to flexibility within defined scope. Project external flexibility relates to adjustments of scope. The approach to flexibility held by the different stakeholders is closely related to the incentives open to the stakeholders. Flexible projects have a value for those who can align a project to their priorities, but flexibility represents a cost for those who have to adapt.

4.1 Stakeholders

According to McElroy & Mills (2000), project stakeholders are persons or groups of people who have a vested interest in the success of a project and the environment within which the project operates. In a study of large engineering projects, Olander & Landin (2005) found that it is important for a project management team to identify stakeholders that can affect a project, and then manage their differing demands throughout the project stages. Stakeholders may be organisations or individuals. The following discussion is focused on four types of project stakeholders: owners, users, project management, and contractors.

It is the project *owner* that takes the risk related to the cost and future viability of a project. Both these risks can to a certain extent be transferred to other actors in a project.

Users can be described using a wide or a narrow definition. The wide definition of users includes all that use the result of the project (the hospital, railway companies, etc.). During the project preparation and execution, users are not easily identified. This means that projects usually interact with user representatives, who act on behalf of those who intend to use the result of the project. The narrow definition of 'users' refers to such user representatives.

The '*project management*' stakeholder refers to the project manager acting on behalf of the project owner and the organisation supporting this function. *Contractors* are responsible for implementing the whole or part(s) of the project.

Results presented in Paper 4 indicate that project owners and users are more likely to be positive towards changes aimed at increasing the benefit side of the projects, or related to effectiveness. Stakeholders whose main responsibility lies on the cost side of the project, such as project management and contractors, are less likely to embrace changes. According to Kreiner (1995), the project management is made the guardian of efficiency. Müller & Turner (2005) claim that owners should impose medium levels of structure on project managers. Too much structure will not give the project manager sufficient flexibility to deal with any uncertainties that arise. Too little structure will lead to anarchy.

4.2 Incentives

Incentives for different project stakeholders are strongly related to the contracting structure of a project and other financial obligations. A common tool for achieving flexibility in projects is the use of option-based contracts, which enable a continuous locking of the projects. Mahmoud-Jouini et al. (2004) point out that a key factor in creating win-win situations between the stakeholders in *Engineering, Procurement and Construction (EPC)* contracts lies in the flexibility of contracts and the implicit relations that are created by the contracts. Garel & Midler (2001) studied contractual structures that enable front-loading and coherent incentives for manufacturers and suppliers in the automotive industry. Their analysis is based on a game theory approach, where dealing with flexibility can be a win-win or zero-sum game between the stakeholders. In the co-development of automotive parts, the supplier receives no additional payments for late identification of the need for modifications in the design phase. The supplier therefore has strong incentives to provide engineering expertise to work closely with the manufacturer in order to understand the needs and the production process (Garel & Midler 2001).

The users are a group of stakeholders that often do not have contracts related to the projects. Their incentives are more likely to be related to quality than project cost. Even though Paper 1 found that the users in the studied projects favoured flexibility in general, especially one case showed that the users preferred bold commitments and clear answers in the front-end phase because they wanted to know as precisely as possible what they could expect from the project.

Flexibility also has to do with politics. In general, stakeholders are less likely to favour a continued flexible decision process when an initial decision has been taken in their favour. Consequently, a continued flexible decision process is valued by those who do not prefer an initial decision. Flexibility options might be used as a tool for stakeholders who want decisions to be remade. Flexible decision processes can be used to justify that decisions do not need to be taken or can be revised, thus becoming a tool for irresoluteness.

4.3 Internal and external flexibility

A distinction can be made between internal and external project flexibility. Project internal flexibility relates to flexibility within a defined scope – *how* requirements will be met. Project external flexibility relates to adjustments of project scope – *what* requirements will be met.

Project internal flexibility has its roots in an efficiency perspective. In an engineering tradition, the objective of front-end management is to provide a well-defined framework for efficient project implementation. This does not mean that flexibility is undesirable, but that adjustments are held within the defined project scope. This perspective is often held by project managers and contractors. It is also the approach to flexibility that is taken by lean construction (including Koskela (2000) and Ballard & Howell (2003)). To illustrate the need for internal flexibility Koerckel et al. (2005) claim that work flow reliability historically has been *c*.50% in construction projects, based on a one-week planning horizon, i.e. only 50% of the tasks scheduled for one week can be expected to actually be completed during that particular week. As discussed in Paper 3 related to major Norwegian governmental projects, the

mandatory quality assurance aims at defining the projects as precisely as possible, but still provides project management with the freedom to decide how the specifications are to be met and budgets to be upheld. In a similar way, Turner (2004) claims that one of four necessary conditions for project success is that the project manager is *empowered*. The project owner should give guidance on how the project can be best achieved, but allow project managers flexibility to handle unforeseen circumstances. Note that Williams (1997) claims that project risk management and empowerment of teams within a project compete with each other in complex projects, because of interconnection between the tasks of different project teams.

Project external flexibility has its roots in an effectiveness perspective. Based on what is termed a social science tradition, an objective of the front-end phase is to align the content of the project to the objectives of the stakeholders. Objectives may be shifting; implying certain needs for flexibility. It is primarily the value of this type of flexibility that is quantified by real options (Amram & Kulatlaka 1999, Brennan & Trigeorgis 2000). This type of flexibility option appears particularly desirable to users and project owners.

Internal and external flexibility, on the one hand, and internal and contextual uncertainty on the other hand, are related issues. However, internal flexibility is not necessarily a response to internal uncertainty, and external flexibility can, but does not have to, be a response to contextual uncertainty. Figure 5 shows that all combinations of the two dimensions can be found.

The empirical data that this thesis is based on provide mainly information about external flexibility. In-depth analysis of project internal flexibility would require different empirical sources. The distinction between project internal and external flexibility was made for two reasons. First, it is intended to clarify the flexibility approaches that have been the main focus in the thesis. Secondly, the distinction between project internal and external flexibility is intended as a contribution to the general framework for analysis of project flexibility.

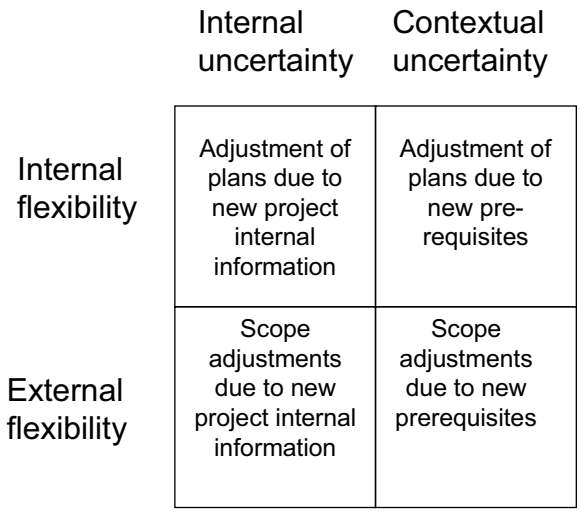

Figure 5. Internal and external flexibility, combined with internal and contextual uncertainty.

Figure 6 is a summary of the observed approach on external flexibility seen in a time perspective, as presented in Paper 1. Project management was the only type of stakeholder that showed the expected shift from promoting a flexible front-end, hesitating towards a flexible planning phase and finally being negative to a flexible execution phase. As a possible explanation, the project management might be the stakeholder that is most likely to see the effects of flexibility, both on the benefit and cost side.

In general, project owners appeared as advocates of flexible projects. Contractors were not observed as advocates of flexible projects. Figure 6 also shows that users and project management have different and potentially conflicting needs for external flexibility in different project phases. As long as the funding model for projects means that the users have nothing to lose from demanding changes and extensions, they have incentive to push for scope changes. This is typically, though not always, the case in the Norwegian public sector, which accounts for the majority of the projects in the analysis in Paper 1.

	Front-end	Planning	Execution
Owner	+	+	+
Users	+/-	+	+
Project management	+	+/-	-
Contractor	N/A	-	-

Figure 6. Stakeholder perspectives on external flexibility in project phases. + indicates that flexibility is advocated; - indicates a desire for flexibility minimisation; +/- indicates that both approaches were observed. (Paper 1, fig. 2.)

Kreiner (1995) termed project management 'the guardian of efficiency'. The results from Paper 1 indicate that this guardian role is dependent upon the organisational connection to the project owner. In cases where the project management was found to be in the same organisation as the owner, project management was more likely to be positive to flexibility, compared to cases where project management had a weaker organisational connection to the project owner and the guardian role could be exercised more freely.

Incentives open to the stakeholders is an explaining factor for the stakeholders' perspective on project flexibility. Flexibility options have a value for stakeholders that benefit from changes and late locking of final scope. In the study presented in Paper 1, the stakeholders that had their incentives related to achieving the project's purpose were the advocates of flexibility. Stakeholders that had their incentives related to delivering the project on time and within budget saw flexibility as a threat. External flexibility usually means that the contractors have to spend resources on adapting. However, contractors may also have incentives to embrace change because this gives them room to ask for additional payments. This is discussed by Garel & Midler (2001) in relation to contract structures.

Based on results presented in Paper 1 and Paper 3, Figure 7 indicates that the room for external flexibility decreases over time. As the project scope becomes clarified, the relative focus on internal flexibility increases. The analysis of scope reductions presented in Paper 3 can be seen as an illustration of external flexibility. The shape of the right half of Figure 7 is based on these results, where external flexibility decreases rapidly after the final approval of a project.

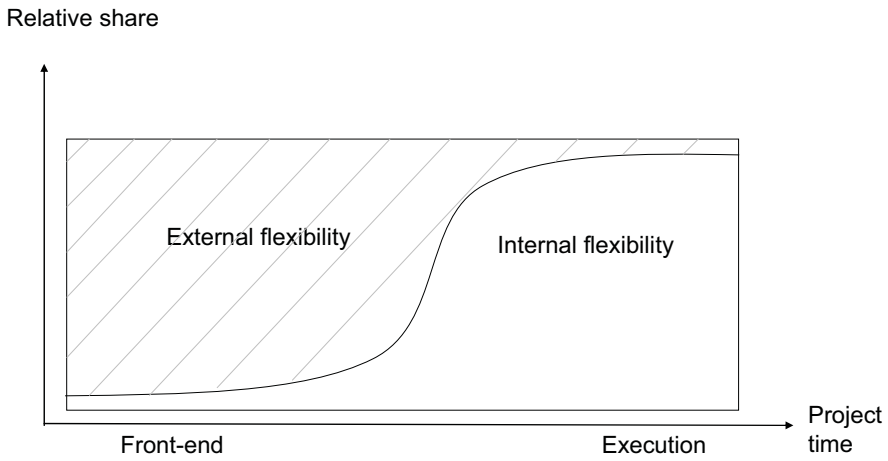

Figure 7. External and internal flexibility in a time perspective.

5. Effectiveness and efficiency

Project success is often measured in terms of *efficiency* and *effectiveness*. In general, efficiency is related to producing direct outputs, and effectiveness is related to added value for owners and users. Changes usually reduce project efficiency. Flexible approaches in projects are frequently seen as enablers of effectiveness. One key purpose of project flexibility is to achieve flexible projects without creating a flow of scope changes. Cost of changes is a common argument against project flexibility. Changes are key issues when discussing flexibility, but project flexibility as discussed in this thesis is a wider concept than scope change management.

5.1 Cost implications

Figure 8 shows the relative cost in relation to the degree of flexibility. Two curves are drawn: one for internal (how?) flexibility and one for external (what?) flexibility. Increasing cost for high external flexibility is primarily related to external changes. To be highly flexible causes, on average, a higher cost, compared to a project that is less flexible. Increased cost of high flexibility comes either from redundant resources to manage changes and decision iterations, or unintended change to cost if such redundancy was not available but changes came anyway. This relation is similar to the traditional curve with increasing cost of changes over time in a project. It should be noted that increased cost can be compensated for by increased benefits. On the other hand, the cost curve related to internal flexibility decreases with higher flexibility. The fewer restrictions, the better opportunities a contactor or project manager has to optimise the use of available resources. This is a part of the logic behind lean construction.

The results presented in this thesis have shown significant cost overruns for highly flexible projects. Cost overruns have ranged at *c*.100% for highly flexible projects, as shown in Paper 7. These results have justified a steep rising cost curve for external flexibility in Figure 8. In comparison, Jacobsen (2006) refers to cost reductions related to high internal flexibility (or more precisely, related to lean construction implementations in the USA and Denmark) at *c*.10%. Koerckel et al. (2005) report that a lean construction initiative resulted in a 6.4% budget underrun on a railway investment project (related to the railway tunnel between Britain and France). The relatively flat curve related to cost reduction for internal flexibility is drawn with these numbers in mind.

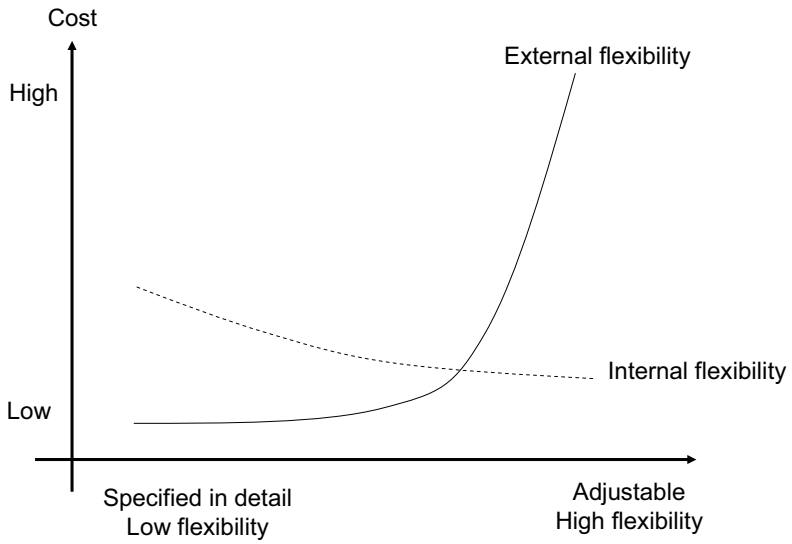

Figure 8. Indications of cost in relation to the degree of flexibility for internal flexibility and external flexibility.

Changes are a source of major disagreements between different project stakeholders. This issue deserves some attention, and is addressed in the next section.

5.2 Changes

As pointed out by Williams (2000), change control is an established part of project management. Many textbooks on project management, including those by the PMI (2004) and Samset (2001), include explanations and illustrations which show that the scope change cost is typically low in the front-end phase of projects, and becomes increasingly higher with time. This increase in scope change cost over time is widely accepted, and is a major challenge to project flexibility. Once a project has been decided upon and the planning or execution has begun, scope changes are likely to reduce the efficiency of the project, as shown by Hanna et al. (2002).

The PMI (2004) defines the management of both changes and extensions as scope change control. A wide range of authors (including Morris & Hough 1987, Eikeland 2001, Love et al. 2004) have pointed to scope changes as a key driver to cost overruns of projects. Based on a study of 448 projects, Dvir & Lechler (2004) showed that changes in both plans and goals of projects typically reduce both the efficiency and customer satisfaction of engineering projects. Scope changes are key issues when discussing flexibility, but project flexibility as discussed in this thesis is a wider concept than scope change management. A change requires that something already has been decided and a project baseline has been established (PMI 2004). One key purpose of project flexibility is to achieve flexible projects without creating scope changes in them.

Typically, a scope change is proposed because the users or project owner want to increase the effectiveness of the project. As shown by Ibbs et al. (2001), using benefit-to-cost ratio, the reduction in efficiency might be compensated by a higher increase in effectiveness, depending on the timing and type of change. Two sources of

conflicts related to scope changes can be identified. First, conflicts may arise regarding quantification of the increase in effectiveness and reduction in efficiency. This is related to the high and unpredictable cost of change orders. The second conflict source is linked to allocating responsibility for reductions in efficiency. Challenges in estimating the effect of changes orders are discussed by Eden, Williams & Ackermann (2005). They particularly point to problems in finding a reference point which describes the performance of a project in a period when the project was not disturbed by changes. Eden, Ackermann & Williams (2005) describes underlying mechanisms for how changes can cause cost overruns. They point to non-linear relations between changes and cost development.

Project internal processes can be simulated, either e*x ante* to predict the outcome of a particular project design or *ex post* to explain and illustrate causes and effects in projects. Kunz, Levitt & Jin (1998) and Christiansen (1993) describe how principles from general management research can be applied in a computer based simulation model. This type of simulation has been used as decision support to predict the outcome of a particular project, as shown by Kunz, Rivero & Levitt (2000) and DNV (2000). Williams (2003) proposes combined use of causal mapping and System Dynamics to analyse the effect of a delay upon a project.

To quantify the effect of changes, Cooper & Reichelt (2004) have performed simulations of the aggregated disruptions caused by changes. Their simulations predicted that a change equivalent to 10% of the total project budget would cause disruptions amounting to 2.8 times the estimated size of a change.

Løken (2005) tested this estimate on a major scope change (called 'U96') in a Norwegian hospital project (Nytt Rikshospital). Based on a cut-off in year 2000, the scope change isolated was estimated to 424 million NOK, equivalent to *c*.10% the total cost. At the same cut-off time, total cost overruns were estimated to 1,105 million NOK. Simulations of Cooper & Reichelt (2004) then predict that such a change causes disruptions in the order of 2.8 times the estimated size of a change, or 1,013 million NOK. One interpretation of this is that disruptions from the scope change caused 92% the total cost overruns. This interpretation is supported by an evaluation report of the project (Arbeids- og administrasjonsdepartementet 2001). The evaluation report claims that this particular scope change was a major contribution to the total cost overruns, even though there were other additional factors.

Paper 3 studied how change management was approached in quality assurance reports. The strong emphasis on scope change management in the quality assurance reports indicates that changes and flexibility are primarily treated as something to be minimised, or at least to have a strict regime for. Management of changes was mentioned as a top issue in half of the projects. In most cases, the purpose was to establish a structured management of scope changes in order to minimise the amount and size of the changes.

Thus, at least two different strategies can be identified to manage scope changes: either to avoid changes or to reduce the negative impact from any changes that do arise. In the following, these two approaches for change management will be discussed in relation to redundancy.

5.3 Redundancy

According to Galbraith (1973), a critical limiting factor of organisations is the ability to handle the non-routine events that cannot be anticipated or planned for. When the 'exceptions' become too prevalent, they overwhelm the hierarchy's ability to process them. Variations in organisation design arise from different strategies to increase planning ability and to reduce the number of exceptional events that management must resolve.

Galbraith (1973) defines a number of organisational forms that firms apply to manage uncertainty. These are either designed to increase capacity for information processing, or to reduce the need for information processing. Improvements in vertical or horizontal information processing are used to increase capacity for information processing. Slack resources or creation of self-contained tasks are used to reduce the information processing need. Self-contained tasks will be discussed in the next chapter, in relation to modularity.

Redundancy is an enabler for flexibility (Sager 1994). According to Landau (1969), redundancy is created by repetition, duplication and overlap. Galbraith (1973) points out that slack resources constitute an additional cost to an organisation. If a firm fails to actively create other strategies to address uncertainty, the slack resources strategy will occur by default. The logic behind redundancy is that a plan incorporating redundancy will be efficient because it can be executed as planned, compared to a plan with no redundancy that is vulnerable and error-prone in reality. Thompson (1967) also points out that the use of buffers or slack is common strategy for coping with uncertainty.

In Figure 9, '*precision*' is used to indicate low redundancy and '*slack*' to indicate high redundancy. The figure is inspired by a table in Olsson & Haugland (2004). Management of changes is another characteristic of alternative project flexibility strategies. Flexibility approaches can either aim at avoiding changes or managing changes. Figure 9 shows how these two perspectives, degree of redundancy and change management, characterise different approaches to project flexibility management. In the following, the different strategies are briefly presented.

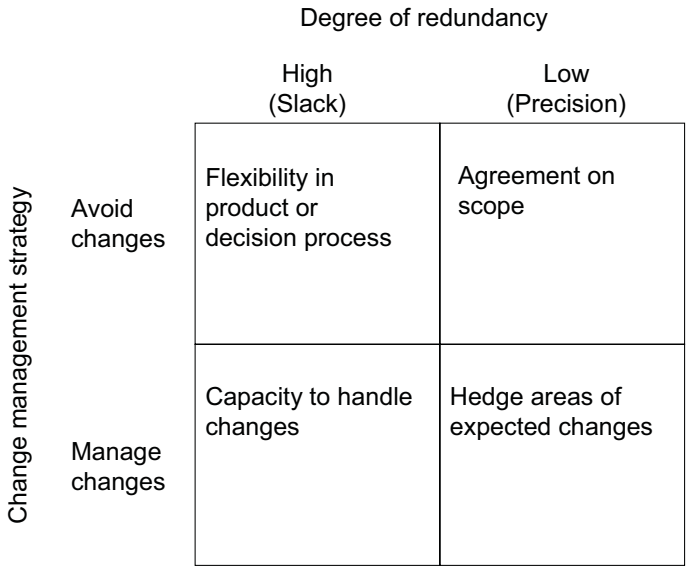

Figure 9. Flexibility strategies in relation to redundancy and change management. (Paper 8, fig. 3)

Avoid changes, high redundancy
Redundancy can be achieved by over-specification of future functionality. Future needs may be met without physical changes. Such needs may emerge during the project execution, or after the project has been delivered. Redundancy can also enable front-end analyses of alternative project concepts, which require recourses and time but may avoid later changes.

Avoid changes, low redundancy
Aiming at a clear agreement on scope represents a traditional project management approach – to zoom in on project scope and then execute. After establishing the scope, project management aims at minimising external flexibility.

Manage changes, high redundancy
High redundancy indicates a general capacity to manage a wide range of changes. 'Slack' is a keyword, including budget reserves, time slack in plans and organisation capacity to manage changes. On average, this increases project cost. However, it may still prove cost effective if the alternative is that the project will face changes which it does not have the resources to manage.

Manage changes, low redundancy
In the process of locking specifications, certain parts are locked later than others. Low redundancy requires ability to identify and hedge areas exposed to changes. The late locking items must therefore be well defined and of a limited relative size.

6. Project flexibility categorisations

One aim of the thesis is to identify and describe different aspects of project flexibility. The previous chapters have discussed flexibility related to project phases, stakeholders and incentives, efficiency and effectiveness as well as redundancy.

Regarding categorisations of project flexibility, a distinction has already been made between internal and external flexibility. This chapter discusses flexibility related to modularity, flexible decision processes and flexible final products. The results of the analysis indicated that it was appropriate to make a distinction between planned and actual flexibility approaches.

6.1 Producing a flexible result or producing the result in a flexible manner

Flexibility in a project can be associated with the decision process or the final product. This chapter describes these two dimensions of flexibility, and investigates interaction between them.

Flexibility in the decision process is based on an approach where decisions and commitments in the projects are made sequentially over episodes. The use of decision gate models provides a successive commitment to a project, as shown by Eskerod & Östergren (2000). Iterative and successive project decisions were also recommended by SIS TR 321 (Systems development reference model). The philosophy of not taking decisions until the last responsive moment, as shown by Ballard & Howell (2003), is also an example of flexibility in the decision process.

Flexibility in the product means that the design of the final product (what the project will produce) has taken into consideration possible future changes in use or requirements. If requirements are altered, no changes are needed because the design can accommodate the revised requirements. Flexibility in the product is achieved when the final product of the project is prepared for alternative use. As described by Brand (1994) and Blakstad (2001), this approach to flexibility is used in building construction. According to Arge & Landstad (2002), a commonly used classification of building adaptability was made in Sweden during the 1960s and 1970s. Based on this classification, *generality* is the ability of the building to meet shifting demands without physical changes. In this terminology, *flexibility* is related to possibilities for technical changes with minimum cost and disturbance. Lastly, *elasticity* means the potential for adding to or reducing the size of the building. In this thesis, all three characteristics collectively are referred to as flexibility.

Flexibility in the decision process and the product has been analysed independently by researchers previously (e.g. Brand 1994, Slaughter 2001, Boehm & Turner 2003). However, fewer studies have been made on the interaction between dimensions, Gill et al. (2005) being a notable exception. Flexibility in the decision process and the product may interact for any given project. Different types of interaction are depicted in Figure 10, each characterised by high or low flexibility in the process and product respectively. In Figure 10, high flexibility in the decision process in the study includes changes, extensions and iterations in the project preparations. A high flexibility in the product means that the result of the project is prepared for alternative use.

The situation with low flexibility in both the product and the decision process means that no preparations for project flexibility are made. A strategy characterised by high flexibility in the product and low flexibility in the process is termed a 'robust concept'. One assumption was that the decision process related to this type of project can be fairly straightforward because the result of the project is prepared for alternative use.

A basic principle in the situation with low flexibility in the product, and high flexibility in the process is that final decisions can be postponed in order to gain as much knowledge as possible. The situation with high flexibility in both the product and the process contains many of the aspects related to the other two strategies with high flexibility in either the process or the product.

The degree of flexibility in the product is typically intentionally established at an early stage in a project. On the other hand, a flexible decision process may either be intended or ad hoc.

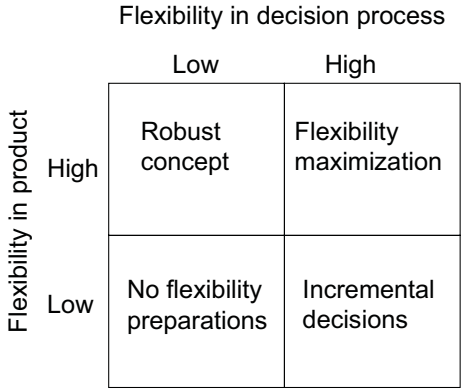

Figure 10. Flexibility in the product and the decision process. (Based on Paper 1, fig. 1)

Paper 1 describes studies of observed flexibility in 18 projects. Less than one-third of the projects had prepared for flexible decision processes. Paper 7 analyses flexibility in the decision process and the product related to cost overruns for the same 18 projects. Regardless of flexibility in the product, the 10 projects with highly flexible decision processes resulted in more than a 100% cost overrun, compared to the initial budgets. Most of these projects were subject to changes, extensions and iterations (summarised as 'flexibility in the decision process').

There are indications that projects with highly flexible product designs also had flexible decision processes as a response to contextual uncertainty. If this is the case, flexible products and flexible decision processes cannot compensate for each other as clear-cut as described in connection to Figure 10. It should be noted that the results are based on studies of few projects, especially when the projects are divided into subgroups.

6.2 Modularity

Flexibility can be related to the degree of *modularity* in projects. Modularity refers to the possibility to divide a project into more or less independent sub-units. According to Miller & Lessard (2000), modularity can enable projects to cope with uncertainty because individual components do not have a critical role.

Design modularity is a common approach to achieve flexibility (Thomke 1997, Hellström & Wikström 2005). Hellström & Wikström (2005: 394) define modularisation as '*decomposition of a part of a product into building blocks (modules) with specified interfaces, driven by company-specific reasons*'. Thomke (1997) claims that modularisation in product development projects is primarily a tool to improve project efficiency. One benefit of design modularity is that the 'knock-on' effects of changes can be reduced.

Galbraith (1973) defined organisational forms that firms apply to manage uncertainty. One strategy for reducing the need for information processing is the creation of self-contained tasks. This can be seen as a form of modularisation.

An approach of minimal commitment at each decision stage is a part of the 'anti-disaster methodology' proposed by Hall (1980: 267). According to Hall (1980: 272) '*this would generally mean an incremental or adaptive approach to development of any kind, rather than a new major departure; it would suggest enlargement and adaptation of existing airports rather than building new ones*'. Lee & Xia (2005) found that smaller and shorter information systems projects experienced fewer changes than larger projects and were more efficient in dealing with changes. They advise that projects with a duration of more than three to six months can be divided into *time-boxes* with well-defined deliverables. Another approach to incremental decision making is also found in real options (Amram & Kulatlaka 1999, Brennan & Trigeorgis 2000).

Civil engineering projects are often seen as indivisible and irreversible. Statements such as 'we do not build half a bridge' are used to argue against flexibility and modularisation. Miller & Lessard (2000) point to the irreversibility of large engineering projects and the importance of bold commitment from key stakeholders. In contrast, Genus (1997) advocates flexible and incremental decision making in large engineering projects, based on experiences from the Channel Tunnel between Britain and France.

The results presented in Paper 1 and Paper 8 also indicate that modularity frequently is an enabler for flexible decision processes. Highly modular projects were found likely to have highly flexible decision processes.

Modularity has been presented as an enabler for flexible project management. Modularity can be applied on a micro and macro level. On a micro level, design modularity is a tool for efficiency, including minimising the negative effect of changes. On a macro level, modularity is an enabler for flexible decisions processes. By dividing projects into independent sub-units, decision makers can make the incremental commitments.

As an example of modularisation on macro level, major infrastructure investments can be treated as one entity, or be divided into smaller, more or less independent projects. To analyse the effect of dividing a major project into a set of smaller ones, four railway investments have been analysed in Paper 5.

Figure 11 visualises that the four projects all had different characteristics regarding how they were planned, and how they actually were carried out. In Figure 11 'Planned approach' relates to how the project was intended to be decided upon and executed in the front-end phase; 'Actual approach' describes how the projects were finally decided upon and executed.

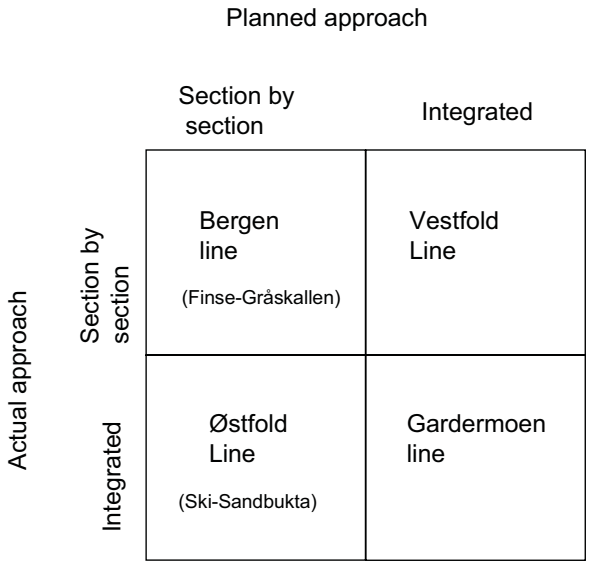

Figure 11. A model for planning and execution of railway investment projects, and how the studied projects fit the model. (Paper 5, fig. 2)

Figure 12 shows the location of the studied projects in the Norwegian railway network.

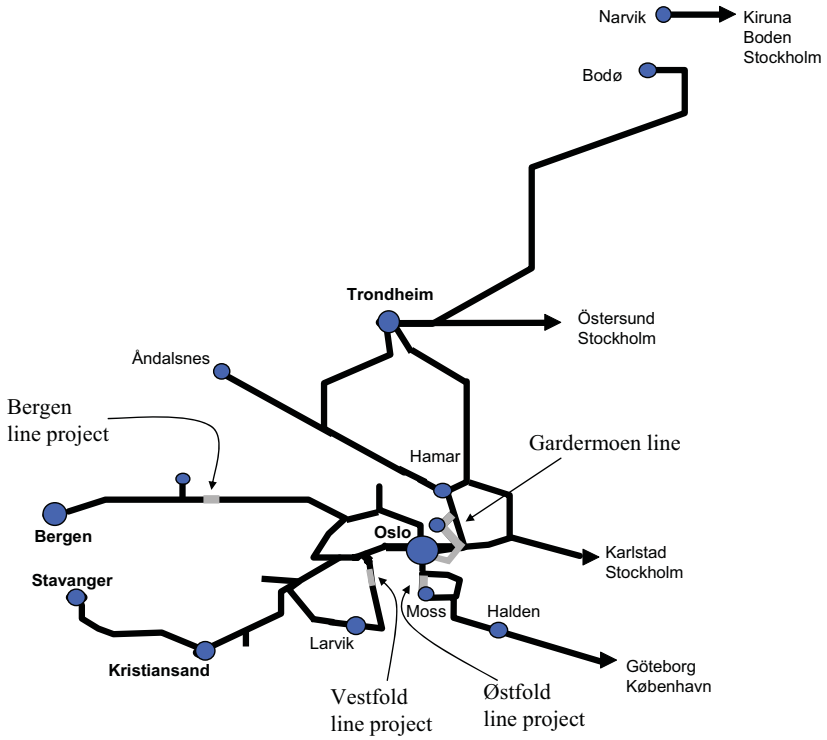

Figure 12. The Norwegian rail network and location of studied projects (in grey). The size and location of the new built rail lines are only for illustrational purpose. (Paper 5, fig. 1)

Table 2 presents a summary of the impact of the four railway projects studied. A comparison was made between the forecast and actual outcome of selected variables: travel time, frequency, punctuality, and number of travellers. The analysis also included a comparison between the situation before and after the investments. The study presented in Paper 5 indicates that the major drawback with section-by-section investments is that the traffic is not adjusted when each new railway section opens. Timetables must be adjusted to utilise new and potentially faster railway sections. Results presented in Paper 5 indicate that a critical mass of potential improvement is needed to justify timetable changes that utilise new infrastructure. Investments that are executed as integrated projects appear to be more likely to achieve timetable adjustments, compared to investments built and decided upon section by section.

Actual project approach	**Development in number of travellers, compared to before**	**Train traffic compared to before**	**Cost**
Section by section	Small changes	Moderate improvements	Control
Integrated	Major increase	Major improvements	Overruns

Table 2. Observed impact from the studied project strategies. (Paper 5, table 8)

A real options approach to railway investment aims at maximising the benefit/cost ratio by sequenced decisions, continuously utilising updated information. The study in

Paper 5 questions the possibilities to actually achieve reliable information related to benefits. The effects of investments do not materialise until the combined investments on a line reach a certain level. Dividing an investment into a series of sections, decided upon individually, may therefore result in lower benefits in terms of, for example, travel time, compared to an integrated project approach. These results are contrary to common understanding in the project management field, where flexibility usually is seen as a means of achieving increased benefit from a project, as described in Paper 4.

If modularisation of railway investments has disadvantages related to the realisation of benefits, it appears to provide cost control. These results are in accordance with Flyvbjerg et al. (2004), who point out that cost escalation of major transportation investments is highly dependent on the length of the project implementation phase. Longer implementation causes higher cost escalation.

7. Conclusions

This thesis aimed at structuring knowledge on project flexibility. Based on studies of different parts of the life cycle of projects, it was hoped that the research would provide indications to how flexibility can be addressed in the front-end phase of large public investments. This chapter summarises the findings and implications from the research. It should be borne in mind that it cannot be statistically proved that the findings are generally applicable. Validity and reliability associated with the data used in this thesis are not sufficient to provide solid answers, taken in isolation. Further research is needed to clarify to what extent these indications are of a general nature or project-specific.

7.1 How can different aspects of flexibility in projects be analysed?

One aim of the thesis is to identify different aspects of flexibility and to discuss how they can contribute to analysis and management of project flexibility. Figure 13 shows how the different aspects can be put together as a framework for analysis of project flexibility. The framework for analysis consists of project flexibility categorisations, perspectives of analysis, and flexibility drivers and enablers.

Four categorisations of project flexibility have been discussed: planned flexibility versus actual flexibility approaches; internal flexibility versus external flexibility; flexible decision processes versus flexible final products; and modularity on macro and micro level.

Three perspectives on project flexibility are used. Project flexibility is seen from the perspective of different stakeholders, in different project phases and related to efficiency and effectiveness.

Finally, drivers and enables of project flexibility are listed and discussed. Uncertainty, project duration, conflicts, and insufficient project preparations are highlighted as flexibility drivers. The enablers are degree of redundancy, incentives open to the stakeholders, and modularity. The thesis has discussed flexibility, both related to each aspect in the framework individually, and seen in combination. When analysed in combination, the aspects have been combined two and two.

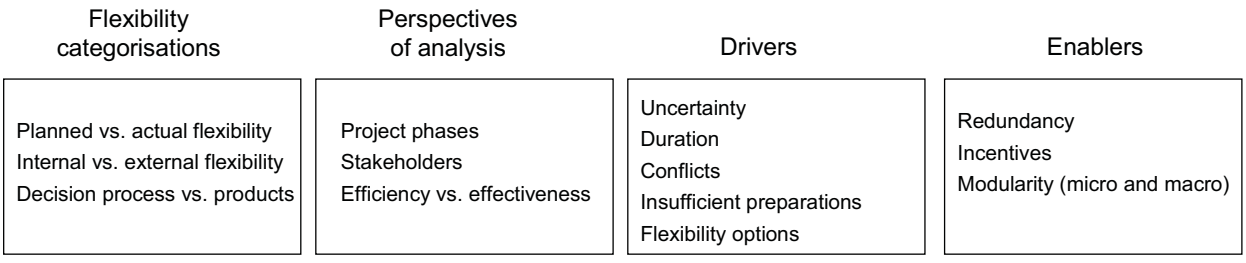

Figure 13. Framework for analysing project flexibility. (Paper 8, fig. 1)

Flexibility categorisations

The following is a short summary of findings related to the applied flexibility categorisations.

Planned flexibility versus actual flexibility approaches

Approaches to project flexibility have been analysed over time. In the studies, there was a need to make a distinction between planned and actual approaches to flexibility. Approaches to flexibility changed during the projects. Actual approaches turned out to be different from planned approaches.

Internal flexibility versus external flexibility

Another distinction was made between internal and external project flexibility. When flexibility is discussed in the literature and in general, it is most often related to external flexibility, referring to adjustments of project scope. This was also the case for the early work on this thesis. Project internal flexibility relates to flexibility within a defined scope – how requirements are to be met. Particularly, analyses of stakeholder approaches to flexibility are highly dependent upon whether internal or external flexibility is the subject of discussion. Internal and external flexibility are responses to contextual and internal uncertainty. However, internal flexibility is not limited to being a response to internal uncertainty. External flexibility can be, but does not have to be, a response to contextual uncertainty. All combinations of the two dimensions can be found.

Flexible decision process versus flexible final products

Project flexibility was divided into flexibility in the decision process and the product may interact for any given project. For the purpose of categorising flexibility, a distinction between the flexibility types has been meaningful. This thesis has also made an attempt to study the interaction between flexibility in decision processes and the product. It was expected that flexible final products would compensate for less flexible decision processes and vice versa. The results show that this interaction is not as visible as first expected. This may be due to the small sample of projects. It may also be an indication that flexible projects utilise both flexible products and flexible decision processes, rather than emphasising one of these dimensions at the expense of the other.

Perspectives of analysis

The results indicate that project flexibility is perceived differently depending on whose view one takes, and which part of a project's life cycle is subject to analysis.

Stakeholders

As mentioned above, incentives open to stakeholders affect their approaches to project flexibility. Flexible projects have been presented as a blessing and curse. One aspect of this duality is that the flexibility for one project stakeholder can be another stakeholder's risk. Project internal flexibility appears to be particularly desirable to project managers and contractors. Project external flexibility is more likely to be looked upon favourably by users and project owners, than by project managers and contractors.

Project phases
Flexibility in the front-end phases is the least controversial aspect of project flexibility. This is particularly related to external flexibility. One objective of front-end management is to provide a well-defined framework for efficient project implementation. Project flexibility can then be restricted to adjustments within the strategic framework. The thesis has discussed the theoretical foundation for this approach, and shown empirically that minimising external flexibility after the front-end phase increases the likelihood of completing projects on time, within budget and according to specifications.

Efficiency and effectiveness
Project flexibility has been studied from both efficiency and effectiveness perspectives. The case in favour of flexibility emphasises the possibility to increase a project's effectiveness. As indicated in Figure 14, effectiveness is primarily addressed by external flexibility. Project scope is adjusted to utilise benefit opportunities. Regarding efficiency, such adjustment of project scope typically causes cost of changes. The net effect comes from a balance between the values of benefit opportunities and incurred cost of changes.

Internal flexibility (within the scope of a project) is primarily linked to cost reduction opportunities, which can be utilised by project management or involved contractors.

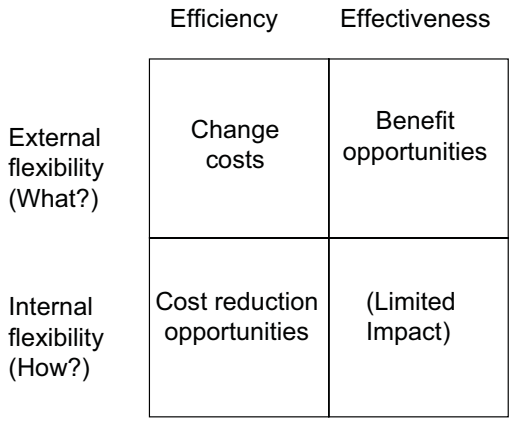

Figure 14. Internal and external flexibility versus efficiency and effectiveness.

The analyses presented in this thesis indicate a major challenge in materialising the expected benefits. On the other hand, the expected decrease in efficiency as a consequence of project flexibility has been frequently observed throughout the analysis.

Drivers

In this context, *drivers* are factors that create needs or impose pressure on projects to be flexible.

Uncertainty

Uncertainty is the key driver for project flexibility, and arguably the only one. The other drivers mentioned below are in fact only highlights of selected types of uncertainty. In this thesis, uncertainty has been related to a gap between the amount of information needed to make a decision and the amount of information available (based on Galbraith 1993). In order to manage this information gap, flexibility is primarily a way of reducing the amount of information needed. Other project management approaches often focuses on increasing the available amount of information.

Duration

The longer the duration of a project, the more likely it is that some prerequisites become no longer valid. Long duration is likely to result in more or less suppressed need for scope changes. Both cost and demand estimates are more uncertain the longer the time perspective is. What is 'long' duration is highly dependent upon the type of project. Experiences from previous projects of the same type provide indications of how long prerequisites are likely to stay sufficiently stable.

Conflicts

Flexible projects can contribute to conflict solutions. However, conflicts that arose during the preparation or execution of a project have been observed as an important driver for flexibility. Project flexibility can also be an issue of conflict. Flexible decision processes are likely to be valued by those who do not prefer an initial decision. Stakeholders who benefit from the initial decisions are less likely to favour a continued flexible decision process.

Insufficient preparations

Even though it is not a recommended situation, projects that for political or other reasons are pushed to a premature go-ahead decision are likely to need an active approach to flexibility. This type of project has been observed to be flexible, not because of opportunities for increased benefit or reduced cost, but to be possible to implement. For such projects, project flexibility serves as a cover-up for a lack of preparation.

Flexibility options

Availability of flexibility options and redundant resources can serve as an invitation to make adjustments. Of the studied projects, those with a high planned flexibility in the decision process also had a high actual flexibility in the decision process. If there are possibilities for adjustments and iterations, it is likely that flexibility options will be utilised. This means that the presence (or knowledge) of flexibility enablers can work as a flexibility driver.

Enablers

This thesis refers to e*nablers* as factors that contribute to making it possible for projects to be flexible.

Degree of redundancy

Redundancy has been presented as an enabler for flexibility. Redundancy can be applied to flexibility in both the product and decision process. Flexibility in the product may be achieved by over-specification of future functionality. A flexible decision process calls for redundant recourses and time to perform analyses of alternative project concepts. The rationality behind the use of redundancy is that this use of resources is cost effective compared to later major changes.

Incentives

Incentives for different project stakeholders are strongly related to the contracting structure of a project and other financial obligations. A common tool for achieving flexibility in projects is the use of option-based contracts, which enable a continuous locking of the projects. Flexibility has a value for those that can benefit from adjustments, and it is a cost for those who have to adapt. The fewer restrictions on their part of the project, the better opportunities there are for any stakeholder to optimise the use of available resources.

Modularity on macro and micro level

Modularity has also been identified as an enabler for flexible project management. On a micro level, design modularity is a tool for efficiency because it may reduce negative effect of changes. On a macro level, it has been shown that modularity can be an enabler for flexible decision processes because decision makers can make the incremental commitments. Macro modularisation of projects usually means that each module can be produced over a shorter time period than would have been the case for an integrated project. Shorter execution time reduces the probability for major adjustments during the project. Modularity on macro level was analysed for railway investment projects. In the studied projects, macro modularisation was associated with cost control but also with lower benefit realisation than planned.

7.2 What are the implications for front-end management?

Successful strategies for project flexibility either aim at avoiding flexibility in projects or enabling projects to manage flexibility. Projects avoid adjustments or live with them. To be more specific and using the terminology presented in the thesis, successful strategies aim either at avoiding external flexibility after the front-end phase, or at managing external flexibility during the planning and execution phases. The following discussion is related to external flexibility. Project internal flexibility has not been analysed enough in this thesis to provide implications for project management.

The longer the time-frame of a project, the less likely it is that prerequisites will remain unchanged. This means that the longer the time-frame of a project, the more important it is to prepare the project to either avoid or manage changes.

Even though the results are based on studies of a few projects, this thesis has shown that the potential drawbacks of flexible projects are substantial, both in terms of

efficiency and effectiveness. There are also indications that the drawbacks are largest when projects do not prepare for subsequent adjustments. This notion is consistent with previous works on flexibility, including Sager (1994), Volberda (1997), Abbot & Banerji (2003), and Turner (2004), that view managing flexibility as an orderly response to a changing world.

The thesis has identified some characteristics of successful project flexibility management. These findings can be of value in front-end preparations of future projects. The following summary is based on results presented in the literature, along with results from the studied projects. Four approaches to project flexibility management are presented in Table 3, together with a summary of strengths and weaknesses for each approach.

Objective	**Approach**	**Strengths**	**Weaknesses**	**Applications**
Avoid adjustments (after locking of scope)	1. Late locking of project scope and fast execution	Utilises the strengths of front-end (openness) and execution phase (focus)	Depends on fast locking of scope and execution. Lack of decisions in front-end phase can cause frustration.	Product development projects
Manage (limited) adjustments	2. Shield off areas of uncertainty	Allows the major part of a project to be executed without adjustments	Still-open items must be of limited size (max. 10-15%). Identifying the right items	Technical installations in buildings finally specified later than the rest of project
Avoid adjustments (in modules); Manage adjustments (between modules)	3. Incremental commitments	Allows each module to be executed without changes	Each module will provide benefits. Longer total implementation time	Roads or railways divided into sections
Manage adjustments	4. Absorption	More cost effective than dealing with adjustments with no available resources	Amount of adjustments can escalate beyond control	Over-specification of functionality. Redundant engineering capacity

Table 3. Approaches to external flexibility management.

The four approaches are described in more detail in the following. Each approach is illustrated, including a comparison to the generic figures in Figure 2 and Figure 4. The dashed ‘high to low’ curve that illustrates decreasing freedom for manoeuvre is the same in Figure 15, Figure 16, Figure 17, and Figure 18. This curve represents a ‘traditional’ project preparation and implementation. The purpose of Figure 15, Figure

16, Figure 17, and Figure 18 is to illustrate how each approach differs from a 'traditional' project. In reality, most projects are likely to choose a combination of the suggested approaches.

1. Late locking of scope and fast execution
After an extensive front-end phase, the project scope is defined and the project is executed. This is similar to a traditional project management approach, but emphasises a fast transition from front-end to execution. The approach means minimising external flexibility after the scope is established.

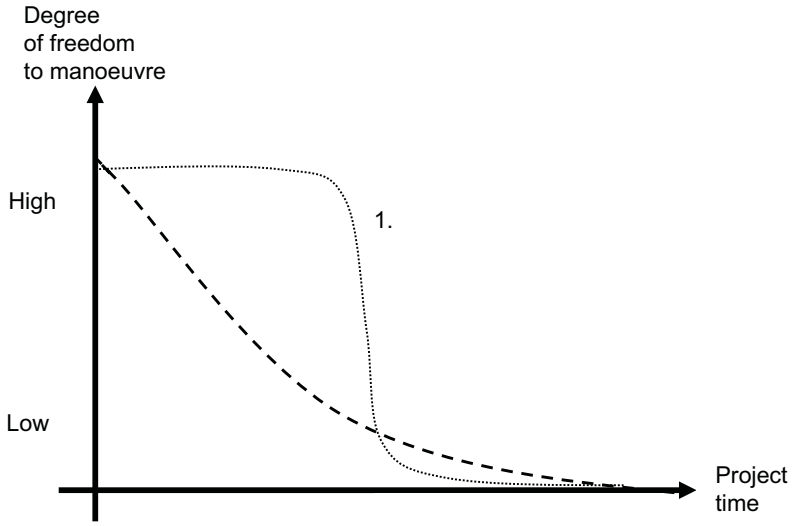

Figure 15. Illustration of a situation of late locking of scope and fast execution. (Based on Midler 1995, fig. 5)

2. Shield off areas of uncertainty
In the process of defining project scope, certain parts may be defined later than others. This can be manageable, provided that the still-open items are well defined and of a limited relative size. Areas where there is substantial uncertainty can be identified. The bulk of the scope can be defined in the front-end phase, while some issues remain unsettled until later stages. There are indications that no more than 10–15% of the scope can be kept open in this way.

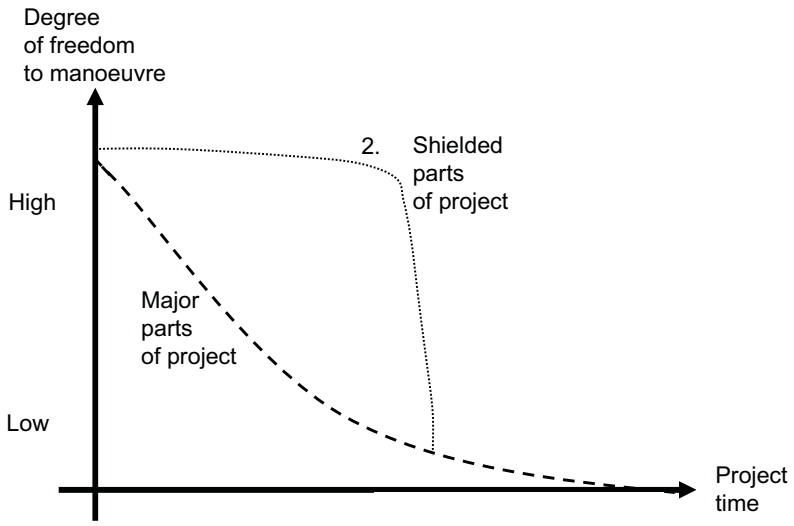

Figure 16. Illustration of a situation of where areas of uncertainty are shielded off for late locking. (Paper 7, fig. 7)

3. Incremental commitments

In an incremental approach, projects are committed to piece by piece. Large projects are decided upon and executed as a series of smaller projects. Each module can be executed relatively isolated due to a relatively short implementation period. Modularising (on the macro level) of major projects offer flexibility options for decision makers. For modular projects, effectiveness may be low unless each module is designed to provide benefits as individual deliveries, and not only providing a foundation for future improvements.

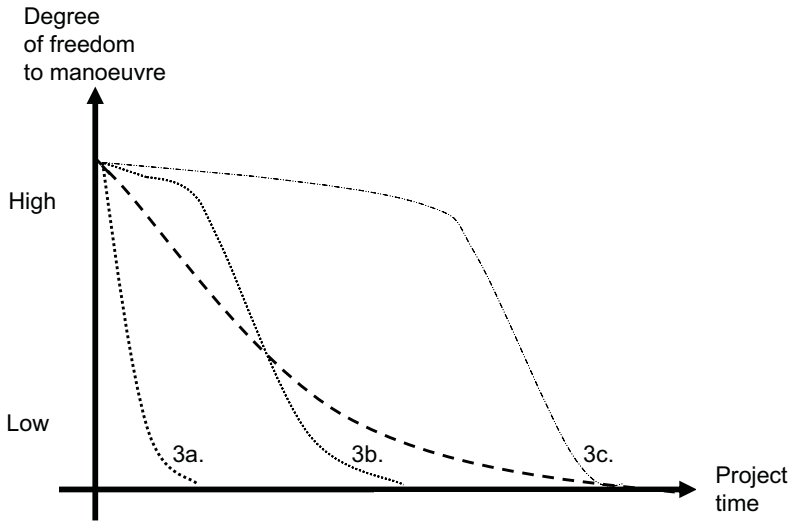

Figure 17. Illustration of a situation of incremental commitments, in three steps.

4. Absorption
Absorption can be obtained by redundancy or decoupling of dependencies. Regarding the physical design, redundancy includes over-specification and other types of flexibility in the product. Decoupling of dependencies can be achieved by a modular design, which reduces domino effects from changes. As for the project organisation, 'slack' is a keyword, including budget reserves, time slack in plans and organisation capacity to manage changes. In the studied projects, the lack of available resources has been observed more frequently than availability of such resources. With reference to Figure 18, means that a project is designed to address some of the desired room for manoeuvring that occurs, even if it violates the actual room for manoeuvring. In practice, this means to manage changes.

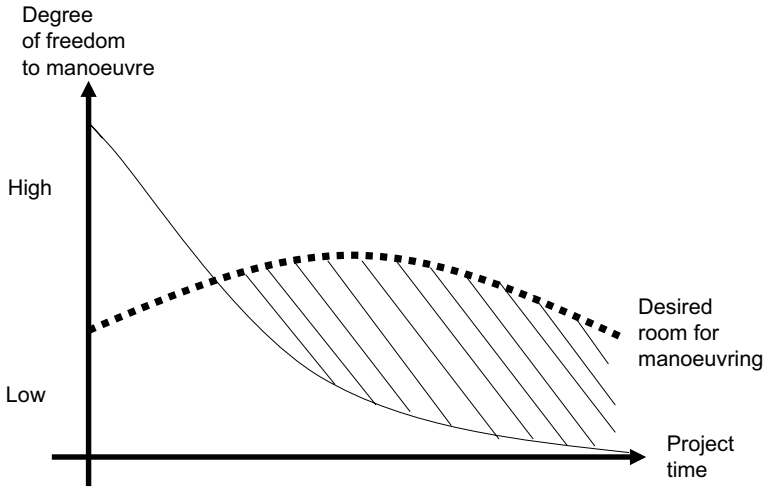

Figure 18. Illustration of a situation where a project is designed to absorb changes. (Based on Figure 4)

7.3 Generalising results

The bulk of the research presented in this thesis is based on case studies. Case studies are generally not intended or suitable for generalisation of the results. The small samples in the studies do not warrant the use of statistical tools to test consistency and co-variation of data, particularly when subgroups of the material are subject to analysis.

Strictly speaking, the findings in this thesis are valid only for the scope of the observations made. However, all major Norwegian governmental investments (as this type of project was defined by the Ministry of Finance in 2001) that were approved between 2000 and 2004, have been included in the analysis. Among major Norwegian governmental investments carried out between 1986 and 2000, the sample is judged to be relatively representative. The studied railway projects include four of the largest railway investments in Norway since 1980. Regarding major Norwegian governmental investments, the sample is probably representative. To a certain extent the sample covers all applicable projects. Focusing on major Norwegian governmental investments, the major weakness of this thesis is probably not whether the studied projects are representative or not, but whether the studied aspects of the projects are comprehensive.

As mentioned, the vast majority of the studied projects are Norwegian governmental projects, and all projects were in a 'public sector context'. While some of the principles discussed in the thesis are likely to be relevant for non-governmental projects, other aspects are likely to be different in commercial projects.

Stakeholder roles are likely to be different in projects where there is a close business link between investment costs and realised benefits. A close business link means both in terms of short time horizon and accountability for investment costs. Such close business links can be present in investments in new production facilities. The investment cost will be compensated for by increased productivity and possibly increased production volume. In such situations, it is likely that more stakeholders will be involved in balancing cost/benefit ratios regarding project scope and adjustments. However, the results from this thesis are likely to be more relevant to commercial projects for which the business link is not so close. This is the case if there is a long time between a decision and the 'moment of truth' when the investment provides payback, or when accountability for investment costs is less direct.

Only Norwegian investment projects have been analysed. The presentation of previous research has not been limited to Norwegian studies. During the literature search, one possible difference was found between experiences from Norwegian projects and general experiences in the project management community. In a Scandinavian management tradition, user involvement is emphasised as a key success factor in projects involving organisational change (see, for example, Trist & Bamforth 1951, Emery & Thorsrud 1976). The degree of user involvement is likely to vary between different countries and traditions. These variations may also influence other stakeholder roles in projects. On a detailed level, Paper 5 includes a discussion about the extent to which experiences from Norwegian railway projects are applicable to other countries.

7.4 Further research

This thesis has explored project flexibility in a general perspective. An analysis of project flexibility in relation to project types; including industry, uncertainty level and degree of innovation is recommended. Industry-specific models and guidelines for project flexibility are likely to appeal to practitioners within the project management field. Further research is needed to map the implementation and effects of different approaches to flexibility in different types of projects.

Four approaches to flexibility management were proposed. A fifth approach can be imagined. With reference to Figure 18, this would mean to lower the 'desired room for manoeuvring'-curve. In practice, this means to reduce the number and size of desired changes. To reduce user initiated changes, alignment, collaboration and communication in the front-end phase are likely issues. Computer-based visualisation tools can contribute to earlier and increased understanding of project deliveries. To anticipate and reduce owner initiated changes, selecting proper project concepts are a key issue, and it has to a certain extent been addressed in the thesis.

There appears to be a gap between the resistance to flexible projects among project management practitioners on the one side, and the promotion of flexibility by academics and stakeholders with no incentives related to project efficiency on the other side. This calls for increased emphasis on active use of present and developing knowledge of project flexibility. In addition, the project management filed can benefit from a pragmatic convergence of an idealistic promotion of project flexibility on one side, and experience-based hesitation to flexibility on the other side.

Regarding change management, analysis of which types of scope changes can be managed without severe reductions in project efficiency is proposed. There exist some developed simulation tools and methods which can be used to illustrate the effect of changes. Further use of such models is suggested. In order to calibrate the models, and gain additional understanding, it is interesting to simulate well documented projects *ex post*, so that simulated and observed results can be compared for the same projects.

The thesis has discussed flexibility relating to selected aspects individually, and in two-dimensional combinations. With larger samples, this type of analysis would benefit from regression analysis along the different aspects.

Further research is also called for to investigate the connection between modularisation of infrastructure investments and the realisation of anticipated benefits. This was especially discussed in Paper 5 in relation to railway investments. One question that arose was whether relatively limited investments in transportation infrastructure, and railways in particular, should be evaluated based on the actual reduction in travel time, or rather the potential travel time.

Finally, continued use of a combination of qualitative and quantitative research in the project management field is desirable. Such designs have the possibility to contribute to enhancing the credibility of project management as a research field. While structured qualitative research designs have been successfully applied, there is a potential for the increased use of quantitative research designs.

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Part 2.

Part 2 - Appendices

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Paper 2.
Magnussen, O.M. & Olsson, N.O.E. 2006. Comparative analysis of cost estimates of major public investment projects. *International Journal of Project Management* 24:4, 281–288.

Paper 3.
Olsson, N.O.E. & Magnussen, O.M. 2006. 'Projects trapped in their freedom: Flexibility aspects of front-end quality assurance of major projects'. Paper submitted to *Project Management Journal.*

Paper 4.
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Paper 6.
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Paper 7.
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Paper 8.
Olsson, N.O.E. 2006.'Flexibility and Front-End Management; Key to Project Success and failure' Paper accepted for presentation by ProMAC International Conference on Project Management, 27-29 September 2006, Sydney, Australia.

Paper 1.

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Management of flexibility in projects

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Abstract

Project managers are challenged to keep their projects focused and at the same time support their organisation's need to adapt to changes and uncertainty in the business environment. The purpose of this paper is to analyse the dynamics related to project flexibility, both from a theoretical and an empirical perspective. To ensure the efficiency of the project organisations, flexibility is usually not desired in the late phases of projects. The projects in this study often applied flexibility even during these phases, usually based on initiatives from project owners or users. It is paradoxical that while flexibility was frequently needed in the studied projects, it was rarely prepared for. As a consequence, structured approaches to project flexibility management are called for. The study indicates that the opinion on project flexibility held by the involved stakeholders can to a large extent be explained by their incentives related to the projects. The empirical results in this paper are based on a multi-case study covering 18 projects.

Keywords: Managing projects; Implementing strategy; Flexibility; Adjustments

1. Introduction

In a changing world, there is a desire of project owners and users to have "room to manoeuvre"; to be able to adjust projects as they gain knowledge about their needs and changes in the project context, as discussed by Midler [1]. A number of scholars, including Kreiner [2], argue that flexibility is necessary to face the changes and uncertainty in the business environment. On the other hand, a wide range of studies (including [3–5]) indicates that a clear project definition is a critical success factor for projects.

This paper analyses flexibility in large investments projects. To begin with, project flexibility is discussed from a theoretical standpoint. In order to illustrate different aspects of flexibility, 18 Norwegian projects have been analysed. The projects include a wide range of different industries, project sizes and types. Most of the projects are publicly financed.

2. Perspectives on project flexibility

Flexibility management is not a new concept. Sager [6] found several examples of flexibility as one approach to prepare for the effects of uncertainty in planning. However, Sager also notes that flexibility is an important term often used by planners but rarely scrutinised theoretically. Kreiner [2] points out that the traditional focus on stability in project management becomes challenged under uncertainty. This creates "drifting environments". Kreiner's drifting environments are not necessarily caused by actual changes in the project context. They may also occur when project stakeholders get a better understanding of their actual needs and improved ability to express the needs. Flexibility can also be seen as a response to environmental uncertainty, as

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discussed by Karlsen [7]. Real options are an established perspective on project flexibility with roots in financial options theory; see for example Brennan and Trigeorgis [8]. In this perspective, the value of flexibility can be quantified in monetary terms. Amram and Kulatilaka [9] compare flexibility to owning an option – the right, but not the obligation to take an action in the future. According to the real-options paradigm, uncertainty can increase the value of a project, as long as flexibility is preserved and resources are not irreversibly committed.

Mandelbaum and Buzacott [10] uses the number of the remaining alternatives after a decision has been taken as a measure of flexibility. In a similar manner as Midler [2], Eikeland [11] discusses project flexibility related to "room for manoeuvring". The "room for manoeuvring" is made up by future yet undetermined internal decisions, and may also be seen as a measurement of internal uncertainty of the project. According to Eikeland [11], a decision is within the room for manoeuvring if it does not violate the consequences of previous decisions. Terms like adaptability and robustness are often used when discussing issues related to what this paper calls flexibility. Flexibility may also be described as a way of making irreversible decision more reversible or postponing irreversible decisions until more information is available. Husby et al. [12] defines project flexibility as "the capability to adjust the project to prospective consequences of uncertain circumstances within the context of the project". The use of the term flexibility in this paper is based on this definition.

2.1. Flexibility in the process and the product

The capability of projects to adjust can be related to how the projects are executed and to how adaptable the final product will be, once it has been produced. Flexibility in the decision process is based on an approach where decisions and commitments in the projects are made sequentially over episodes.

Three strategies to achieve flexibility in the decision process may be identified. Firstly, a "late locking" of project concepts, specifications and organisation can be used, as discussed by Miller and Lessard [5]. Miller and Lessard refer to late locking as an exploring, iterative front-end process. They claim that late locking is as key success criteria for large engineering projects. Once the projects are locked, they are executed in a traditional way. The second strategy is related to a continuous step-by-step locking of the project by a successive commitment to projects. This may be achieved by the use of decision gates models, as shown by Eskerod and Östergren [13] or by incremental decision making, as advocated by Genus [14]. The third strategy is found in contingency planning, where a set of base plans is defined, but also a set of alternative plans that can be activated if needed. According to Chapman and Ward [15], contingency plans reflect anticipated potential departures from the defined plans for a project. Contingency plans are alternative plans that can be used if the baseline plans cannot be executed. Chapman and Ward point out that it is important to restrict the development of detailed contingency plans in order to reduce planning cost.

Flexibility in the product is achieved when the final product of the project is prepared for alternative use. As described by Brand [16] and Blakkstad [17], this approach to flexibility is used in building construction. According to Arge and Landstad [18], a commonly used classification of building adaptability was made in Sweden during the 1960s and 1970s. Based on this classification, generality is the ability of the building to meet shifting demands without physical changes. In this terminology, flexibility is the possibility for construction and technical changes with minimum cost and disturbance. Finally, elasticity means the potential for increasing or reducing the size of the building. In this paper, all these three characteristics are summarised as flexibility in the product.

2.2. Interaction between flexibility in the decision process and the product

Flexibility in the decision process and the product may interact for any given project. The real options approach treats flexibility in the decision process and the product relatively similar. However, from a project management point of view, it makes a major difference if the flexibility lies in the product or the decision process. Different strategies for project flexibility management are identified in Fig. 1, each characterised by high or low flexibility in the process and product, respectively.

As indicated in Fig. 1, the situation with low flexibility in both the product and the decision process assumes stable environments. This does not necessarily mean that the environments are actually stable. It only means that the project concept and the management of the project

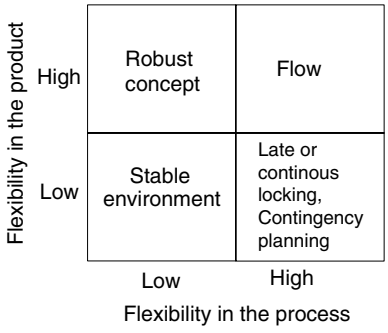

Fig. 1. Flexibility in the product and the decision process.

are not designed for adjustments within the project time frame. A strategy characterised by high flexibility in the product and low in the process is termed "robust concept" in Fig. 1. This project situation assumes that the decision process related to the project can be fairly straight forward because the result of the project is prepared for alternative use. An argument against such a strategy is that flexibility in the product can be costly. It is also challenging to target the flexibility to where it is needed. Flexibility in the product that turns out to not be used, can be seen as a waste of resources.

A basic principle in the situation with low flexibility in the product, and high flexibility in the process is that final decisions can be postponed (for example, the freezing of specifications) in order to gain as much knowledge as possible. A low flexibility in the product is desirable when flexibility in the product is costly. A potential drawback of this strategy is that it might cause frustration among project stakeholders, due to a lack of commitment and perceived uncertainty.

Fig. 1 also includes the situation with high flexibility is both the product and the process. "Flow" has been used as a description of this situation. It contains many of the aspects related to the other two strategies with high flexibility in either the process or the product.

2.3. Modularity

Flexibility can be related to the degree of modularity in the projects. Modularity refers to the possibility to divide the project into more or less independent sub-units. According to Miller and Lessard [5], modularity can enable projects to cope with uncertainty because individual components do not have a critical role. Major "one-piece" projects such as bridges and tunnels have a low level of modularity, based on the "we do not build half a bridge"-approach. Projects that are assumed to have higher levels of modularity include IT-system development and road improvement projects.

2.4. Flexibility in different project phases

This paper makes a distinction between three different project phases: front-end, planning and execution. The front-end phase covers the activities prior to the final decision to go ahead with the project. Even though planning is a part of the front-end phase, most projects also have a planning phase for more detailed preparation after the project has been decided upon. Projects are implemented in an execution phase, which ends when the project outputs are realised.

Most authors agree on the value of flexibility in the front-end phase of projects while flexibility is commonly seen as undesirable in the execution phases of projects. Lundin and Söderholm [19] describe how a project moves from relative openness in the beginning of the project, to relative closeness in the execution phase. In the execution phase, the predetermined action is supposed to be carried out according to the plans, in a "planned isolation". The concept of project flexibility in the execution phase disturbs this planned isolation. In a similar way, Mahmoud-Jouini et al. [20] characterises project management by the speed of three project phases: preparation, freezing and implementation.

Many authors on project management, including Morris and Hough [4], warn against changes in projects once specifications have been established. Miller and Lessard [5] point out the irreversibility of large engineering projects and the importance of bold commitment from key stakeholders. They argue against flexibility once the front-end phase is over.

2.5. Efficiency and effectiveness

Efficiency is linked to the immediate outcome of a project. It is a question of doing things right and producing project outputs in terms of the agreed scope, quality, cost and time. It is an internal measure. Effectiveness, on the other hand, is linked to the longer-term effects of the project, or to do the right things. Effectiveness is an external measure. Eikeland [11] relates effectiveness to how the results of a project contribute to value added for owners and users. According to Samset [21], effectiveness concerns the extent to which the project's tactical objective, or the goal, can be achieved.

The literature review [22] found that flexibility is primarily an approach to improve effectiveness of projects rather than efficiency. Major drawbacks of flexibility are related to reductions in efficiency. Flexibility was seen as a threat to delivering the project on time and within budget. In order to maximise efficiency, projects needs to be clearly defined in the front-end phase and executed according to the plans. Adjustments or remaining decisions shall be minimised. Flexibility promoters emphasise the possibility for increased effectiveness. A project with sufficient flexibility to utilise opportunities to increase the value for owners and users might in the end prove to be more effective, as discussed in [2] and quantified by the real options approach [8].

2.6. Project stakeholders

Key stakeholders who are directly linked to most projects are; project owners, users, project management and contractors. Olsson [22] analysed the expected opinion on project flexibility. That project owners and users are likely to be more positive towards changes aimed at increased effectiveness. Stakeholders those main responsibility lie on the cost side of the project, such as project management and contractors, are less likely to embrace changes. According to Kreiner [2], the project owner is made the guardian of relevance and there-

by the project's effectiveness. The project manager is made the guardian of efficiency.

2.7. Changes and extensions

Changes and extensions are a source of major disagreements between different actors in projects. PMI [23] defines the management of both changes and extensions as scope change control.

Many authors, including [1,4,24], have pointed to scope changes as a key driver to cost overruns of projects. From a project management and contractor perspective, scope changes are generally seen as undesirables, even though contractors can see changes as a possibility to improve the profit from the projects [25]. Scope changes are key issues when discussing flexibility, but project flexibility as discussed in this paper is a wider concept than scope change management.

A typical scope change is proposed because the users or project owner wants to increase the effectiveness of the project. As shown by Ibbs et al. [26] using benefit-to-cost ratio, the reduction in efficiency might be compensated by a higher increase in effectiveness, depending on the timing and type of change. Two sources of conflicts related to scope changes can be identified. Conflicts may arise regarding: (a) the quantification of the increase in effectiveness and reduction in efficiency; (b) the responsibility for the reduction in efficiency.

Based on a study of 448 projects, Dvir and Lechler [27] showed that changes in both plans and goals of projects typically reduce both the efficiency and customer satisfaction of engineering projects.

Many textbooks on project management, including [3,28], include explanations and illustrations that illustrate that the scope change cost is typically low in the front-end phase of projects, and getting higher and higher as time goes by. This increase in scope change cost over time is widely accepted as a rule of thumb, and is a major challenge to project flexibility. Once a project has been decided upon and the planning or execution has begun, changes are likely to reduce the efficiency of the project, as shown by Hanna et al. [30]. However, Poppendieck and Poppendieck [29] argue that the almost exponential increase in scope change cost over time in a project is not always applicable to IT-projects. Some types of changes are less damaging to efficiency than others. An alternative approach to project flexibility is to identify areas or types of changes that are less challenging to accommodate in projects than other changes. Thus, at least two different strategies can be chosen to manage scope changes: (a) to avoid them or (b) to reduce the negative impact from changes that do come. A *change* requires that something already has been decided. One key purpose of the flexibility strategies identified in Fig. 1 is to achieve flexibility without creating scope changes in the project. In this way, scope changes might be avoided or reduced by the use of late locking of projects and by not taking decisions until one really have to. Scope changes may also be avoided by the use of flexibility in the product.

2.8. Contracting and incentives

Incentives for different project stakeholders are strongly related to the contracting structure of a project and other financial obligations. A common tool for achieving flexibility in projects is the use of option based contracts, which enables a continuous locking of the projects. Mahmoud-Jouini et al. [20] discusses time management in projects. Their discussion also includes flexibility aspects. They point out that a key factor in creating win–win situations between the stakeholders in Engineering, Procurement and Construction (EPS) contracts lies in flexibility of contracts and the implicit relations that are created by the contracts. Garel and Midler [31] studied contractual structures that enable front-loading and coherent incentives for manufacturers and suppliers in the automotive industry. Their analysis is based on a game theory approach, where dealing with flexibility can be a win–win or zero-sum game between the stakeholders. In co-development of automotive parts, the supplier gets no additional payments for late identification of need for modifications in the design phase. The supplier therefore has strong incentives to provide engineering expertise to work closely with the manufacturer in order to understand the needs and the production process [31].

The users are a group of stakeholders that often do not have direct contracts related to the projects. Their incentives are therefore less connected to the direct cost of the project, and more often connected to the quality and usability of the final result.

3. Empirical indications

A study was carried out to investigate to what extent the results from the theoretical review of project flexibility corresponds with observations from a number of projects. This section of the paper describes the data material, discusses the applied methodology and presents the results from the study.

3.1. Data collection and analysis

A qualitative case study research approach has been used in this study. In the terminology of Yin [32], the analysis is a multi-case study. The study is based on an analysis of 18 Norwegian projects. Information related to the projects has been obtained from two main sources: third party evaluation reports and personal experience from consulting and applied research engagements. The

third party reports usually have a high professional standard and analyse the projects in depth as well as in a broad perspective. Of the projects, 15 are described primarily based on third part reports. For three of the projects, information is based on both third part reports and personal experience. Case study reports have been established for the projects that have personal experience as a data source. The analysed projects have been carried out between 1986 and 2003, the majority between 1995 and 2000. A wide variety of projects have purposely been analysed in order to capture different aspects of project flexibility. The type of projects in the study is shown in Table 1.

On the basis of the descriptive information, an assessment was made of the project flexibility characteristics. Due to the size of the projects, the analysis is based on the strategies of the projects and major events.

To analyse the information related to the projects, codified data were entered into a database. Table 2 shows the project attributes that were used in the study. The table also shows the alternatives and scales that were used. Some of the information relates to the project itself, such as industry and project budget. The analysis includes information related to approaches to flexibility that were planned for or observed, including scope changes, delays and postponed decisions. In addition, the observed opinion on flexibility for different stakeholders is included in the analysis. In order to validate the data, informants with experience from analysed projects have reviewed the relative scores of the projects.

Table 1
The studied projects by industry and size of project

	Number
Type of project (n = 18)	
Offshore	1
Hospitals	3
Transportation infrastructure	7
Defence	3
Public buildings	4
Project size (n = 17)	
<15 mill euros (100 mill NOK)	3
15–60 mill euros (100–500 mill NOK)	8
60–250 mill euros (500–2000 mill NOK)	3
>250 mill euros (2.000 mill NOK)	3

Table 2
The parameters used in the analysis

Dimension	Scale/alternatives
Type of project/industry	Transportation infrastructure; public buildings; hospitals; defence; offshore (oil and gas)
Size of project	Actual cost for finished projects, latest known budget for on-going projects
Specific type of flexibility	Change; extension; contingency planning; late locking; continuous locking, none
Project phase	Front-end; planning; execution; none
Flexibility in the product	Low; medium; high
Flexibility in the decision process (planned and actual)	Low; medium; high
Degree of modularity	Low; medium; high
Stakeholder who initiated the use of flexibility	Users; owner; project management; contractor; none; N/A
Stakeholder attitude to flexibility (project owner, user, project management and contractor)	Negative; neutral; positive; N/A

4. Results

In the following, the results from the study are presented. The results are divided into different sections, in order to address key research questions.

4.1. What type of flexibility has been used and when?

Changes and extensions are commonly used, and are observed in 11 projects, covering most types of projects. A late locking was applied in 4 projects. One defence project used a contract with predefined options as way of achieving a continuous locking of the project. Contingency planning was the main flexibility approach in one project. In only one project, a college building construction, flexibility was not applied.

Flexibility was used in all phases of the projects, but particularly during the planning phase. Three projects had need for flexibility in the execution phase, two of them being hospitals. One of these projects had extensive changes and extensions, followed by large cost overruns. The other project applied a late locking of the specification related to key medical equipment. Late locking was related only to a limited part of the project. This project was delivered on time and budget. The third project with flexibility need in the execution was a renovation of an old public building. Requirements related to preservation of cultural and historical features of the building proved to be challenging to specify before the work was started. These results are summarised in Table 3.

4.2. Stakeholder perspective on project flexibility

As shown in Table 4, the project owners and the users appear to look favourably upon flexibility. In only one project, the users were negative to flexibility. This was a school building project, where the users (primarily teachers and parents) wanted predictability in the

Table 3
Flexibility use by type and project phase

	Number
Type of flexibility applied in the projects (n = 18)	
Late locking	5
Continuous locking	1
Extensions	4
Changes	6
Contingency planning	1
None	1
Project phase for main use of flexibility (n = 18)	
Front-end	4
Planning	10
Execution	3
None	1

front-end phase regarding the time and scope of the school building refurbishing. The study indicates a mixed opinion on flexibility among project management. Contractors were overall negative (even though the contractor's opinion is based on fewer observations than the other categories).

Regarding project management, there are indications that they look favourably upon flexibility use in the front-end or planning phase, but not in the execution phase. Furthermore, project management appear to be positive to flexibility in projects where they and the project owner are found in the same or closely related organisations. This was usually the case in transportation infrastructure projects. When the project management and the project owner are in different organisations, project management had a negative view on flexibility. This was typically the case for public building construction.

Table 4 also illustrates that the stakeholders that most often initiate the use of flexibility, are also most positive to flexibility. Among the studied projects, it was mostly project owners and users who initiated the use of flexibility in the projects.

4.3. Modularity, flexibility in the decision process and in the product

As seen in Table 5, the majority of the projects planned for low flexibility in the decision process. Table 5 also shows that many projects had a high actual flexibility in the decision process. A high degree of planned flexibility in the decision process indicates that the projects were prepared for an iterative decision, planning or execution process. Projects that clearly illustrated that flexibility, or related terms, in the product was intended are rated as having a high flexibility in the product. Projects that are registered as having a low flexibility had no stated or observed intentions of flexibility. Medium flexibility indicates that the projects planned for flexibility in some phases or some areas, but not as a key issue.

Table 5
The analysed attributes related to flexibility in the projects

	Low	Medium	High	*N* total
Flexibility in the product	8	8	2	18
Flexibility in the process, planned	13	2	3	18
Flexibility in the process, actual	2	6	10	18
Modularity	8	5	5	18

A technical analysis of how different changes have affected the flexibility in the product was beyond the scope of the present analysis. In Table 5, flexibility in the product is therefore not divided into planned and actual, but treated as a characteristic of each project as a whole.

Most projects had a low modularity, particularly public buildings. To achieve a high modularity, two transportation infrastructure projects (one road construction and one railway line) were divided into sections, which could be built fairly independently. The two defence projects with a high modularity were related to system development and acquisition, were the systems were possible to divide into modules, both from a technical and a contractual point of view. Finally, one school building project had a high modularity because the project actually consisted of upgrading of a fairly large number of school buildings. Even if the plans for each school had consequences for the other schools and the decision process addressed the whole upgrading plan, each school building could be managed as a subproject (and some would argue that this "project" was a "programme", and each school was a project).

An attempt was made to investigate the relation between modularity and flexibility in the decision process. If a project was highly modular, flexibility in the decision

Table 4
Different perspectives on project flexibility hold by project stakeholders

		Project owner	Users	Project management	Contractor	None
Stakeholder opinion on flexibility	Positive	12	9	6	0	0
	Neutral	4	3	5	3	0
	Negative	0	1	7	4	0
	n =	16	13	18	7	0
Stakeholder who initiated the use of flexibility (*n* = 16)		8	5	2	0	1

process was likely to be utilised. A high modularity appears also to be the major way of achieving a high planned flexibility in the process, which frequently resulted in a high actual flexibility in the process. The combination of high modularity and low actual flexibility in the decision process was not observed.

5. Discussion

In the following, the results are discussed in relation to the theoretical overview of project flexibility. At the end of the section, some implications for project management practice are listed.

5.1. Different stakeholders have different perspectives to project flexibility

It was expected that project owners and users were more likely to be interested in flexibility than the project management and contractors. On average across the 18 projects, this study supports this assumption.

In the studied projects, users were generally positive to flexibility. However, one case showed that the users did not uniformly favour flexibility in the front-end phase, because they wanted to know what they could expect from the project. Fig. 2 gives a summary of the observed opinion on flexibility seen in a time perspective. Owners of the studied projects appear to be clear in their support of flexibility, and contractors in their dislike.

Most authors agree on the value of flexibility in the front-end phase of projects, and on the undesired effects of flexibility in the execution phase. In this study, project management appeared to be the only type of stakeholder that showed the expected shift from being positive to flexibility in the front-end, less positive in the planning phase and finally negative in the execution phase. As a possible explanation, project management might be the stakeholder that is most likely to see the effects of flexibility, both on the benefit and cost side.

Fig. 2 indicates that users and project management have different needs for flexibility in different project phases. As long as the funding model for a project means that the users have nothing to lose from demanding changes and extensions, they have incentive to push for scope changes. This is typically, though not always, the case in the Norwegian public sector from which the majority of the projects in the study come.

	Front-end	Planning	Execution
Owner	+	+	+
Users	+/-	+	+
Project management	+	+/-	-
Contractor	N/A	-	-

\+ = Positive opinion on project flexibility
\- = Negative opinion
+/- = Mixed opinion

Fig. 2. Stakeholders' opinion on flexibility in different project phases.

Kreiner [2] termed project management "the guardian of efficiency". Results from the studied cases show that this guardian role is depending on the organisational connection to the project owner. In cases where the project management was found in the same organisation as the owner, project management was more likely to be positive to flexibility, compared to cases where project management had a weaker organisational connection to the project owner and the guardian role could be exercised more freely.

The opinion on flexibility held by the different stakeholders can also be explained based on the incentives faced by the stakeholders. Flexibility has a value for the stakeholders that benefit from changes and late locking of projects. In this study, the stakeholders that have their incentives related to achieving the project's purpose were the advocates of flexibility. Stakeholders that have their incentives related to delivering the project on time and within budget saw flexibility as a threat. Flexibility usually means that the contractors have to spend resources to adopt. This disturbs the efficiency of their organisations and typically causes waiting or rework. Note that this study has been carried out on rather strategic level. Garel and Midler [31] show that the contractors, depending on the contract structure, may have incentives to embrace changes because this gives them room to ask for additional payments.

5.2. If flexibility is prepared for, it will be used. It will often be used even if it is not prepared for

In the analysed projects, changes and extensions were found in more than half of the projects, in spite of the well-known risk for cost overruns in such occasions. This may be characterised as a traditional type of flexibility. The structured approaches to project flexibility that are discussed in the literature are also found, but in a minority of the projects.

It appears to be a strong desire to use flexibility in the studied projects. This was particularly the case when it was prepared for, but also when it was not. Most projects did not plan for flexibility in the decision process, but used flexible approaches anyway. All projects with a high planned flexibility in the decision process also had a high actual flexibility in the decision process. Flexibility in the product could only to a limited extent result in less use of flexibility in the decision process. This indicates that if there is a possibility for flexibility in a project, it will probably be utilised.

5.3. Implications for project management practice

In the studied projects, flexibility was often managed in a traditional way. It appears to be a potential for more frequent use of structured approaches to management of project flexibility.

Flexibility in the front-end phase is the least controversial part of project flexibility. The study indicates that after the front-end phase, flexibility in well-defined parts of the projects can be managed without major reductions in efficiency. To manage flexibility, it is beneficial to identify critical part of projects where flexibility is needed. It is likely that these parts of the projects are similar to the critical parts that are identified in project uncertainty analyses. In the next step, appropriate strategies for project flexibility of the identified areas are chosen. In this way, project flexibility can enable utilisation of the often neglected opportunity side of uncertainty management.

Note that flexibility as discussed here is not seen as an alternative to strategic management, but as a means to help realising a strategy. This is in accordance with Samset [28] who argues that successful projects are characterised by a distinct strategy in combination with sufficient tactical flexibility.

The observed tendency for users to advocate flexibility in late phases of projects indicates that projects with a high user influence should have a higher need for an active approach to project flexibility than other projects. Even though it is not a recommended situation, projects that for political or other reasons are pushed to a premature go-ahead decision also need an active approach to project flexibility.

6. Conclusions

This study indicates a paradoxical approach to project flexibility: flexibility is frequently used but rarely prepared for. As Engwall [33] and Jugdev [34] point out, current project management knowledge is a practitioner-driven theory focusing on supporting advices to the project manager. In this perspective, efficiency is the prime focus and flexibility should de minimised once the front-end phase is over.

Projects in this study often had need to be flexible even after this point, usually based on initiatives form the project owners or users. Current project management theory then proposes a stronger emphasis on the front-end phase in order to prepare the projects as well as possible. Given the volume of flexibility use in the studied projects and generally changing environments of projects, it seems unrealistic to strive for an elimination of project flexibility. Flexibility appears to be so commonly used that it must be addressed seriously.

The opinion on flexibility held by the different stakeholders appears to be related to the incentives faced by the stakeholders. In general, flexibility has a value for the stakeholders that benefit from changes and late locking of projects, and it is a cost for those who have to adopt. In this study, the project owners and users had their incentives related to achieving the project's purpose and they were often the advocates of flexibility. The stakeholders that have to adapt to different forms of flexibility were primarily the project management and contractors. Changes, late locking and other forms of flexibility usually disturb the efficiency of their organisations and typically cause waiting or rework. Project management had their incentives either primarily related to the project purpose, or the delivering the project according to specification, on time and within budget. The opinion on flexibility among project management appears to vary accordingly. Incentives related to project purpose increases the likeliness that flexibility is look favourably upon. Stakeholder incentives related to direct project outcome increases the likeliness that flexibility is looked negatively upon.

Interesting areas for further research include studies of actual use of different approaches for flexibility in different types of projects. In addition, analysis of which types of scope changes that can be managed without severe reductions in project efficiency is proposed.

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Paper 2.

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Comparative analysis of cost estimates of major public investment projects

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Abstract

This paper reports findings from a study of cost estimates of 31 major public investment projects in Norway. It is aimed at analysing the development of cost estimates before the decision to execute the projects and in what way the scheme of mandatory quality assurance influences this process. Two important results are highlighted and discussed: The differences in the proposed cost estimates appear to have decreased systematically since the introduction of the quality assurance and the project owners rely to a large extent directly upon the cost estimates from the quality assurance when the decision to execute the project is taken.

Keywords: Managing projects; Design and appraisal

1. Introduction

To meet the demand for better management and control of major public investment projects, an arrangement for external Quality-at-entry analyses of all public investments in Norway with an expected budget larger than NOK 500 million (≈EUR 60 million)[2] has been established. This so-called Quality-at-entry Regime became operative from year 2000 and was the result of an initiative from the Norwegian Ministry of Finance. The main factors leading to the establishment of a mandatory external assessment of public multi-million projects were the poor performance of many such projects especially in terms of cost. The introduction of the Regime was, among other factors, an attempt to avoid and control cost overruns [1].

This paper is the first attempt to analyse the development of cost estimates in the early stages of the quality assured projects. Very few of the projects have yet reached completion, which explains why studies of actual costs do not constitute a part of the present research. The objective is to develop an understanding of the current Quality-at-entry Regime and to point out its relevance and impact on the cost estimation process and how it could contribute to more realistic budgets. The paper is thus concerned with impacts of quality assurance concerning the efficiency issue, i.e., focus on the cost criterion. In a broader perspective, however, it also concerns the more substantial issues of project viability and long term effects since the end result of inaccurate estimates could be that nonviable projects are prioritized (a central perspective in [2,3] for example).

2. The scope of the paper

The scope of this paper is to consider the relevance and significance of the current Quality-at-entry Regime on cost estimation in major public projects. Our preconception is

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[2] EUR 1 = NOK 8. Expected budget > NOK 500 million is the general rule. This general rule does not prevent the possibility for a Quality-at-entry analysis carried out on projects with expected budget less than NOK 500 million.

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that studying the development of the cost estimates from different actors through the stage of quality assurance can tell us something about how this affects the decision. In studying the divergence we are in effect studying the extent to which estimates may be biased.

3. Cost overrun and its causes

Nijkamp and Ubbels [4] point out the need for better insight into cost estimation. It is because cost estimation play a major role in the decision-making process of the government.

Studies of major projects show that cost overruns are not uncommon. Morris and Hough [5] suggest that cost overruns in large projects are typically between 40% and 200%. The study of large transportation infrastructure projects reported in Flyvbjerg et al. [6] shows that 9 out of 10 projects fall victim to cost escalation, actual costs are on average 28% higher than estimated costs, and it appears to be a global phenomenon observed over a long period of time. Kolltveit and Grönhaug [7] include an example of costs in Norwegian large-scale projects varying from 6% saving to 160% overrun.[3]

The causes of the observed tendency seem to be connected to factors not only hard to predict but also difficult to manage. Morris and Hough [5] point out that overruns are caused by circumstances outside the project's area of control. According to them, many projects overrun because of factors like price escalation, government action, strikes and so on. A big issue is then related to the ability to predict such factors and their potential impact.

Flyvbjerg et al. [8] attempt to explain the causes of cost overrun in projects. They found that cost escalation was strongly dependent on the length of the implementation phase. Delays and long implementation phases translate into risks of substantial cost escalations. They also observe that projects grow larger over time, and for some project types, larger projects have larger percentage cost escalation. That bigger projects having a larger risk of cost escalation than smaller ones (for all project types) is not supported by their data, but they emphasize that the risk of substantial cost escalation is high for all project sizes and types. Since the same percentage cost escalation would typically cause more problems in terms of budgetary, fiscal, administrative and political dilemmas in a large project than in a small one, they conclude that an increase in project size translates into a need for improved planning processes.

Nijkamp and Ubbels [4] found on the basis of their study that the influence of inflation was clearly large in the projects they studied. Because of the length of planning and construction, price rises played a major role. What they call incompleteness of the estimations, the practice that some elements of costs are omitted or not included, are also important. They argue that project changes also is an important cause of underestimation, which lead to a conclusion that the estimates in their sample were rather reliable.

The cost estimation process, which can be viewed as a factor more closely related to the project organization, has also received some attention among authors in this field of research. Flyvbjerg et al. [6] deliver an interesting contribution on this issue. First of all, it must be noted that their study focuses on a certain category of projects, so-called transportation infrastructure projects, and secondly, the data comes from projects all around the world from a period of time stretching from 1910 to 1998. They study the differences between actual and estimated cost and argue that "*the cost estimates used to decide whether such projects should be built are highly and systematically misleading.*" [6, p. 279] This underestimation could, according to Flyvbjerg et al. [6], best be explained by strategic misrepresentation. Olsson et al. [9] suggest that "strategic budgeting" is a commonly used technique in major public projects. This technique includes using a budget that only visualises part of the total cost in order to initiate the project, and then exploit the fundamental logic that a project, when defined and planned, is less likely to be reversed or terminated. Nijkamp and Ubbels [4] discuss a similar explanation when investigating the reliability of cost estimates in infrastructure projects.[4] They state that at the time of the decision to build:

"*One may safely assume that the costs of the project at that stage are as low as possible to ensure that the project will be executed. This suggests that the cost may be somewhat underestimated at the beginning of a project.*" [4, p. 3]

They further state that there is some space for negotiations in the cost estimation process since estimators tend to take the demands of governmental institutions into account.

Nijkamp and Ubbels [4] conclude that, since large changes is a major cause of cost escalation, it is necessary to increase the importance of the first planning phases. In recent years more authors seem to agree on the importance of a better design process in order to create more successful projects [10–12].

4. Ensuring Quality-at-entry

The initiative to investigate the need for better management and control of major public investment projects in Norway was based on the understanding that a number of large projects did not accomplish according to the requirements vital for the decision to execute the project. Additionally, large cost overruns and change of scope during implementation were observed. After a closer study of

[3] The example included only 5 projects and was used to illustrate the challenges of the construction and building industry.

[4] It must be noted that the study in Nijkamp and Ubbels [4] includes a total of only 8 projects and that they describe this cause of underestimation as less important.

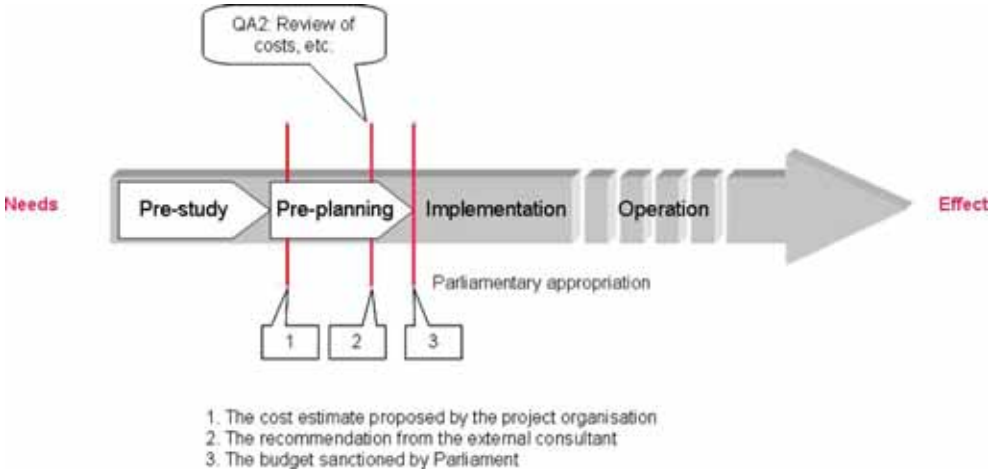

Fig. 1. The estimates prepared in the QA-process – the arrow represents phases in the project life cycle.

11 projects, where 6 of them showed cost overrun, a government committee concluded that failures in the initial phases of the projects were the main cause of the cost escalation during implementation [1].

4.1. Description of the current Quality-at-entry Regime

The Quality-at-entry Regime is in this paper a label for the formal requirements that public investment projects must meet before the preparation of proposal for the Parliament. The basic exercise connected to the present Regime is mandatory quality assurance and uncertainty analysis of the project carried out by external consultants on behalf of the responsible ministry, the so-called quality assurance 2 (QA2). In this paper the term "quality assurance" is used shorthand instead of referring to the "exercise under the present Quality-at-entry Regime". The aim of the Regime so far has been to evaluate the quality of the foundation for the chosen alternative. The more particular focus regarding revision of cost estimates and identifying major risks must be seen in light of the specific goal for the quality assurance. It is a tool for evaluating the quality of information and for providing new information on the basis of which the decision makers can judge the project.

4.2. The quality assurance – when and how

The quality assurance, which typically takes place at the pre-planning stage, and the cost estimates provide an opportunity to track how three main stakeholders; the project organisation, the external consultant, and the Parliament,[5] view the project cost at this stage.

An illustration of the process and how the cost estimates relate to a certain stakeholder and point in time is given in Fig. 1.

The duration between the steps in the process varies from project to project, and it is not uncommon to observe a time-span from several months up to a year between 1 and 3 in the figure. A suitable question here is: As some elements of the project may change in the course of its development, how is it possible to compare the cost estimates connected to the different points in the process? The question is a fundamental one, and a brief explanation is appropriate. First of all, the formal requirement is that the project does not proceed beyond the pre-planning stage until it is approved by the Parliament. Secondly, the quality assurance does not take place until updated project documentation exists, and the cost estimate is a central part of this information. This pertains to the situation between 1 and 2 in the figure. Information concerning the expected budget of a project is crucial when deciding to go ahead with the project. In this way it is safe to assume that the recommended budget from the external consultant and the approved budget fundamentally refer to the same project, unless it would be explicitly stated. This pertains to the situation between 2 and 3 in the figure.

The cost estimate connected to 1 in the figure stems from the uncertainty analysis conducted by the project organisation. This is an expression of the project organisation's view concerning the project cost. The consultants deliver an external evaluation of the project and give their recommendation of a budget for the project based on an independent uncertainty analysis (2 in the figure). The end of the pre-planning stage is the parliamentary approval of a budget and permission to implement the project (3 in the figure).

4.3. The estimates and how they are prepared

The prevailing method among project organisations and consultants in the projects studied here is the stochastic uncertainty analysis regarding the project cost. The estima-

[5] Formally, the decision to go ahead with the project and the financing lies in the hands of the Parliament. In practice, however, the budget decided by the Parliament corresponds with that proposed by the responsible ministry (the project owner).

tion technique is the so-called judgmental forecasting and the forecast serves the purpose of predicting the future factors that may influence project costs. A statistical model where it is assumed that the uncertainty is normally distributed is used [3]. The proposed budget for the project, prepared by the project organisation before the quality assurance takes place, pertains in most cases to the 50% subjective probability, i.e., there is a 50% expected probability that the project will be completed within this cost. The recommendation from the external consultant consists of the expected cost and total budget, most often based on 50% and 85% probability, respectively. The uncertainty analyses performed by the project organisation and the external consultant represent the basis when the project owner decides upon the estimates that are to be presented in the national budget or in a separate project-specific Government white paper. Formally, the Parliament reaches whatever conclusion on the matter it would find appropriate. In practice, however, the estimates presented in the national budget or the project-specific white papers are sanctioned by Parliament without changes.

4.4. The new approach to project costs

Olsson et al. [9] describe the situation that, as a consequence of the Quality-at-entry Regime, a more sophisticated overview of the project cost is presented. The external consultant recommends a total budget that is expected to cover the consequences of the identified uncertainties. The reserves are, however, not expected to be used, and specific rules for the management of reserves have been established. The budget allocated to the executing government agency is the basic budget plus expected extra costs (based on 50% subjective probability), which also was the typical standard before the Quality-at-entry Regime was established. Use of the reserves must be approved by the responsible ministry. This implies that there is a binding upper financial level for the projects and a new control scheme for budget compliance. Olsson et al. [9] point out the need for management of project reserves for portfolios of projects since a project owner often deal with many major projects at the same time. If this succeeds, it is expected that the new approach will reduce the need for additional funding and result in increased reliability of the cost estimate. Attempts to summarise some of the effects of quality assurance suggest that:

"*The involved ministries, being projects owners, have expressed a general satisfaction with the analyses, since they give a "second opinion" of the projects. They also feel that they get a better basis to prepare the decision proposal for the Norwegian parliament.*" [9, p. 38]

The new approach also raises some concerns. Olsson et al. [9] refer to the situation that some projects may become more expensive as a result of the allocated reserves. Planned use of the reserves could occur, and this could enhance the observed tendency that projects at least fill their allocated budget. Some claim that costs might soar because of the situation that the external consultants have no responsibility for the actual budget. They recommend a budget, but have no role in the execution of the project. This could lead to a situation where the external consultants systematically exaggerate the recommended total budget in order to reduce the risk that cost overruns could occur. On the other hand, if cost elements are omitted in the initial estimates, quality assurance is designed to intervene, and in this respect have a rather direct impact on the cost estimation process.

5. Data collection and refinement

The quality assurance report, which is a compilation of the results from quality assurance, represents the fundamental data source in our research. From the quality assurance report it is possible to obtain cost estimates prepared by the project organisation/the executing government agency and of course the recommendation from the external consultant. The project budget approved by the Parliament is obtainable from the national budget or project-specific Government white paper presented by the responsible ministry. When it was deemed to be necessary to ensure the quality of the data, projects were contacted separately via e-mail.

To compare the cost estimates presented at the specific points in the process (cf. Fig. 1), cost data had to be corrected for inflation. This basically means that cost data in each individual project are brought to the same price level as the approved budget, either with the aid of specific methods for the single project, or by appropriate indices for discounting.

Before a presentation of the important findings from analyses done on the existing material, it should be noted that the aim of this paper is not to present a final evaluation of the effects of the quality assurance scheme, since most of the projects are still in the planning stages or in the early stages of implementation.

6. Presentation of important findings

The collected data are stored in a research database. Proper storage and the possibilities for fast retrieval of large quantities of data seem to be the most important characteristics of a database [13]. Fifty-two projects have been through the quality assurance procedure between 2000 and 2004. On the basis of these projects a sample of 31 projects representing a broad range of project types was established (cf. Table 1).

6.1. The external consultant's recommended budget – project reserves

In this section a closer look at the recommendation of the external consultant is presented. A special interest is connected to the size of the reserve. The allocation of pro-

Table 1
The sample

Type of project	Number of projects	Per cent
Transportation infrastructure	12	39
Building	9	29
Defence procurement	8	26
Information technology	2	6
Total	31	100

ject reserves in major public projects is a fundamentally new approach in Norway [9].

Table 2 describes the size of the project reserves recommended by the external consultant with respect to project type (upper part of the table) and size (lower part of the table). Since the reserves are not expected to be used, they are here presented as a mark-up above the 50% probability budget.

The fundamental information provided by Table 2 is that the size of the typical project reserve lies in the area between 8% and 11%. The average reserve in this sample is a 9% mark-up. An analysis based on a categorisation with respect to project type (transportation infrastructure, building, defence procurement, and IT) shows that the sub-category mean values deviate little from the overall mean.

Table 2 also shows that there is no obvious connection between the project size and the size of the reserve expressed in per cent. The three sub-categories including projects from NOK 300–750 million, NOK 750–1500 million and projects larger than NOK 1500 million all show mean values close to the overall mean value. One might expect that it would be more difficult to predict all aspects that could have an impact on costs in large projects. The intention with the allocated reserve is to mitigate project risks that can not be fully predicted [14]. Seen in relation to the literature referred to above, where it was stated that major projects often suffer from cost overrun, one might expect that large projects would call for larger reserves. This is contradicted by the unsubstantiated notion that in major projects there exist more alternative courses of action, i.e., there are more opportunities to influence costs.

Table 2
Size of the recommended reserves (after project type and size)

Type of project	Number of projects	Mean reserve percentage (sub-category)	Standard deviation percentage (sub-category)
Transportation infrastructure	12	8	3
Building	9	11	6
Defence procurement	8	7	4
Information technology	2	11	5
Total	31	9	4
Size of project (million NOK)			
300–750	13	8	4
750–1500	12	9	4
1500–	6	10	6
Total	31	9	4

The results here are nevertheless not surprising. The recommended reserves basically reflect the uncertainty in the performed calculations. As described above, the size of the reserve in most cases is the difference between the 50% and the 85% subjective probability, which roughly equals one standard deviation. The robustness of the result from the uncertainty analysis depends on the ability to predict possible factors and their influence on project cost. Table 2 indicates that there is a rather typical reserve percentage, independent of project size or type. Building and information technology projects display a somewhat higher mean reserve and standard deviation than transportation infrastructure and defence procurement projects, but the existing material does not allow us to draw sharp conclusions whether there is a pattern here. The results from analyzing projects categorized by size, show even smaller differences between the sub-categories.

One of the major concerns has been the possibility that actual costs will be higher with the new approach, where reserves are allocated, compared to the old procedure. The point here is that it is questionable to assume anything about actual costs as long as the projects have not been completed yet, and adequate measures to obtain more realistic budgets have been established. Many authors emphasize the importance of better planning in the early stages of large projects to increase the potential for project success and reduce the occurrence of cost overrun.

6.2. The difference between the proposed estimate from the project organisation and the recommendation from the external consultant

The main issue here is related to the significance of quality assurance on the cost estimation process. This is the background for the attention paid to the comparison between the initial estimate and the revised estimate.

When comparing the estimates, fixed prices are used, and the numbers describe the ''same project'', which means that it has been controlled whether fundamental elements of the project have been changed between the proposed estimate and the recommended estimate (cf. the discussion above concerning that a project could be subject to modifications over time). This is an important prerequisite, because when the cost focus and control aspect is dominating, one must not only consider the different answers, i.e., the numbers from the uncertainty analyses. One must also ask whether they are answers to the same question.

To present an aggregate view of the data, the differences have been calculated in percent and divided into categories based on the size of the difference.

Table 3 shows that the recommendation from the external consultant is lower or equal to the projects' proposal in 8 out of 31 projects (26%). For the majority of the projects (74%), the external consultants recommend higher budget limits, in some cases up to 15% or more. On average the

Table 3
External consultant's revised estimate compared to the project organisation's initial estimate

Revised estimate is (compared to proposed estimate)		Number of projects	Per cent	
Lower	5–10% lower	3	9.7	26
	5% lower than or equal to	5	16.1	
Higher	Up to 5% higher	7	22.6	74
	5–10% higher	8	25.8	
	10–15% higher	5	16.1	
	More than 15% higher	3	9.7	
Total		31	100.0	

external consultants recommended 5% higher budgets. Some might argue that the observed differences are rather small. Why should we deal with differences that in an analytical sense equal the uncertainty in the results? First of all, even a 5% difference in projects of this scale could, expressed in money, be substantial. Secondly, it must be kept in mind that studies of initial estimates and actual costs that show deviations up to several hundred percent could include large distortions for instance with respect to inflationary backgrounds. This study is different, obviously because initial estimates from two different actors rather than initial estimates and actual costs are compared, but also because price escalations, project changes and other factors are not an issue or have been accounted for. The compared figures are indeed "answers to the same question from two different actors". With this in mind, one question immediately arises: What could explain the observed result? An exact explanation must be left open at this stage, but a closer look into the sources can be a basis for discussion. It could be that the external consultants apply a broader view and include more elements assumed to have an impact on the cost of the project. The project organisation's major concern is the implementation of the project according to specific requirements. The external consultants must also consider the potential impact of factors that to the project organisation may appear to be of a more unpredictable and unmanageable character. These could be factors connected to the market, financing, and changes imposed by the government.

It must also be recognized that the prevailing methods to calculate the estimates rely on subjective assessments. As described by Olsson et al. [9], in some cases different estimates have been a source of discussion between the project organisation and the external consultant. In cases where there are fundamentally different subjective views concerning central uncertainty elements, this will clearly be manifested in the results. Still, this does not explain why the external consultants present a higher estimate in so many cases.

Some may claim that this indicates an exaggeration of the estimates from the external consultants. Since they do not have any responsibility for the actual budget compliance and it is claimed that nobody wants the label that they underestimate costs, this could lead to a situation where extra costs are included just to be sure. It would be hard to establish data that could describe this issue, because this fundamentally is an assumption about the intentions of actors.[6] It must otherwise not be forgotten that the foundation for the external consultants' recommendations are explained in the reports from the quality assurance exercises. In this way the underlying premises for the recommended estimate can be verified.

The major question in this paper is the Quality-at-entry Regime's influence on the initial decisions connected to the projects. Does it lead to different practices and other methods? In this perspective an analysis that maintains the time dimension is presented.

The difference between the proposal from the project and the revised estimate is calculated in percent. A plot of the differences for all the projects in the sample against the month of presented report and the result is shown in Fig. 2.

Visual inspection indicates that the largest differences occurred when the quality assurance scheme was new, and interestingly, no revised estimate substantially lower than the initial estimate is observed before late 2002. Another indication from Fig. 2 is the clear decrease in the differences from the first quarter of 2002.

What explanations are there? A number of possible factors spring to mind. One possibility might be that the focus on more realistic cost frames launched by the Regime has led to an increase in the use of relevant methods by the project organisations to identify the uncertainties in the early stages of the projects. Observations made during the collection of the data suggest that more equal estimates coincided with a more consistent use of the most commonly used terms. At the same time, the Ministry of Transport and Communications, which accounts for a large number of the projects in the sample (cf. Table 1), specified how the results from the quality assurance of projects in their area of responsibility should be employed. This indicates that a change in practice and learning has taken place.

The literature referred to above suggest that so-called "strategic budgeting" could be a cause of underestimation in public projects. This is based on the assumption that projects that appear to be inexpensive have a greater chance of being prioritized. It is easy to predict that the Quality-at-entry Regime could have a rather direct impact on strategic budgeting; assuming that such practice actually has taken place. It is, however, impossible to answer this question on the basis of this study. The differences observed here could just as much be explained by overestimation from the external consultant as underestimation from the project organisation, and a possible interpretation of the development towards more equal estimates could also be that an adjustment to the demands of governmental institutions has taken place, either by external consultants, project organisations, or both.

[6] Flyvbjerg et al. [6, p. 289], face the same problem when trying to answer the question whether project forecasts are intentionally biased.

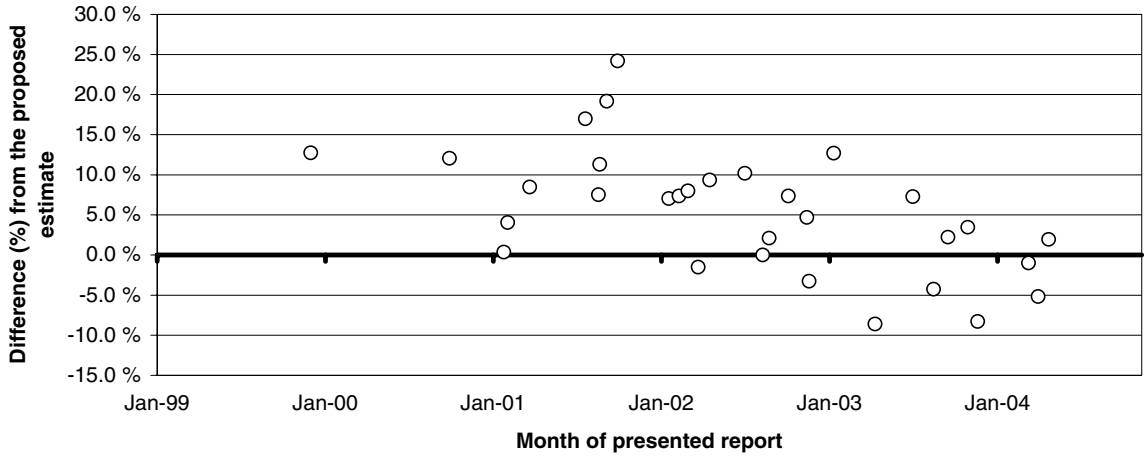

Fig. 2. The difference between the project's proposal and the revised estimate from the external consultant.

6.3. The difference between the recommended budget from the external consultant and the final budget decided by the Parliament

The formal approval and resolution on budget limits for each single project is dealt with by the Parliament. In practice, however, the Parliament accepts the Government's proposal without changes. The project presented to the Parliament is prepared by the responsible ministry based on the information from the subordinate agency responsible for the day-to-day activities in the project.

Table 4 shows that in 58% of the projects, the upper financial level decided for the project equals the total budget recommended by the external consultant. This means that in most cases, the project owners directly use the recommendation from the external consultant when submitting the proposal. At least there is a strong tendency toward this as reflected by the table. The table also clarifies that the recommendation can be disregarded. It must also be noted that in many cases new estimates are prepared from the project as a response to quality assurance. To give a closer illustration of how the recommendation is applied by the project owner, i.e., the direct response to the results from quality assurance, descriptions from some of the projects included in the sample are presented:

"*External quality assurance has taken place which gives an estimate of NOK 738 million with 50% probability for budget compliance, and NOK 788 Million with 85% probability. Based on the quality assurance the Norwegian Public Roads Administration has reviewed the project and presented a revised estimate of NOK 718 million.*" ([15, p. 117], author's translation)

Another example describes a case where the difference was rather small:

"*The quality assurance shows recommended budget numbers marginally lower than those proposed by the Norwegian Public Roads Administration. In the Ministry of Transport and Communications' opinion the quality assurance confirms that the Norwegian Public Roads Administration's estimate is on an appropriate level.*" ([16, p. 4], author's translation)

The examples illustrate how the external consultant's recommendation is used by the project owner to verify the numbers proposed by the project organisation and that the quality assurance could result in updated cost estimations from the project organisation. It is shown that there is no rule of thumb whether the final decision is based upon the project organisation's or the external consultant's estimate. Each project is considered on an individual basis by the responsible ministry and the project organisation.

An explanation to the observations made here can be connected to some of the results from Olsson et al. [9] where it was concluded that the project owner particularly finds the quality assurance useful. The study reported in Olsson et al. [9] was based on fewer projects and did not include analyses of the cost estimates. The study in this paper is a quantitative one, but it supports the results in Olsson et al. [9] because it clearly states that the external recommendation, at least concerning the project cost, is followed up by the project owner. An important conclusion, drawn from the analysis presented here, is that the involved ministries, being the project owners, actively use the information provided by the external analysis in the preparation of the project. The cost estimates are a central part of this information, and the fact that the project owners in so many cases directly build upon the calculations from the external consultants, is a strong indication concerning the significance of this contribution.

Table 4
The approved budget is often based on the recommendation from the external consultant

Sanctioned budget	Number of projects	Per cent
Lower than the revised estimate	7	23
Equal to the revised estimate	18	58
Higher than the revised estimate	6	19
Total	31	100

7. Concluding discussion

The performed analyses show that the recommended project reserves on average are 9%. It is furthermore observed that no matter the scale of the project, the size of the reserves measured in per cent appear to be rather typical, which is rather surprising, when it is kept in mind that existing studies report overrun up to several hundred per cent.

A discussion concerning the potential cost effect of the stochastic cost estimation and budgeting in public projects is conducted. It is concluded that a final evaluation of the cost development must be done when the actual costs are available. Compliance to the approved budget rely to a large extent on the management of the reserves and it is also argued that it is questionable to judge projects not yet completed against past experience, which indicates that projects use at least their allocated budget, when adequate measures to reach realistic estimates at an early stage have been established.

It is possible to conclude from the present study that there is a difference between the numbers proposed by the project organisation and the revised estimates from the external consultant. This is based on the observation that the revised estimates were higher than the initial estimate in 74% of the projects studied here. This is a rather strong indication since the estimates compared here are answers to the same question. The study also shows that the differences were higher in the early stages of the Regime. The observed differences have decreased systematically since quality assurance was initiated in 2000. Some suggestions based on empirical observations, the prevailing methods and different views upon the analysed project are discussed, but the most important result here is the revealed tendency in the existing material.

The study further shows that for many projects in the sample, the parliamentary decision directly rely on the estimates provided by the external consultant. This supports the claim that the involved ministries, i.e., the project owners, benefit from the external assessment of the project, and actively use the provided information when preparing the decision proposal for the Parliament.

The observations here lead to the identification of important issues that need to be addressed in further research. Are the differences in the estimates systematic and statistically significant? Are the differences observed when the scheme was new cost underestimation by the projects or overestimation by the consultants? Does the systematic decrease imply a learning curve, or does it indicate an adjustment to external demands? A closer look at the historical records will help to cast light on these issues.

This paper is a report from the first analyses of cost estimates in major public investment projects after the initiation of the Quality-at-entry Regime. Some experiences have been gained, but there are many questions that need to be answered to get a picture of the effect of this initiative not only in terms of reduction of cost overrun but also long-term feasibility and profitability of public projects.

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Paper 3.

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(This version includes minor proof reading adjustments, compared to the submitted version.)

Projects trapped in their freedom: Flexibility aspects on front-end quality assurance of major projects

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Projects trapped in their freedom: Flexibility aspects on front-end quality assurance of major projects

Abstract

This paper aims to use experiences from major governmental investment projects to illustrate aspects on project flexibility, both from a theoretical and empirical point of view. Projects appear to be trapped in their freedom. The potential freedom of projects as temporary organizations is so large that major management emphasis is directed towards reducing and controlling flexibility. The empirical study is partly prospective, in the meaning that the projects and parameters to be studied were selected prior to conducting the analyses. Based on empirical data, flexibility in different project phases is quantified for illustration.

Keywords: Projects, Front-end, Flexibility, Quality-at entry

1. Introduction

The purpose of this paper is to use experiences from the Norwegian Quality-at-entry regime for major governmental investments to illustrate aspects on project flexibility. The paper is also an attempt to contribute with empirical results on some project management issues related to project flexibility.

To begin with, theoretical traditions in project management are discussed. Some models for illustration of project flexibility are also presented. Secondly, the nature of the Norwegian quality-at-entry regime for major governmental investments is analyzed in general. Project flexibility is chosen as a perspective to illustrate some aspects of the regime in more depth. An attempt is also made to quantify one aspect in the general project flexibility models based on empirical data. Finally, the results are discussed and some models for explanation of the results are proposed.

1.1 Project management

Söderlund (2004) discusses two main theoretical traditions in project management research. The first tradition has its intellectual roots in engineering science. Planning techniques and methods of project management, including the recent emphasis on uncertainty quantification and risk management, have been the major focus. This is in accordance with Packendorff (1995), who claims that a number of writers trace the intellectual roots of project management research and knowledge to various types of planning techniques, such as PERT and CPM. The other tradition has its intellectual roots in the social sciences and is especially interested in the organizational and behavioral aspects of projects. Söderlund (2004) terms these "the engineering tradition" and "the social science tradition", respectively. In a similar distinction between project management traditions, Crawford and Pollack (2004) uses the terms "hard" and "soft". Crawford and Pollack (2004) relates "hard" project management approaches to objectivist, scientific approaches and has parallels to Söderlund's (2004) engineering tradition. The "soft" project management approaches of Crawford and Pollack (2004) stem from an interpretivist and constructivist schools of thought, and share similarities with Söderlund's (2004) social science tradition.

According to Engwall (2003), research on project management has been dominated by what he calls "the lonely project" perspective, with little emphasis on project context and organizational history. Engwall (2003) and Jugdev (2004) point out that current project management knowledge is a practitioner-driven theory focusing on supporting advices to the project manager, apparently referring to the engineering tradition.

The discussion on project management traditions can also be related to how "project management" is defined. One way is looking at it, is to consider the engineering tradition as a hard core of project management. This is not necessarily because it is the core competence in project management. The reason is that no or few other disciplines claim that this is also "their" area of competence, with the possible exception of operations research. As the perspective shift to the social science tradition, influence from other disciplines becomes stronger. In such a perspective, the social science tradition draws on experiences and research approaches from areas such as organizational science, planning, decision analysis and political science, all applied in a project context.

1.2 Flexibility and project management

Flexibility is one approach to prepare projects for the effects of uncertainty. Terms like adaptability and robustness are often used when discussing issues related to what this paper calls flexibility. Flexibility may also be described as a way of making irreversible decision more reversible or postponing irreversible decisions until more information is available.

The uncertainty of a decision in a project can be described by the gap between the information needed to make a decision that is entirely consistent with the actual outcome, and the information available at the moment of decision making (Galbraith, 2001). Mikkelsen and Riis (2003) identify a fundamental dilemma in project planning: that the importance of decisions is at the highest at the same time as the available information is at its lowest. A common way of reducing this dilemma is to increase the available knowledge about the project. One key idea in project

flexibility is to postpone irreversible decisions in the front-end phase of projects, in addition to (or instead of) gathering more information.

The engineering tradition of project management, referred to by Söderlund (2004) and Crawford and Pollack (2004) is focused on stability for the project, particularly in the later phases of a project. The social science tradition has a greater understanding of the needs for flexibility and adaptability. Kreiner (1995) points out that the traditional focus on stability becomes challenged under uncertainty, which creates what he calls “drifting environments”. The drifting environments (or “context” as termed by Engwall, 2003) of a project are not necessarily caused by actual changes in the project context, but may also be the result when the project owners and users stakeholders get a better understanding of, and ability to express, their actual needs. According to Samset (2003), contextual uncertainty is associated with the surroundings or context of a project and usually considered beyond the scope and authority of the project. The project has limited possibility to influence the contextual uncertainty. Olsson (2004) indicate that flexibility is generally not desirable when the unit of analysis is limited to the project itself, but it can be rational when a wider context is included in the analysis.

Projects are traditionally seen as temporary organizations designed for unique tasks (Cleland, 2004), often in contrast to the mass producing core activities of organizations. At present, projects are initiated to solve tasks of almost any type (Engwall, 2003) to the extent that the Western society seems to be heading towards a “projectified society” (Lundin and Söderholm, 1998, Gareis, 2004). A major benefit of organizing a task as a project is the freedom to create an organization more or less from scratch. While uniqueness is the competitive advantage of projects as a way of organizing, changes and lack of predictability is commonly seen as the major pitfalls of projects. Successful projects are characterized by control and governance (Hall, 1980; Morris and Hough, 1991; Miller and Lessard, 2000).

Permanent organizations, on the other hand, are traditionally seen as repetitive tasks, suitable for permanent organizations (Taylor, 1912). Focus in manufacturing and supply chains has moved from mass production, via lean to agile production, (Asbjørnslett, 2003). As a part of this development, the emphasis on flexibility has increased, to the extent that “changeability” is listed on equal terms as effectiveness and efficiency when establishing performance measurement systems (Andersen et al., 1998).

We noted that the engineering tradition of project management is focused on stability while many other management sciences are focused on adaptability. Kaderfors (1995) illustrates a similar paradox regarding projects. Projects are on the one hand viewed as situation-specific organizations, designed to solve a specific and unique task. However, several project intensive industries, including construction, have a reputation of being conservative and slow to change. This indicates that the potential flexibility in projects is controlled by conformity in the working process, creating a conservative tradition.

So far, flexibility has been discussed in general terms. The empirical part of this paper includes an analysis of observed flexibility aspects of projects. Flexibility is used in a rather wide meaning in this paper, based on the definition of Husby et al. (1999): flexibility is "the capability to adjust the project to prospective consequences of uncertain circumstances within the context of the project". In such a wide definition, flexibility includes preparations to manage both internal and contextual uncertainty, such as: scope change management, iterative decision process, adjustments related to uncertain funding in general and budget reserves in particular.

1.3 Visualizing project flexibility

Most authors agree on the value of flexibility in the front-end phase of projects while flexibility is commonly seen as undesirable in the execution phases of projects. Lundin and Söderholm (1998) describe how a project moves from relative openness in the beginning of the project, to relative closeness in the execution phase. In the execution phase the predetermined action is supposed to be carried out according to the plans, in a “planned isolation”. The concept of project flexibility in the execution phase disturbs this planned isolation. Midler (1995) describes a management strategy for modern concurrent engineering projects. First prevent early commitment while at the same time trying to gather as much information as possible on the project. In the second phase, the project is locked as precisely as possible. Finally, at the end of the project, speed is given maximum priority in order to solve the remaining technical obstacles. In a similar way, Mahmoud-Jouini et al. (2004) characterizes project management by the speed of three

project phases: preparation, freezing and implementation. A similar approach is discussed by Verganti (1999). He identifies two different approaches to achieve flexibility in product development projects; anticipating and reaction. Anticipating means that future requirements should be analyzed as early as possible in the front-end phase. In contrast, reaction is the capability to rapidly introduce changes late in the process. Using the untraditional reaction approach, choices are delayed until later in the projects, when information is available. Verganti (1999) shows that a combination of the two approaches typically are used by successful companies.

Many textbooks on project management present illustrations concerning the relative size of project attributes during different project phases. The attributes include uncertainty, significance of decisions, freedom to maneuver, accumulated cost and available information. Figure 1 is an attempt to summarize the different models. Even though the shapes of the curves vary between different authors, the models all have in common that the uncertainty, significance of decisions and the degree of freedom to maneuver are typically high in the beginning of the project, and low in the end. At the same time, variables such as the accumulated cost and available information begin at low levels and end up at a high level at the end of the project. Even though this type of figure is very common and appears to be logical, the models appears to primary serve as summaries and illustrations, and seems to a lesser extent to be based directly on empirical evidence. There are obvious challenges in quantifying and measuring the different variables. One study in Miller and Lessard (2000:34) shows that for one particular project, regulatory, political and financial risks were at there highest during the middle of the project. However, this type of models can be used to illustrate different issues related to project flexibility.

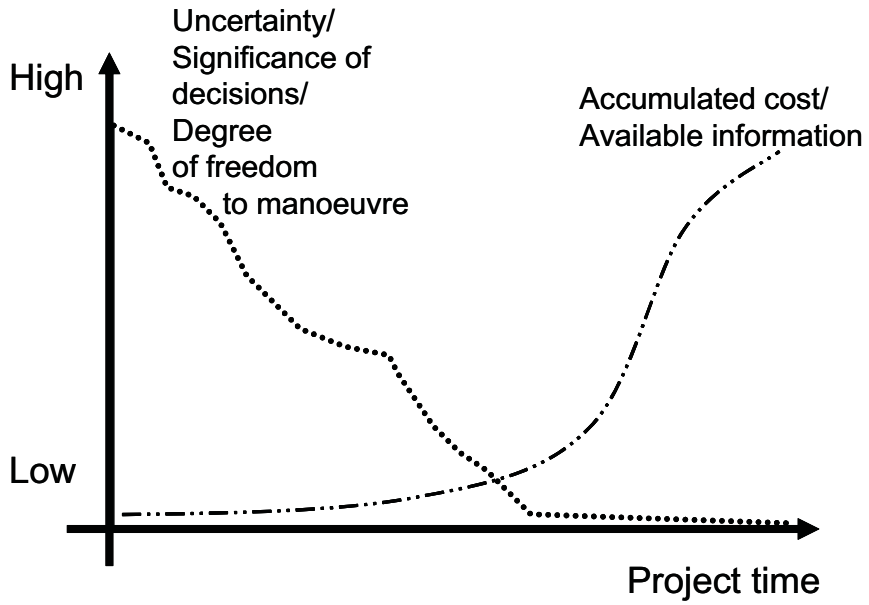

Figure 1. The uncertainty, significance of decisions and the degree of freedom to maneuver are typically high in the beginning of the project, and low in the end. The accumulated cost and available information have a reverse development through the project, beginning at a low level and ending at a high level. (Based on Christensen and Kreiner, 1991:40; Mikkelsen and Riis, 2003:47; Midler, 1995:369, Samset, 2000:32).

The "high to low"-curve may have different direct meaning, but the underlying message is similar. Christensen and Kreiner (1991:40) uses Galbraith's (1977) definition of uncertainty as the difference between the needed and the available information. As the available information increases the uncertainty also decreases through the project. Samset (2000) uses a similar definition of uncertainty. Eikeland (2001) on the other hand, equalizes "room for maneuvering" with the internal uncertainty of the project, related to internal decisions that will be, but are not yet taken. A decision is within the room for maneuvering if it does not violate the consequences of previous decisions.

Midler (1995) relates the decreasing degree of freedom to maneuver with a rising degree of irreversibility in project decisions. Mahmoud-Jouini et al. (2004:361) describes the descending curve as "possibilities of action in the project". Mikkelsen and Riis, (2003:47) let the "high to low"-curve represents importance of decisions.

The "low to high"-curve usually represents either accumulated cost (Eikeland, 2001) or the relative amount of information or knowledge available related to the project (Mikkelsen and Riis, 2003; Midler, 1995; Samset, 2000 and Mahmoud-Jouini et al., 2004).

1.4 Stakeholder's opinion on flexibility

Olsson (2004) analyzed the expected opinion on project flexibility. Project owners and users were likely to be more positive towards changes aimed at increasing the benefit side of the projects, or related to effectiveness. Stakeholders whose main responsibility lie on the cost side of the project, such as project management and contractors, are less likely to embrace changes. According to Kreiner (1995), the project management is made the guardian of efficiency.

In manufacturing industry, it has long been established that task control is a key to achieve high efficiency and productivity. The theoretical foundation for this include scientific management theory (Taylor, 1912), administrative management theory (Fayol, 1949) and bureaucracy theory (Weber, 1922). These theories all have in common that they assume closed systems in order to minimize uncertainty and disturbance (Thompson, 1967). Stability, predictability and control are key elements. Project management techniques such as Work Breakdown Structure (WBS) and other elements of the engineering tradition in project management are descendants from these theories.

Samset (2001:116) discusses and illustrates the need for a division between the project itself and the strategic frame of the project. While the financing party has limited possibility to influence the execution of the project, they have incentives to define the strategic prerequisites as precisely as possible. This reduces the tactical room for maneuvering, and consequently the chances that the project will be carried out as planned. In a similar way, Müller (2003) claims that the owner should impose medium levels of structure on the projects manage. Too much structure will not give the project manager sufficient flexibility to deal with uncertainties that arise. Too little structure will lead to anarchy.

1.5 Flexibility as blessing and curse

Project flexibility is part of a fundamental dilemma in project management. On one hand, projects need stability and control to be executed efficiently, typically measured by time, cost and meeting specifications. Thus, flexibility shall be minimized. On the other hand, important decisions in projects must be taken based on limited information in an unpredictable world, creating a need for flexibility. We briefly discussed different approaches to this dilemma from a theoretical standpoint. In the following, methodology and results from a study is presented in an attempt to illustrate some aspects of project flexibility. The empirical data are based on the preparation and execution of a Quality-at entry regime of Norwegian governmental investments. To begin with, this regime is presented.

2. The quality-at-entry regime

The largest public investment projects in Norway amount to about 3 billion USD per year totally, mainly channeled through the Ministries of Labor and Government Administration, Finance, Defense, and Transport and Communications (St.prp 1 (2001-2002)). In 1998, the Norwegian ministry of finance initiated an analysis of a number of major governmental investments. Effective from 2000, the Norwegian Ministry of Finance initiated mandatory quality assurance and uncertainty analysis of all governmental investments in Norway exceeding NOK 500 millions (60 million USD), the so-called Quality-at-entry Regime. The regime was introduced in response to a situation with large overruns (Berg et al., 1999).

As a consequence, the responsible ministries are required to undertake assessments prior to the parliament's appropriation of the projects, with a particular aim to review cost estimates and major risks that might affect the projects when implemented. Such analyses are given the short name Quality Assurance 2 (QA2). The aim is to

establish realistic cost and time frames for the projects. Four consulting groups were commissioned to undertake the assessments. Related to the project phases, the quality-at-entry analyses are made in the end of the front-end phase.

Important elements in the QA2 Quality-at-entry assessments are (St.prp nr. 1. (1999-2000)):

- Verify the cost estimates in order to achieve commitment for realistic project budgets
- Establish a list that specifies how the cost can be reduced if the set budget cannot be met
- Advice on budget reserves that can cover unforeseen cost. The reserves should serve as a realistic tool to ensure that the projects could be carried out based on the allocated funds and, if need be, by also using the reduction list
- Advise on how the budget reserves should be managed, specifically who would have the authorization to use the funds.

The Quality-at-entry assessments shall also address issues such as important prerequisites, contract management and project organization.

The purpose of the QA2 assessments was to give the ministry of finance and other involved ministries an independent analysis of the project before approval in parliament. In the consultant's mandates, it is clear that the controlling aspect is the main focus. Based on the chosen content of the Quality-at-Entry regime, it appears to have its roots in the engineering tradition of project management. Main attention is paid on securing that he projects can be carried out as planned, with a particular emphasis on the budget. An important part of the QA2 assessments has been on stochastic calculations of the expected cost. Dedicated software tools are used for such calculations. Even though organizational aspects of the projects are included in the Quality-at-entry assessments, this is done from a controlling perspective: how do we secure that the projects can be carried out as planned? The reasons for such a perspective are documented in the preparations for the regime, were cost overruns and varying treatment of uncertainty in project estimates were identified as major challenges.

Experiences from the quality-at entry QA2 regime have indicated a need to focus on the basic rationale of projects as to satisfy needs. The Quality-at-entry Regime has been revised and extended to include an external assessment of different project concepts. This new part of the regime is called Quality Assurance 1 (QA1). Quality assurance concerning the basic project concept has not yet taken place. Awarding of framework agreements to consultants was in progress at the time of writing.

3. Method and material

The methodological terminology used in this paper is inspired by methodology used in medical research. In clinical research, two common research designs are cohort studies and cross-sectional studies (Hulley et al. 2001). In cohort studies, a group of subjects is followed over time. In cross-sectional studies, observations are made on a single occasion. Furthermore, two basic variations of cohort studies are possible: prospective and retrospective studies. In prospective studies, the investigator defines the sample and measures variables before any outcome have occurred. Studies in which the sample and data collections are made after the outcome have occurred are retrospective. While many studies in project management are of the retrospective type, the research material in this paper also includes prospective studies. The applied methodology is partly prospective, in the meaning that the results are generated from a trailing research were the projects and parameters to be studied were selected prior to conducting the analyses.

In the medical tradition, retrospective cohort studies have the advantage over prospective ones of being much less costly and time-consuming. Prospective studies give the investigator better control over the study (Hulley et al. 2001). The parallels between medical and project management research shall not be drawn too far, but the prospective design has contributed to a relatively consistent data material and overview of the data collection process.

Two data sets have been used. Table 1 gives an overview of some characteristics of the two data sets. The first data set describes the background for the Quality-at entry regime. This material includes 14 projects initiated between 1986 and 1998. The prime source is reports written as a preparation of the quality-at entry-regime. Theses analyses are well documented and submitted to public inquiry before a summary of the results were included in a

parliamentary bill. In addition, public evaluation reports of governmental projects that have been submitted to the parliament have been used. Both types of reports are comprehensive and quality assured analyses of the projects.

The second source of information consists of 48 Quality-at entry reports carried out between 2000 and 2004. As a part of the Norwegian Quality-at-entry regime, a forum was established consisting of the involved consultants and ministries. A key issue if this forum was to ensure a uniform structure and terminology of the Quality-at entry reports. As a consequence, the research data used in this study has a uniform and quality assured structure. Both these data sets have been codified and entered into a research database. The purpose of the database was to provide proper storage of all relevant data regarding the projects.

Data set	Background for the Quality-at entry regime		Projects under the Quality-at entry regime (QA2)	
Number of projects (N)	14		48	
Time if project initiation	1986-1998		2000 -	
Data source	Evaluation reports		Consultant reports	
Type of study	Retrospective		Prospective	
Project type	Number	Per cent	Number	Per cent
Hospitals	2	14 %	1	2 %
Transportation infrastructure	6	43 %	25	52 %
Defense	3	21 %	16	33 %
Public buildings	3	21 %	6	13 %
Total	14	100%	48	100%
Project size (final or last known)				
<15 mill USD (100 mill NOK)	2	14 %	0	0 %
15 - 60 mill USD (100-500 mill NOK)	4	28.6 %	5	10 %
60 - 250 mill USD (500-2000 mill NOK)	4	28.6 %	34	71 %
>250 mill USD (2 mrd NOK)	4	28.6 %	9	19 %
Total	14	100%	48	100%

Table 1. An overview of the two used datasets.

As Table 1 shows, the material related to the preparations for the Quality-at entry regime is of a retrospective type. The data related to projects that were subject to analysis under the Quality-at entry regime is of a prospective type. A research program, CONCEPT, was established to do research on the effects of the new regime and to follow the projects that were subject to analysis. The projects to be studied were therefore defined before the data collection took place. The variables to be studied were also defined prior to the data collection based on the format of the Quality-at entry analyses.

In addition to the written material, structured interviews are carried out with key stakeholders in many of the projects, including the ministries, government agencies and project organizations. The ministries and project organizations in eight of the first 20 projects were interview and the results are presented in Olsson et al. (2003). Further interviews of agencies and project managers in the Defense, the Public Roads Administration and the Directorate of Public Construction and Property were carried out and presented by Langlo and Olsson (2003). In relation to the mentioned previous studies, this paper aims to add results from a quantitative study to the previous qualitative studies and present an overview based on multiple data sources.

4. Results

In the following, the empirical data are presented. To begin with, we present results from a re-analysis of the material that served as a decision basing when the Quality-at entry regime was established. Secondly, there are results based on performed Quality-at entry analyses. Finally, there is a brief presentation of the next steps in the development of the regime.

4.1 Background for the quality assurance regime re-analyzed

Based on the available reports from the analysis that was done as a preparation for the Quality-at-entry regime, we have re-analyzed the projects in a flexibility perspective. The type of projects in this part of the study is shown in Table 1. The analyzed projects were been initiated between 1986 and 1998.

The types of flexibility that was observed in the projects have been analyzed. As can be seen in Table 2, scope changes were common, particularly during the planning phase. Only one project could be executed as planned.

The original analysis (Berg et al. 1999) claimed that unsatisfactory project results, mostly cost overruns, often came as a consequence of poor preparations of the projects before they were presented to the parliament for final approval. In a flexibility perspective, this re-analysis indicates that the analyzed projects were subject to project flexibility particularly in the planning and execution phases. The background for the Quality-at entry regime therefore indirectly point to project flexibility as a major problem in governmental investments.

	Front-end	Planning	Execution	No phase
Scope changes	0	7	2	N/A
Iterations	2	2	0	N/A
No flexibility	0	0	0	1
Total	2	9	2	1

Table 2. Type of flexibility applied in the first set of studied projects (N=14)

4.2 Results from quality-at-entry reports seen in a flexibility perspective

Mandatory Quality-at-entry analyses of governmental investments were carried out by external consultants on behalf of the responsible ministry. The consultants present a report that compiles the results from the quality assurance. By the time this paper was drafted, 54 projects had been subject to quality-at-entry analysis. General information was obtainable for 48 of these projects. Table 1 shows a summary of the type and size of the projects.

Flexibility is, with some exceptions, not directly addresses as a term by its own in the QA2 analyses. However, several issues discussed previously in this paper as different aspects of flexibility are to be found. The QA2 reports include an overview of critical success factors and pitfalls. Table 3 shows a summary of how frequent three aspects of flexibility were mentioned in the summaries of the Quality-at-entry reports. The aspects were change management, structured approach to flexibility and finally predictable funding. Issues related to scope change management are summarized in the column for change management in Table 3. Iterative decision processes and flexibility in the technical solutions are summarized in the column labeled structured approach to flexibility. This was the only area where the term “flexibility” was explicitly used. Finally, management of uncertain funding is covered in the column labeled predictable funding. Table 3 shows a summary of how frequent these aspects of flexibility were mentioned as one of the top issues in the project analyses. The overview only covers occurrence in the summaries of the reports, meaning that a prioritization has been made.

	Change management	Structured approach to flexibility	Predictable funding
Pit fall	16	2	2
Key success factor	13	3	1
Pit fall or key success factor	24	5	3

Table 3. Key project aspects related to project flexibility as mentioned in the summaries of the Quality-at-entry reports (QA2). N=48

Management of changes was the most frequent issue. It was mentioned as a top issue in 24 of the projects, or 50%. In most cases the purpose was to establish a structured management of scope changes in order to minimize the amount and the size of the changes. For five projects, change management was mentioned as both as success factor and pit fall, usually addressing the same issue, in essence an emphasis of the importance of change management. The apparent "double counting" in five projects means that the total number of projects addressing change management are not equal to the sum of each issue individually in Table 3. Flexibility in the product or decision process was mentioned in 10% of the projects. The availability of predictable funding often was frequently mentioned in the text of the reports. However, it was only in three projects that it was listed among the top pit falls or key success factors in the summaries of the reports.

4.3 Reduction lists

It is a part of the consultants' assignment to assess the possibility for potential reductions that can be carried out if other parts of the project turn out to be more costly than planned. These possible reductions are summarized as reduction lists. Reduction lists are the most explicit use of project flexibility in the Quality-at entry regime. These reduction lists cover parts of the project scope that are planned to be part of the projects. However, if necessary, these parts of the scope can be taken out of the projects without threatening the fundamental functionality of the delivery. The scope reductions shall be described, the cost reduction shall be estimated and a priority list shall be presented. Prerequisites and consequences shall also be described. Even though it was not a formal requirement, many of the consultants chose to add due dates for the scope reductions, to indicate when decisions have to be made to realize any cost saving from the reductions.

Information on reduction lists was possible to obtain from 42 of the projects. As shown in Table 4, reduction lists were used in 30 of these projects. For 23 of the projects, the reduction lists also included due dates to define when the window of opportunity closes for each item on the reduction list. The total value of all mentioned possible reductions was 7% if only the projects with reduction lists are used as basis for percentage calculation, and 5% if all projects are included, i.e. also those project without reductions lists.

	Number	Percentage (based on 47 projects)
Projects with reduction lists	33	70 %
Projects that subtracted reductions in the recommended budget	18	38 %
Projects with due dates in the reduction lists	24	51 %

Table 4. Occurrence of reduction lists (N=47)

Table 5 shows a categorization of the reductions, their frequency and total amount. Flexibility in the product represents primarily preparations for alternative use of for future projects. Reductions in quality or functionality

lowered the quality but the volume remained the same as planned. A common type of reduction for roads was related to planned actions on existing roads in connection to the new construction. These occasions are registered as reductions in quality. Adjustments of the ambitions related to the visual impression of the project delivery might be seen as a subgroup of quality reductions. Due to its frequency in transportation infrastructure projects in particular, it is presented as a separate category. Common examples of this category include planting fewer trees, lower ambition as to establishing lawn and lower ambitions for the esthetic appearance of concrete walls. Reductions in volume relate to number of items delivered, fewer kilometers of road etc. The dependencies between different projects were typically of the type that "if another project includes this particular delivery in their scope, we can take it out of our scope". Finally, any type of reduction that did not match the identified categories is listed as "other". As can be seen in Table 5, quality and volume issues were most frequent and represented the largest monetary value.

	Total observations		Amount	
Type of reduction	Number	Percent	Mill. NOK	Percent
Flexibility in the product	9	5 %	70	3 %
Quality, functionality	71	42 %	804	36 %
Visual impression	22	13 %	239	11 %
Volume	48	28 %	864	39 %
Dependencies between projects	4	2 %	41	2 %
Other	15	9 %	221	10 %
Total	169	100%	2 239	100%

Table 5. Reductions by type, frequency and size. Based on data from 37 projects.

Several concerns regarding the scope reductions are raised. One issue is related to cost sharing between stake holders in the projects, for example between the government represented by the Public Roads Administration on the one hand, and the local counties on the other hand. Some type of scope reductions may only represent a relocation of the cost.

A similar discussion related to weighing investments versus maintenance cost is also present for many projects. In some cases, it is commented that future maintenance cost becomes neglected by the use of a fairly high discount rate in cost/benefit calculations.

In many cases, reductions are claimed to only be possible by reducing the volume of the projects, for example in terms of highway meters or defense equipment units. A common comment is that by reducing the volume, the unit cost will increase in the projects because of fixed costs. There is also a tendency towards frustration because the projects have been through several rounds of reductions to focus the scope prior to the external quality-at entry analysis, where a new round of reductions is asked for.

The need for fast decisions regarding possible reductions is very common. According to one consultant, reductions in system architecture and quality standards have to be made early in the projects. Reductions in volume are possible to make at later stages, depending on the contract structure. Another common comment is that the potential volume of the reductions is so small that it is not justified to set up a system to manage reductions.

The purpose of the reduction lists is to have possibilities to reduce the scope in response to cost overruns. A major challenge is that the due dates for the reductions typically comes before one can expect that project management have updated cost estimates that may indicate potential overruns.

4.4 Calculating the remaining flexibility of projects

Based on the reduction lists and due dates, it was possible to illustrate how the due dates of the items on the reduction list expire on a time scale. Quality assurance reports were typically delivered a few months prior to the final decision in parliament to go ahead with the projects. The time span of the projects are equal to the time from the date of the quality assurance report, until the planned delivery date of the final project result. To perform the calculations, the time span of each of the projects was divided into quarters of years. For each quarter, the value of the still open items on the reduction list was calculated as percentage of the total project budget. Remaining flexibility of the project decreased each time a due date for an item on the reduction list passed. This value can be seen as an indication of the remaining flexibility, or room to maneuver. It was possible to perform such calculations for 19 of the projects. The shortest of these projects had duration of 1 year, the longest 10 years and average was 4.1 years.

Table 6 shows values of the remaining flexibility for each quarter of the projects. The value is presented as average, maximum, minimum and standard deviation, for each quarter. In this table, all projects are analyzed (and usually approved by parliament) at year number 0. In reality, all projects did not begin at the same time, but in a sequence, usually independent of each other. As the number of projects decrease in the right column, this indicates that the projects reach their completion. When the number of projects drops from 19 to 16 between year one and two, this means that the three shortest of the projects only had duration of less than two years. Only one project had duration over 7 years. The average remaining flexibility drops sharply during the first year of the projects, from almost six to less than two percent. After 6 years, none of the projects had any remaining items on their reduction lists. Only three projects had such long duration.

Year	Average	St.dev	Max	Min	N
0	5,9 %	5,0 %	18,2 %	0,2 %	19
1	1,8 %	2,1 %	7,4 %	0,0 %	19
2	1,2 %	2,1 %	7,4 %	0,0 %	16
3	1,0 %	1,7 %	5,2 %	0,0 %	12
4	1,0 %	1,5 %	3,8 %	0,0 %	10
5	0,3 %	0,5 %	1,2 %	0,0 %	7
6	0,0 %	0,0 %	0,0 %	0,0 %	3
7	0,0 %	0,0 %	0,0 %	0,0 %	1
8	0,0 %	0,0 %	0,0 %	0,0 %	1
9	0,0 %	0,0 %	0,0 %	0,0 %	1
10	0,0 %	0,0 %	0,0 %	0,0 %	1

Table 6. The size of the reduction lists as percentage of total budget at the end of each year of the project tine span, beginning from the date when consultants supplied their reports, and ending when the projects are delivered.

To achieve a uniform presentation of the projects, regardless of their duration, the time scale was then converted to percentages of time span. Thus, all projects begin at 0% on the time scale. At this point, the initial remaining flexibility is represented by a full reduction list (on average 5.9%, the same as for year 0). The projects were completed at the 100% mark on the time scale, which in reality varied from a little more than one year to ten years, with an average of 4.1 years. At 50%, all projects were halfway between the delivery of the quality assurance report and their planned finish date. At this stage, the average project had open items on the reduction list equivalent to 0.8% (and 3,4% at the most) of the total budget. Table 7 shows remaining flexibility presented as average, maximum, minimum and standard deviation on the uniform time scale.

Percent of project on time scale	Size of remaining items on reduction lists			
	Average	St.dev	Max	Min
0 %	5,9 %	5,0 %	18,2 %	0,2 %
10 %	5,2 %	4,9 %	18,2 %	0,0 %
20 %	2,9 %	4,0 %	17,2 %	0,0 %
30 %	1,7 %	1,8 %	5,7 %	0,0 %
40 %	1,5 %	1,7 %	5,4 %	0,0 %
50 %	0,8 %	1,2 %	3,4 %	0,0 %
60 %	0,4 %	0,9 %	3,4 %	0,0 %
70 %	0,3 %	0,8 %	3,4 %	0,0 %
80 %	0,2 %	0,8 %	3,4 %	0,0 %
90 %	0,1 %	0,3 %	1,2 %	0,0 %
100 %	0,0 %	0,0 %	0,0 %	0,0 %

Table 7. The size of the reduction lists as percentage of total budget at different phases of the projects, beginning from the date when consultants supplied their reports, and ending when the projects are delivered. N=19

4.5 Reserves

It is also a part of the consultants' assignment to recommend a budget for the project. The projects are typically assigned a budget which consists of the expected cost including expected extras. In addition, reserves were allocated to the investments in order to avoid the need for additional funding. The intention with the allocated reserves was to mitigate project risks that could not be fully predicted

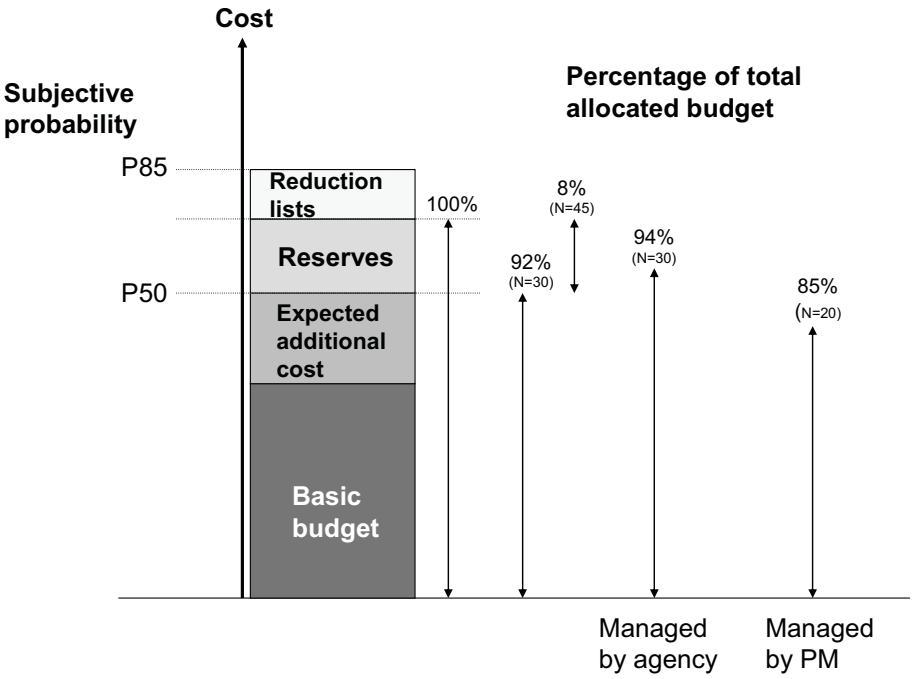

Figure 2. Project budget and reserves

As Figure 2 illustrates, the external consultant recommends a total budget that is expected to cover the consequences of the identified uncertainties. The allocated budget shall represent the cost that has 85% probability of being met (referred to as "P85"), minus the identified potential for reductions. The reserves are, however, not expected to be used, and specific rules for the management of reserves have been established. The budget allocated to the projects, or the executing government agency is usually the most probable final cost (P50). The reserves were not managed by the project manager, and usually not even by the executing government agency. Use of the reserves must be approved by the responsible ministry. Reserves are not intended for expanding the scope of the projects, but solely to cover unexpected expenses.

The size of the reserves recommended by the external consultants could be established for 45 of the projects. On average the external consultants recommended a 9 % reserve (interpreted as a mark-up above the expected cost). Viewed as a share of the total allocated budget the recommended reserve is 8 % on average. In 30 projects the external consultants directly recommended a budget managed by the subordinate agency, and in 20 projects a project manager cost target.

A closer look upon the recommendation on how the reserves should be managed reveals that the subordinate agency on average is pointed out as responsible for 94 % of the total allocated budget. The recommended expected cost is on average 92 % of the total budget, which means that the subordinate agency is granted somewhat more than the expected cost. In the 20 projects where a project manager cost target was recommended, the analysis shows that the project manager is pointed out to manage less than the expected cost (85 % on average). This is supported by the fact that during the collection of the data it was observed that in many cases where a specific project manager cost target was not directly recommended. Instead, it was frequently mentioned that a reasonable level would be in the P45-P50 area. This was expected to launch a cost focus that ultimately would result in cheaper projects.

4.6 QA1 - societal and stakeholder perspectives

After presenting empirical results related to the preparations and execution of the Quality-at-entry regime, we now continue to a brief analysis of a new aspect of the regime. After the first round of four years, the Quality-at-entry Regime has been revised and new consultant contracts were awarded in June 2005. In the revision of the regime, a new part has been added that includes an external assessment of different project concepts, termed Quality Assurance 1 (QA1). Five years of trailing research served as input to the revision of the Quality-at-entry regime. Results from this research are presented by Olsson et al (2004) as well as Magnussen and Samset (2005). According to Magnussen and Samset (2005), QA1 is established based on a belief that in order to achieve substantial improvements of project performance, the basic concepts of projects shall be analyzed, not only the final proposal, as is done in QA2.

At the time of writing this paper, no QA1 have been carried out and this short description is based on the description of the intentions of QA1. QA1 include an analysis of the prerequisites for a proposed project, a need analysis, analyses of the documented strategy and requirements and finally, a comparison of alternative concepts. An important element of QA1 is that at least three alternatives shall be analyzed, including a reference alternative which only includes maintenance and other actions needed to continue to use existing resources. QA1 has a wide perspective and focuses on the future users and society as a whole. The purpose is to identify the right project. The societal effects and the interest of different stakeholders are key criteria in the comparison of project alternatives to be carried out in QA1.

5. Discussion

The analysis indicates that flexibility was seen as one of the major problems with the governmental projects prior to the Quality-at entry regime. As discussed in the introduction section, the engineering tradition in project management theory then proposes a stronger emphasis on the front-end phase in order to prepare the projects as well as possible. In this perspective, one of the objectives of the Quality-at-entry regime was to reduce the flexibility of the projects. The purpose was to make sure that the project is well defined, both in terms of project scope and organization.

The strong emphasis on scope change management in the QA2 reports indicates that changes and flexibility primarily are treated as something to be minimized, or at least to have a strict regime for. A structured approach to

flexibility is introduced by the use of reduction lists. However, the sole purpose of the reduction lists is to keep the project within budget. This might be described as a "negative" or internal freedom to maneuver. There is no intention to use the freedom to maneuver to increase the effectiveness, or the benefit side of the projects. In contrast, a "positive" or external freedom to maneuver would include options for increased user satisfaction with the projects. This can be explained by the background to the Quality-at entry regime, where the observed flexibility of the projects often was aimed at increasing the benefit from the projects for the involved stakeholders. This frequently resulted in cost increases. A key purpose of the Quality-at entry regime was to stop this development.

We noted that the possibility to establish a more or less customized organization for a unique task is one of the main reasons that projects are set up. As a contrast, control is a key issue in the Quality-at entry regime. Once established to have freedom and adaptability, project management, or at least the engineering tradition of project management, is focused on reducing or controlling this freedom of the projects. Projects appear to be trapped in their freedom. The potential freedom of projects is so large that major management emphasis is directed towards reducing and controlling flexibility. Permanent organizations have a different perspective. Repetitive tasks are traditionally organized in ways that utilize economies of scale and to utilize the learning curve. This has usually meant rigid processes and high investment. Coming from a tradition of repetitive tasks, successful permanent organizations are characterized by adaptability (Mintzberg, 1994).

	Permanent organization	**Project**
Strength	Repeatability	Flexibility
Success criteria	Flexibility	Focus

Table 8. Flexibility is a success criterion of permanent organizations and strength of projects.

Table 8 illustrates, with the lack of nuances that comes with such matrixes, that flexibility is not the inherent strength, but a success criteria of permanent organizations. As a contrast, flexibility is the inherent strength of projects or temporary organizations, and controlling this flexibility by focus is a key success criterion of this type of organizations. The lack of nuances in Table 8 includes the fact pointed to by Engwall (2003) that many organizations are neither purely projects nor permanent. Reality is therefore more like a continuum of gray scales, where the degree of "permanent" or "project" character of organizations varies. The discussion above then relates to organizations with a high degree of repetitive tasks and "permanent" and similar for "projects".

It is claimed that QA2 aims to reduce flexibility, at least in the planning and execution phases of projects. Seen in isolation, this means a reduction of flexibility. However, the introduction of QA1 means a stronger emphasis on analyzing alternatives in the front-end phase than has previously been required in this manner. By seeing QA2 and QA1 in combination, the Quality at-entry regime is an opportunity to reduce flexibility options in the planning and execution phases, and to increase and structure these options in the front-end phase.

Different aspects on the Quality at-entry regime have been presented from a flexibility perspective. This paper argues that QA2 to a large extent has its foundation in the engineering tradition, with its focus on control. Using the categorization of projects management perspectives, the intentions of QA1 are different from QA2 and bring associations to the social science tradition in project management.

Some authors on project management, including Söderlund (2004), argue that the engineering and social science tradition are incompatible from a theoretical standpoint. The discussion about QA1 and QA2 indicate that the two perspectives might be practically compatible when analyzing one particular project, but with a displacement in time. The Norwegian Quality-at entry regime strives to utilize the best of the two perspectives, drawing on the social science perspective in the early phase (represented by QA1), and then switching focus to the engineering perspective in the execution phase (represented by QA2). The engineering tradition appears to have its strengths in the execution phases and the social science tradition in the front-end phase, as illustrated in Figure 2. The fact that these traditions co-exist in the minds of different actors involved in a project does not contradict Söderlund's (2004) notion about the mutual incompatibility from a theoretical standpoint.

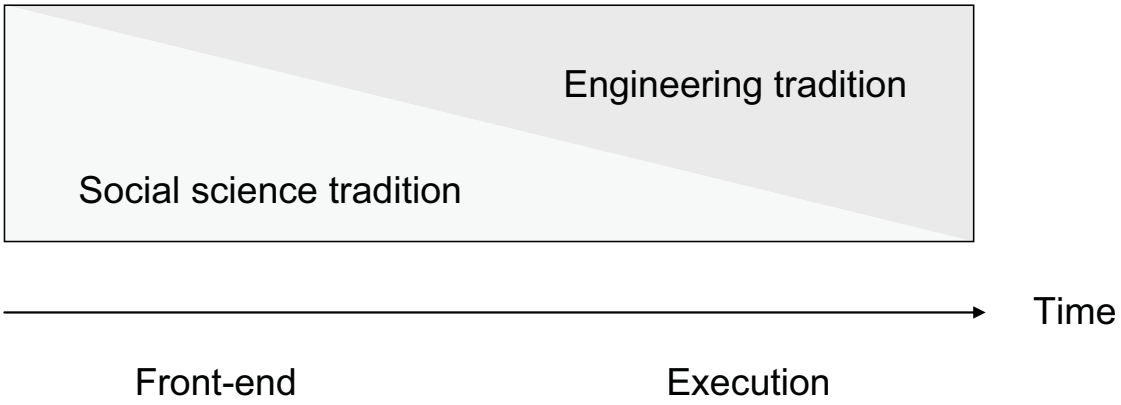

Figure 3. The relative impact of the social science and engineering traditions over time in a project

In accordance with the engineering tradition in project management, the Quality-at entry regime strives to provide the project owner and project management control over the environments related to the project, or a type of "framing" of the projects. To achieve a high efficiency in the projects, the stakeholders appear to strive for control of the prerequisites for their tasks. It is in accordance with the engineering tradition, with its roots in project planning, that project management shall strive for control of the environments related to the project. In the QA2 reports, this is represented by the high priority given to change management, as shown in table 3. As shown by the use of project reserves and reduction lists, stakeholders also strive for freedom to maneuver within the defined prerequisites. The QA2 aims at defining the projects as precisely as possible, but still provide project management with the freedom to decide how the specifications shall be met, work carried out and budgets to be held. In a similar way, Turner (2004) claims that one of four necessary conditions for project success is that the project manager is empowered. The project owner should give guidance on how the project can be best achieved, but allow the project manager flexibility to handle unforeseen circumstances as they chose.

One purpose of this paper was to contribute with empirical data on some issues related to project flexibility. By using the results presented in Table 7, a part of the curve for the freedom to maneuver in Figure 1 can be drawn based on empirical data. The relative size of the remaining open reductions can be seen as an empirical illustration of the "room for maneuvering". Figure 4 shows the curve generated from the reduction lists placed into the whole project time span. To do so, another reference point on the scale of the room for maneuvering was calculated based on information from eight of the 48 projects. This reference point is located earlier in the front-end phase and is related to the first budget estimated budget of projects to be found in official documentation. This first estimate is on average 3.4 years before the final approval. As an illustration of the room for maneuvering at this point, the first budget is compared to the final approved. An average of 42% of the final budget was not locked at this point. Because all differences were positive, the final approved budget was on average 42% higher than the first estimate, with a standard deviation of 17%. The reference point in Figure 4 represents the average plus one standard deviation, in a similar way as for the curve based on the reduction lists. The position of the first estimate point in relation to the zero-point on the time scale raises questions – when does a project start? Previous experience indicates that this time span may vary from about 30 years to one or two. As an indication, this point is located at the equivalent to four years after project initiation in Figure 4. This was done because more than 50% of the projects are related to transportation infrastructure, and the strategic planning of such projects is repeated every four years in Norway.

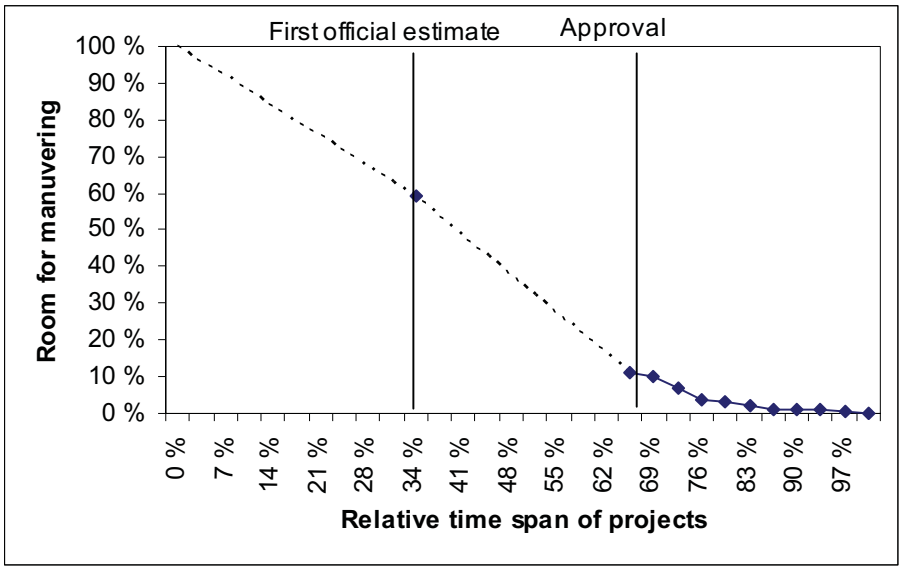

Figure 4. The size of the reduction lists as percentage of total budget at different phases of the projects. The observations indicate average plus one standard deviation. The trend line is only a linearization between observations. N=19

The observations and indicated curve in Figure 4 have similar features as the model presented in Figure 1, which means that these quantitative results support the illustrative models used in many text books.

Another way of quantifying the remaining flexibility at the time for final approval of projects is to see the reduction lists and allocated reserves in combination. On average, the reduction lists amounted to 6% of the total project budget. At the same time, an average of 8% of the project budgets was allocated as reserves, to cover unexpected expenses. Adding these two types of flexibility gives an approximate total remaining flexibility of 14% of total budget at the time of parliamentary approval. This number shall be used as an approximation. Table 4 shows that when calculating the recommended budget, 13 out of 42 projects subtracted the reduction list value before the recommended budget was set. These numbers indicate that a remaining flexibility ranging between 9 and 14% of the total budget appears manageable at the time of final project approval, measured by the relative size of reduction lists and allocated reserves.

6. Conclusion

The purpose of this paper was to use experiences from the Norwegian Quality-at-entry regime for major governmental investments to illustrate aspects on project flexibility. From a flexibility perspective, project management as a discipline was compared to other managerial disciplines. Projects are described as trapped in their freedom. The potential freedom of projects as temporary organizations is so large that major emphasis in project management must be directed towards reducing and controlling the freedom, or flexibility, of projects.

Theoretical traditions in project management were discussed. The analysis of the Norwegian Quality-at-entry regime for major governmental investments indicate that the regime have its theoretical roots in the engineering tradition of project management. However, the extension to include an early analysis on project alternatives appears to have more in common with the social science tradition that the engineering one. This means that the quality assurance regime, including both QA1 and QA2, is an attempt to use the best of the two worlds divided by the time scale; use social science “glasses” when analyzing the alternatives, then switch to engineering “glasses” to execute the project.

Models for illustration of project flexibility in a time perspective were presented. An attempt was also made to quantify one dimension in project flexibility models based on empirical data. Remaining flexibility has been

quantified during the life cycle of projects and the result is a curve similar to the illustrative models used in many text books on project management. Around the time for final approval, the project management consultants saw it manageable to have an average of 6% of the total project budget still open, with a standard deviation of 5%, maximum 18% and minimum 0.2%. These numbers are based on the 23 projects that did use reduction list with due dates. Another representation of the remaining flexibility at the time of final approval is the fact that 8% of the project budgets were allocated as reserves, to cover unexpected expenses. An approximation of the manageable total remaining flexibility at the time of parliamentary approval is therefore estimated to be in the range between 9 and 14% of total budgets.

The applied methodology is partly prospective in the meaning that the projects and parameters to be studied were selected prior to conducting the analyses. The methodological discussion in the paper on prospective and retrospective research designs is inspired by medical research. Regarding future research, continued use of prospective research designs in project management is interesting and desired. Such designs have the possibility to contribute to enhancing the credibility of project management as a research field.

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FLEXIBILITY IN ENGINEERING PROJECTS: BLESSING OR CURSE?

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ABSTRACT

This paper gives an overview of research on project flexibility in engineering projects. Project flexibility is viewed from different perspectives. Firstly, the concept of flexibility in projects is discussed. Secondly, the cases against and in favour of flexibility are presented. Finally, a short overview is made to identify under which circumstances and during which part of a project that flexibility proves most useful and most damaging. The paper suggests that project owners are more likely to be in favour of flexibility than contractors. Viewed in a time perspective, flexibility in the front-end phase could help to increase the probability of success, while flexibility in the execution phase is claimed to reduce efficiency of projects. Furthermore, industrial development projects are more likely to benefit from flexibility than civil engineering projects are. Related to the degree of uncertainty, flexibility is claimed to be desirable in high uncertainty environments and less important in situations with low uncertainty. Flexibility is discussed as a double-edged sword. Flexibility for one stakeholder is often viewed as another's risk. The case in favour of flexibility emphasise the possibility to increase a project's effectiveness while the case against flexibility highlights that it might reduce efficiency. Project flexibility can be used to increase the project owner's value of a project. The major drawbacks lie in the negative effects of changes on the project organizations and a possible frustration regarding lack of decisions and commitment.

KEYWORDS

Project, Management, Flexibility, Efficiency, Effectiveness.

1. INTRODUCTION

The ability to adapt to changes along with short response time is heavily emphasised in disciplines such as strategic management and supply chain management (Bettis & Hitt, 1995). However, study after study (including Hall, 1980; Morris & Hough, 1991; Miller & Lessard 2000) indicate that a clear project definition is a key success criterion for projects. It appears as a paradox that the mainstream of project management focuses on stability for the project, while major parts of other management disciplines strongly emphasise flexibility.

The purpose of this paper is to give an overview of research on project flexibility in engineering projects. The following issues are covered: (1) the concept of flexibility in projects, (2) the cases against and in favour of flexibility and (3) under which circumstances and during which part of a project that flexibility proves most useful or most damaging. While many authors on the issue of flexibility have clear standing in favour or against the use of flexibility in projects, the paper is an attempt to summarise the arguments used by both sides.

Research methodology

The paper is based primarily on literature search of flexibility management in projects. However, the presentation is also influenced by a number of case studies and personal experience from consulting and research engagements. In the case studies, a research methodology based on the works of Yin (2003) regarding case studies as a qualitative paradigm has been used. One of the characteristics of case studies is that multiple sources of information are used, including archives, interviews and observations. The research has primarily been of a qualitative nature.

The concept of project flexibility

Flexibility management as a systematic approach is not a new concept. Sager (1990) found several examples of flexibility as one approach to prepare for the effects of uncertainty in planning. However, Sager also points out that flexibility is an important term very often used by planners but rarely scrutinized theoretically.

One approach to project flexibility is based on theory related to financial options, referred to by Brennan & Trigeoris (2000) as the real options paradigm. In this paradigm, flexibility is compared to owning an option - the right, but not the obligation to take an action in the future (Amram & Kulatlaka, 1999).

Koskela (2000) describes how production principles such as just-in-time has been adopted in a theoretical framework aimed at the construction industry under the term lean construction. In this framework, the term "last responsive moment" is used to achieve flexibility in projects (Ballard & Howell, 2003). According to Ballard & Howell (2003), the last responsive moment means that decisions must be made within the lead time for realizing alternatives and that a decision should not be made until it has to be made.

Mandelbaum & Buzacott (1990) uses the number of the remaining alternatives after a decision has been taken as a measure of flexibility. Eikeland (2001) discusses "room for manoeuvring" related to project flexibility. He relates "room for manoeuvring" to the internal uncertainty of the project, represented by future yet undetermined internal decisions. According to Eikeland (2001), a decision is within the room for manoeuvring if it does not violate the consequences of previous decisions. Terms like adaptability and robustness are often used when discussing issues related to what this paper calls flexibility. Flexibility may also be described as a way of making irreversible decision more reversible or postponing irreversible decisions until more information is available.

Note that flexibility as discussed in this paper is not seen as an alternative to strategic management, but as a means to help realising a strategy, in the way that Samset (1998) argues that successful projects are characterised by a distinct strategy in combination with sufficient tactical flexibility.

Flexibility in the process and the product

Flexibility in a project can be associated with the process or the product. The former refers to flexibility in the project's decision process. The real-options paradigm recognises that decisions are made sequentially over episodes. The use of decision gate models provides a successive commitment to a project, including the possibility of iterations, as shown by Eskerod & Östergren (2000). The philosophy of not taking decisions until the last responsible moment, as shown by Ballard & Howell (2003) is also an example of flexibility in the decision process. The latter refers to the effects of a project, in the sense that the final product of the project is prepared for alternative use. This approach to flexibility is used in office building construction, as described in Brand (1994) and Blakkstad (2001), where the need for adaptability is well known.

Efficiency and effectiveness

In this paper, the term efficiency is linked to the immediate outcome of a project. It is a question of doing things right and producing project outputs in terms of the agreed scope, quality, cost and time. It is an internal measure related to what Samset (1998) refers to as the project or contractor perspective. The term effectiveness is linked to the longer-term effects of the project, or in other words, to do the right things. It is an external measure. Eikeland (2001) relates effectiveness to how the results of a project contribute to value added for owners and users. According to Samset (1998), effectiveness measures the realization of the project's purpose, or the project's long-term consequences. This is the perspective of the project owner or financing party, who to a large extent have a similar perspective as the users.

2. RESULTS

The arguments against and in favour of project flexibility are summarised in the following. Different stakeholders in a project have different perspectives on flexibility. Flexibility is also seen differently depending upon the different phases of a project. The context and type of a project also influence the attitudes toward and benefits of flexibility.

The case against project flexibility

A wide range of studies and authors (including Morris & Hough, 1984; Eikeland, 2001 and Love et al. 2003) have pointed to changes in specifications as a key driver in cost overruns of projects. Change orders are widely seen as undesirable, even if contractors do see them a possibility to improve the profit from the projects (Christensen & Gordon, 1998). Once a project has been decided upon and the planning and execution has begun, changes will often reduce the efficiency of the project. Change orders are also a source of major disagreements between different actors in projects.

Morris & Hough (1991) specifically argue against concurrency between development and production. Miller & Lessard (2000) point out the irreversibility of large engineering projects and the importance of bold commitment from key stakeholders, arguing against flexibility once the front-end phase is over.

Flexibility commonly is seen as undesirable in the execution phases of projects. The high and unpredictable cost of change orders is the key argument against flexibility. The negative consequences of the use of flexibility in projects are also emphasised by project stakeholders that are responsible for the execution of projects, such as contractors. The potential for utilising flexibility in civil engineering projects is seen as limited, due to their indivisibility and irreversibility. Arguments such as “we do not build half a bridge” are used. There is also the possibility that visualising flexibility in a project, such as the openings for later adjustments or even cancellation, will reduce the likelihood that the project will be approved and carried out as planned. In such a perspective, commitments, not adjustability, are required to communicate credibility to affected parties.

The case in favour of project flexibility

Kreiner (1995) points out that the traditional focus on stability in project management becomes challenged under uncertainty, which creates what he calls “drifting environments”. A number of scholars, including Mintzberg (1994) and Bettis & Hitt (1995), argue that flexibility is necessary in order to face the changes, uncertainty and turbulence in the business environment.

The real options paradigm (for example Amram & Kulatlaka, 1999) illustrates that uncertainty can increase the owner’s value of a project, as long as flexibility is preserved and resources are not irreversibly committed.

Miller & Lessard (2001) lists "late locking" as a key success criterion for large engineering projects, along with an exploring, iterative front-end process. Hall (1980) suggests a risk-avoiding strategy, based on minimal commitments at each stage where decisions are necessary. He argues for an incremental or adaptive approach, rather than creating new projects. He suggests enlargements and adaptation of existing projects rather than building new ones, whenever possible.

Modern approaches to development of IT-systems include functional specifications and iterative development. This is described by authors such as Poppendieck & Poppendieck (2003) and Boehm & Turner (2003).

Most authors agree on the value of flexibility in the front-end phase of projects. Flexibility is also generally seen as an advantage in industrial development project (Verganti, 1999). Clark & Fujimoto (1991) and Midler (1995) illustrate this based on the automotive industry. The benefits of flexibility are easier to visualise and implement in industrial development projects than in more standardised civil engineering projects. Flexibility is more valued by the stakeholders that have a responsibility for the overall profitability or societal benefit of a project, compared to those who are only responsible for the cost side of the project.

3. CONCLUSIONS

What seems to be implied by authors quoted above is that flexibility is primarily useful to improve effectiveness of projects rather than efficiency. The arguments in favour of flexibility emphasise the possibility for increased effectiveness while the arguments against highlight the problem of reduced efficiency. Flexibility is often seen as a threat to delivering the project on time and within budget. In such a perspective, a project needs to be clearly defined in the front-end phase and executed according to the plans with as few adjustments or remaining decisions as possible, in order to maximise efficiency. On the other hand, flexibility is also seen as a help to achieve the project's purpose. A project with sufficient flexibility to utilize opportunities to increase the value for owners and users might in the end prove to be more effective.

The literature gives indications as to whom and when flexibility is beneficial or harmful:

- The financing party or owner is more likely to be interested in flexibility than the contractor
- On average, flexibility in the front-end phase increases the probability of success
- The active use of flexibility in the execution phase is likely to reduce efficiency
- Industrial development projects, including IT system development, are more likely to benefit from flexibility than civil engineering projects are
- Flexibility appears desirable in high uncertainty environments and less important in situations with low uncertainty

Change orders are not popular and flexibility may increase the probability of changes. However, a *change* requires that something already has been decided. The logic behind late locking of projects and that a decision shall not be taken until it really has to means that changes should be reduced by locking solutions as late as possible.

Flexibility appears as a double-edged sword: the flexibility for one project stakeholder can be another's risk. The case against project flexibility highlights the negative effects of changes along with the possibilities for frustration due a lack of decisions and commitment. Flexibility can thus be used to justify the opinion that decisions do not need to be taken or can always be revised. On the other hand, the case for project flexibility emphasises the possibility to utilise opportunities that arise and to manage the uncertainty, particularly in the front-end phase of projects.

Finally, project flexibility is found to not necessarily be a question of good or bad, right or wrong. With proper precaution and knowledge, the drawbacks of flexibility might be avoided or reduced and the benefits utilised.

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Paper 5.

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Impact Analysis of Railway Projects in a Flexibility Perspective

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ABSTRACT *In a multiple case study, using both quantitative and qualitative data, the traffic impact of four Norwegian railway investment projects was analysed, focusing on the development of punctuality, frequency, travel time, number of travellers and construction cost. Front-end ex-ante predictions are compared with observed ex-post outcome. Key success criteria for realization of planned benefits in the studied railway investment projects have been a combination of infrastructure development and acceptance for timetable adjustments. Investments that are executed in a large-scale continuous construction process appear to be more likely to achieve such acceptance compared with investments built and decided upon section by section. Of the studied projects, section-by-section commitment to investments provided a better cost control than what was the case for continuous construction projects. In addition, this study points to challenges in realizing travel time reductions in a system with a combination of single tracks and high capacity utilization of double tracks. It is advised to clarify in appraisal documentation that benefits related to railway infrastructure investments are depending on appropriate timetable adjustments. The results indicate that a flexibility option (to sequence a decision process) may actually reduce the benefit potential of an investment.*

Introduction

The purpose of this paper is to analyse the impact on the railway traffic of four railway investment projects. The study includes a comparison between the front-end ex-ante predictions and the observed ex-post outcome, with an emphasis on punctuality, frequency, travel time and the number of travellers. According to Small (1999), reductions in travel time typically represent the dominant component of benefits from transportation investments, and the choice to focus on scheduled travel time, frequency and punctuality was made with this in mind. An analysis of project costs is also included. By comparing the ex-ante, expected and

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ex-post situations for the selected project parameters, the paper is a contribution to ex-post analysis of transport projects, as recently asked for (Short and Kopp, 2005).

A special interest of this paper is related to the effect of sequencing of decisions to commit to railway investment and the corresponding sequencing of the actual construction. The possibility to divide a large project into sections, and commit to the sections one by one, is seen as a strategy for flexibility that is applied by the financing party of the projects. Hall (1980) favours such stepwise developments due to the unpredictability of major investments, both on the cost and benefit side. In ex-ante analysis, real options can be used to estimate the value of future flexibility. Bergendahl (2002) shows how a real options approach can be used to view investments in railway infrastructure as a series of options. While the principles of real options are well established (e.g. Brennan and Trigeorgis, 2000), there are fewer studies of the ex-post effects of different decision approaches related to commitment and sequencing, and this paper aims to make a contribution here.

Mackie and Preston (1998) identified 21 sources of error and bias in the appraisal of transport projects. They particularly pointed to a systematic tendency to appraisal optimism. More recently, Flyvbjerg *et al.* (2003) have made comparisons between ex-ante forecasts and ex-post outcome of major transportation investments, including analyses of the development of cost and number of travellers for railway projects (also Skamris and Flyvbjerg, 1997; Flyvbjerg *et al.* 2005). Their work shows significant deviation between predicted and actual traffic volumes, especially for railway projects. According to Flyvbjerg *et al.* (2003), the average number of travellers on new railway lines was 39% lower than estimated. SIKA (2000) found that the actual number of travellers on three studied Swedish railway lines was between 58 and 79% of the estimated. According to SIKA, possible explanations for the differences include an increase in ticket prices, changes in the services on the lines, a generally lower economic growth than expected and possible inaccuracies in the applied estimation models. Fröidh (2003) shows an increase in the number of travellers related to introductions of new railway services in Sweden. In four studied projects, the increase ranged from a factor of 1.4 to 6.0. New services were typically a combination of new infrastructure, new trains and increased frequency.

Flyvbjerg *et al.* (2004) point out that cost escalation is highly dependent on the length of the project implementation phase. Longer implementation causes higher cost escalation. The analyses carried out by Flyvbjerg *et al.* (2003) are focused on mega-projects. In Norway, many railway investments are decided upon and built section by section in contrast to many of the mega-projects.

The marginal benefit of a transport investment is declining as the complete network is getting increasingly more complete (Guiliano, 1995). This has particularly been documented for highway investments. Major investments in new infrastructure may, however, give significant effects. Rietveld and Nijkamp (2000) claim that infrastructure systems show identifiable life cycles. Large changes, such as the introduction of new high-speed trains, give higher impact than gradual, stepwise development. Based on their argumentation, it can be expected that a sequenced commitment to large projects, by deciding upon one section at a time, may result in a low impact. However, such sequenced commitment can provide the project owner with room for manoeuvre to adjust if the prerequisites for the project change, including political priorities, the availability of funds and the observed impact. This type of incremental commitment is supported by Hall (1980).

The possibility and effect of dividing railway investments into smaller independent projects, or sections, is affected by the high integration in a railway system. Bruzelius *et al.* (1993) point out that railways are the only transportation mode (except pipelines) where each vehicle has only one dimension of freedom. Ships, vehicles on roads and aeroplanes on the ground have two modes of freedom (even though the sideway freedom may be limited for vehicles on roads and aeroplanes). Aeroplanes in the air have three degrees of freedom. In contrast to other transport modes, a whole trip must therefore be allocated in one planning step for railways. While a bus company can schedule its individual services largely independently, a rail operator must consider the interaction between vehicles and infrastructure (Nash, 1992). A potential travel time reduction on railways cannot be realized unless the whole timetable system is adjusted to accommodate the change. Consequently, Nash claims that railway infrastructure project appraisal cannot be seen as a separate activity, isolated from the general business planning of the railway operation.

Challenges related to forecasts are also known in other disciplines, such as supply chain management. Tyndall *et al.* (1998, p. 75) advise strategies to de-emphasize forecasts, rather than trying to improve them, because "forecasts are always inaccurate". A key issue in de-emphasizing forecasts is short lead-times. Thereby, production volumes can be adjusted by actual, rather than estimated, demand. The real options approach to railway investment decisions used by Bergendahl (2002) is based on a similar logic, where the decision to build the next section of a major railway project is dependent on the demand generated by the improvements from the construction of a first section. The projects analysed in the present paper are chosen to illustrate effects of different decision and execution models of the investment projects.

Methodology

The study is a multiple case study, in the terminology used by Yin (2003). One characteristic of case studies is that multiple sources of information are used.

The analysis of four railway projects is based on a range of information sources, the most important of which are as follows:

- Archives, both within the involved organizations, as well as publicly available information. These include project documentation, evaluation reports, and quantitative information such as timetables and statistics.
- Interviews.
- Participating observation in meetings, etc., where the projects have been discussed.

The analysed projects were carried out between 1986 and 2003. An overview of the projects in the study is shown in Table 1. The overview shows that the projects were largely carried out in parallel. The studied projects included four of the largest Norwegian railway line investments since 1980.

Norwegian Railways

Before the results are presented, a short introduction to the railway situation in Norway is given. The former public enterprise NSB was split into the train operator

Table 1. Overview of the studied projects

	Final cost (millions)	Type of project	Construction begun	Construction ended
Gardermoen line	968	new line (double track)	1994	1999
Vestfold line	159	from a single to a double track	1993	2002
Østfold line (Ski–Sandbukta)	195	from a single to a double track	1987	1996
Bergen line (Finse-Gråskallen)	101	major improvements of the existing single-track line	1990	1999

NSB BA (now NSB AS), The Norwegian Railway Inspectorate and the Norwegian National Rail Administration in 1996. Competitive bidding for subsidized traffic is under introduction and new train operators have entered the freight market.

The Norwegian railway network consists of 4077 km of railway line, of which 38% is not electrified (based on information given at http://www.jernbaneverket.no). A special characteristic of the Norwegian rail network is the relatively low share of double tracks. Only 5% of the network consists of double tracks. All double tracks are close to Oslo. All long-distance, regional and freight trains mainly run on single tracks. Many commuter trains in the Oslo region are run on both single and double tracks. Figure 1 shows an overview of the Norwegian rail network along with the location of the studied projects.

Between 1975 and 1991, the number of passengers on Norwegian railways was fairly stable at around 33 and 38 million passengers per annum, respectively, with a declining tendency from 1981. From 1991 to 2000, there was an increase in numbers. In 1991, the total number of passengers was 33.4 million, while the number was 55.3 millions in 2000 (data from http://www.ssb.no). Beginning in 2001, there was a downward trend in the numbers of passengers, which at the time of writing have levelled out and show signs of improvements. Buses have represented a fairly constant transport volume for most of the last 30 years, with an increase during the last few years, when express coach traffic has been deregulated (JBV Utredning, 2004). Air traffic volumes affect rail ridership in two ways: first, as competition to long-distance trains; and second, related to train traffic to and from airports, and Oslo Airport Gardermoen in particular. Norwegian air traffic has been growing for a number of years, until 2000. After a few years of decline and fierce price completion, air travel is now growing again.

Results from an Analysis of the Projects

Figure 2 shows that the four projects all had different characteristics about how they were planned to be executed, and how they actually were carried out. In Figure 2, a 'planned approach' relates to how a project was intended to be decided upon and executed in the front-end phase, typically described in a 'main report' for the project, dated at least 1 year before final approval of the project in parliament. An 'actual approach' describes how the projects were finally decided upon and executed.

All the studied projects were divided into sections for practical purposes. The distinctions between an 'integrated' and 'section-by-section' approach in Figure 2 relate primarily to the decision process. Projects that actually were executed as

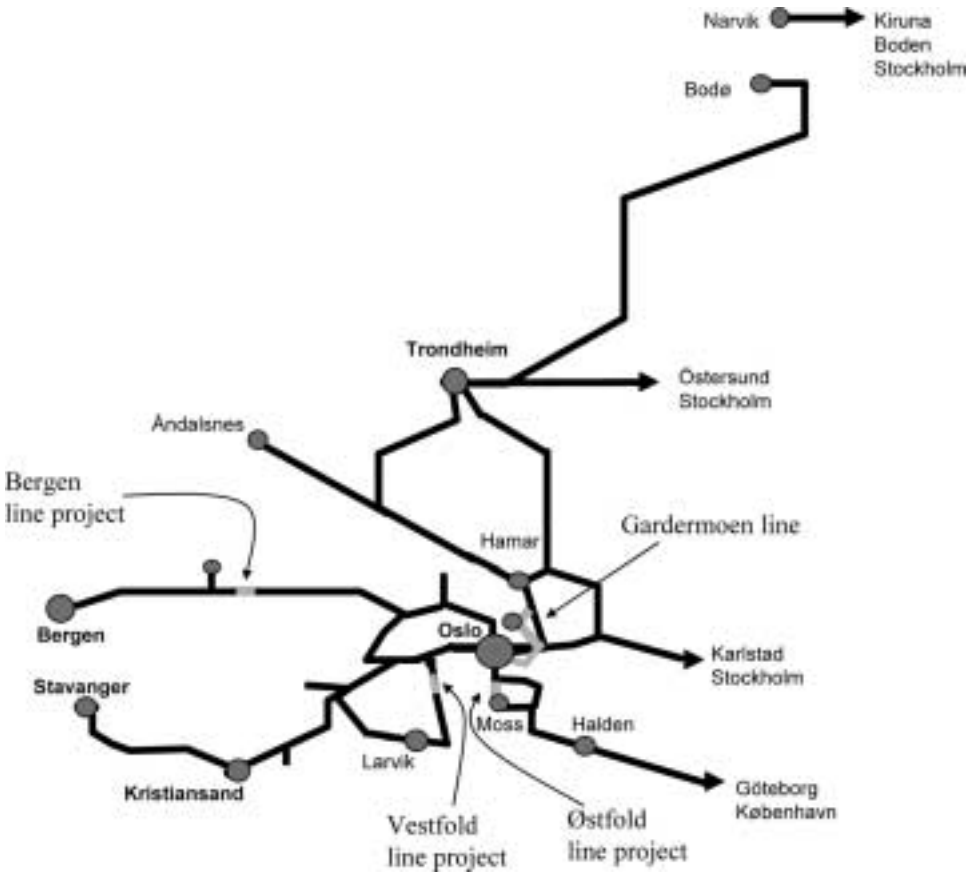

Figure 1. Norwegian rail network and location of studied projects (in grey). The relative size and location of the new built rail lines are only indicative

integrated projects were decided upon at one point. Actual construction was divided into sections, but each section did not require new approval by parliament. Projects that were decided upon section by section did require a new approval before each new section was funded. A distinction between the planned

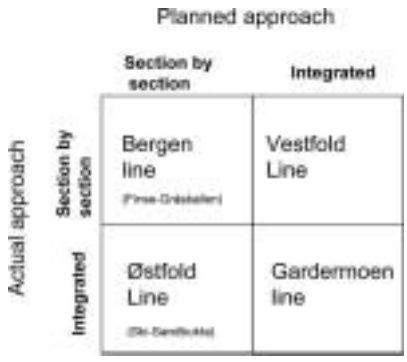

Figure 2. Model for the planning and execution of railway investment projects, and how the studied projects fit into the model

and actual approach has parallels to the distinction between a rational/analytical model and a 'muddling through' model, as discussed by Mackie and Nellthorp (2003) in a transport appraisal context. In the following, the results for each of the studied projects are presented.

Table 2 shows a comparison between the forecast and actual outcomes of selected variables. Negative values for travel time means that travel time is shorter than planned, while negative values for punctuality means that punctuality is lower than planned, meaning that more trains are delayed. Costs are adjusted for inflation. The first cost estimates presented to the Norwegian parliament are used as references.

The forecasts for the Vestfold line are related to the initial plans of an integrated project. Compared with the cost estimates of the individual sections, the Vestfold line had a 33% cost overrun.

In a similar way, Table 3 shows the difference between the situation before and after the investments, not taking the forecasts into account. Negative values for travel time mean shorter travel time after the investments than before. Positive values for the number of trains means increased traffic, and positive values for punctuality means fewer delays trains. For the number of passengers, a negative value means fewer passengers before the investment than after.

In the following, the results for each project are presented, along with some background of the traffic patterns along each route.

Vestfold Line

Table 4 shows some selected characteristics for the Vestfold line before and after the construction, along with the expected situation after full development of the line.

After 1999, only regional trains are run on the Vestfold line. Key customers are long-distance commuters living in Vestfold who commute to Oslo. The planned increase in frequency is to a large extent carried out, even though only 12% of the planned double track is built. No freight trains have run on the line since 1999, and a more uniform train mix provides increased capacity on the line. A sharp drop in the number of travellers on the Vestfold line occurred after 2000. According to JBV Utredning (2004), the main reasons include improvements of the motorway running in parallel to the railway, increased competition from motorway buses, increased ticket prices along with reduced access to ticket distribution and, finally, relatively poor punctuality.

Gardermoen Line

The Gardermoen line was an integrated part of the decision to build Oslo's new airport Gardermoen. The line runs from central Oslo to the airport. Major parts of the railway traffic in the greater Oslo area changed when the Gardermoen line opened, making it an integrated part of the railway network. The Oslo–Gardermoen line handles not only the Airport Express trains, but also regional, long-distance and some local trains. The old line, running more or less in parallel to the new one but taking a longer and slower route, handles mainly local and freight trains. The number of passengers on Airport Express trains was based on a year 2000 forecast of 50% market share for the Airport Express train, and 11.7 million airline passengers at the airport (Ministry of Transport and Communications, 1991–92). In 2000, the Airport Express train had a market share of 33% and the

Table 2. Difference between actual development and forecast (%)

Project characteristics			Variables					
Planned approach	Executed approach	Project/line	Travel time, built section	Travel time, whole line	Number of trains	Punctuality	Number of travellers	Costs
Integrated	Section	Vestfold	9	18	3	–6	–53	–79
Section	Section	Bergen	10	4	0	–4	–22	1
Integrated	Integrated	Gardermoen	–3	2	11	0**	–38**	55
Section	Integrated	Østfold	12	3	*	2	*	262

Differences are given as a percentage = (actual – forecast)/forecast. Costs are adjusted for inflation.
*No forecast in the available documentation. Gardermoen data relate to regional trains, except for **, which relates to Airport Express trains.

Table 3. Difference between the situation before and after the investments (%)

Planned approach	Actual approach	Project	Travel time, built section	Travel time, whole line	Number of trains	Punctuality	Number of travellers
Integrated	Section	Vestfold	–10	–5	52	24	4
Section	Section	Bergen	–13	0	0	3	–9
Integrated	Integrated	Gardermoen	–36	–18	94	15	108
Section	Integrated	Østfold	–41	–10	16	76	71

Differences are given as a percentage = (after – before)/before.
Gardermoen data relate to regional trains.

airport had 11.3 million passengers, not counting transfers (JBV Utredning, 2004). Table 5 uses 2002 as a reference.

Østfold Line

Going south from Oslo to the Swedish boarder, the Østfold line has a mix of local, regional, freight and long-distance trains. Close to Oslo, commuting traffic dominates and capacity utilization is high. The project was approved at a very early stage of the planning process. At the time, a crossing where trains can meet or overtake was planned along this line. Few preparations were made for a large-scale construction. Table 6 shows development on the Østfold line of selected indicators.

Bergen Line

The single-track Bergen line is characterized by long-distance passenger and freight traffic between Oslo and Bergen, the two largest cities in Norway, with

Table 4. Summary of key indicators for the Vestfold line: estimated, ex-ante and ex-post

	Before construction (1990/91)[a]	Expected after[b]	Actual autumn 2004 (13 June 2004–8 January 2005)
Travel time whole line (Oslo–Larvik)[c]	2 h 14 min	1 h 48 min	2 h 07 min
Travel time over the built section (Skoppum–Drammen)	42 min	(35 min), 7-min reduction[d]	38 min
Number of trains per day (including both directions)	27	40	41
Punctuality (%)	72[e]	95	89[f]
Length of construction (km)		140[g]	17
Costs (€ millions)		755 (2001)	160 (2002)[h]
Number of travellers (thousands per annum)	1 478	1708[i]–3196[j]	1510[k]

[a]Based on the reference alternative in NSB (1992); [b]'Alternative A' in NSB (1992); [c]average of passenger trains; [d]Jernbaneverket (1997); [e]punctuality within 5 min; [f]official statistics show 86% punctuality, but based on punctuality within 3 min. The estimate numbers from 1992 refer to punctuality within 5 min. The 3-min values have therefore been converted to 5-min values for correct comparison; [g]based on NSB (1989, 1992); [h]based on Table 2; [i]2000 estimate, reference alternative with no construction; [j]2000 estimate, the last year in the prognosis; based on full development; [k]2003.

Table 5. Summary of the key indicators for the Gardermoen line: estimated, ex-ante and ex-post

	Before construction (1991)	Expected after	Actual 2002
Airport Express:			
Travel time		19 min[a]	19 min
Number of travellers (thousands per annum)		6360[b]	3961
Punctuality		95% (2 min)	95% (3 min)
Frequency (each direction)	0	6 trains/h	6 trains/h
Regional trains:			
Travel time, whole line (Oslo–Hamar)	1 h 41 min	(1 h 21 min) 20-min reduction	1 h 23 min
Travel time over the built section (Oslo–Eidsvoll)	59 min	(39 min) 20-min reduction	38 min
Number of trains per day (including both directions)	22	(22) no stated change	42
Punctuality (%)	71	improvement	82
Number of travellers (thousands per annum)	410	not stated	851[c]
General:			
Number of trains per day (at Lillestrøm, including both directions)	262	460	509
Length of construction (km)		64	64
Costs (€ millions)		625 (1998)	970 (1998)

[a]NSB (1991a); [b]based on Ministry of Transport and Communications (1991–92); [c]2003.

local trains in addition closer to the two cities. The new sections on the Bergen line were built not only for increased capacity and reduced travel time, which were the main justification of the other investments in this paper. The main objectives were also to reduce operations and maintenance costs as well as the number of

Table 6. Summary of the key indicators for the Østfold line: estimated, ex-ante and ex-post

	Before construction (1986)	Expected after[a]	Actual, spring 1998
Travel time whole line[b] (Oslo–Halden)	2 h 01 min	(1 h 46 min) reduction by 15 min	1 h 49 min
Travel time over the built section (Ski–Moss)	32 min	17 min 40 s	19 min 45 s
Number of trains per day (including both directions)	88	increase	102
Punctuality (%)	50		88
Length of construction (km)		35.3	32.69 (double-track Ski–Sandbukta)
Costs (€ millions)		54 (1986)[c]	195 (1996)[d]
Number of travellers (thousands per annum)	458		783

[a]Based on NSB (1986); [b]regional trains; [c]Berg *et al.* (1998); [d]based on Hoff and Moen (2000).

Table 7. Summary of the key indicators for the Bergen line: estimated, ex-ante and ex-post

	Before construction (1989)	Expected after[a]	Actual 2002
Travel time whole line (Oslo–Bergen)[c]	6 h 23 min	(6 h 10 min) reduction by 13 min	6 h 24 min
Travel time over the built section (Ustaoset–Myrdal)	63 min	(50 min) reduction by 13 min	55 min
Number of trains per day (including both directions)	16	(16) no stated change	16
Punctuality (%)	73	78	75
Length of construction (km)		22.7[b]	25.4
Costs (€ millions)		100 (2000)	101 (2000)
Number of travellers (thousands per annum)	684	799	623

[a]Based on NSB (1991b); [b]based on NSB (1987); [c]train 61.

cancellations due to severe weather conditions. As a consequence of the construction, a maintenance and snow clearing base in the alpine region was not needed and line operational costs were reduced (Aspengren, 1999). As for the other projects, Table 7 shows development on the Bergen line of selected indicators.

Discussion

The analysed projects were either intended to be built one section at a time or integrated in one project, and the same categorization can be made for the actual execution of the projects. This study indicates that new infrastructure alone cannot provide the anticipated effects of investments.

The section-by-section projects in this study, the Vestfold and the Bergen lines, have prepared for travel time reductions that have not been realized. One reason is that the timetable system in Oslo has not been adjusted to accommodate train paths at desired times. Due to the complexity of the system and high-capacity utilization, it is not realistic to make major timetable adjustments for every minor new rail section that is taken into use. An increase in frequency on the Vestfold line was related to the introduction of the Gardermoen line, and not primarily to the infrastructure development on the Vestfold line itself. Challenges related to timetable adjustments as a result of infrastructure extensions in railway networks with high complexity and capacity utilization is addressed by Fransso and Bertrand (2000) using the Netherlands as a case study. Compared with many other railway networks, the Norwegian network has a relatively large share of single tracks. The two projects that have had the smallest improvements in travel time (the Vestfold and Bergen lines) are the two that are most influenced by single-track traffic. The Vestfold line has single tracks on both sides of the new double track. The Bergen line project is an upgrade from old to a new single-track line. A main obstacle to the realization of travel time reductions on the Vestfold and Bergen lines lies in finding train paths that match both new crossing possibilities and the traffic pattern in the Oslo area, with very high-capacity utilization. Single-track restrictions are therefore an explanation factor, in addition to the sequencing of the construction, for limited realization of potential travel time

reductions for these two projects. This appears not to be a unique Norwegian situation, but related to single-track traffic in general. Challenges related to partial double-track traffic in Sweden are documented by Lindfeldt (2001).

A major investment such as the Gardermoen line was given priority for a complete redesign of timetables in order to utilize the new infrastructure. Timetables on the other integrated investment, the Østfold line, have also been adjusted to utilize the new infrastructure. The two integrated projects achieved a momentum in construction, as well as in the timetabling to achieve desirable travel times. In addition, both the Gradermoen and Østfold projects consist of new double tracks connected to the double-track network around Oslo, even though both are located on the present end of this double-track system, with single tracks continuing further away from Oslo. Note that the size of the investment also matters. The integrated investments are larger than the section-by-section investments.

If a section-by-section approach has disadvantages related to the realization of benefits, it appears to provide cost control. Even taking into account the 33% overrun for the individual sections on the Vestfold line, the integrated investments have higher overruns that the section-by-section based ones. Cost overruns on mega-projects are documented by Flyvbjerg *et al.* (2003), showing that this is not a unique Norwegian issue.

Table 8 summarizes the impressions from the case studies. This paper argues that major improvements of traffic-related benefits for integrated projects are a consequence of investment size, adjusted timetables and location related to a double-track system.

A real options approach to railway investment aims at maximizing the cost–benefit ratio by sequenced decisions, continuously using updated information. This study questions the possibilities to achieve reliable information related to benefits. The effects of made investments are not materialized until the combined investment on a line reaches a certain level. Dividing an investment into a series of sections, decided upon individually, may therefore result in lower benefits in terms of, for example, travel time compared with an integrated project approach. As a consequence, a flexibility option (to sequence the decision process) may reduce the benefit potential. A real options approach emphasizes the value of flexibility options. This study indicates that a cost, or a reduction of benefits, should be included in calculations of flexibility value. These results are also contrary to common understanding in the project management field, where flexibility usually is seen as a means of achieving increased benefit from a project, as described by Olsson (2004).

One question that arises is if relatively limited investments shall be evaluated based on the actual reduction in travel time, or rather the potential travel time. New sections by themselves cannot provide reduced travel time unless the new infrastructure is integrated in the complete timetable, which may include interaction

Table 8. Observed impact from the studied project strategies

Actual project approach	Development in number of travellers compared with before	Train traffic compared with before	Cost
Section by section	small changes	moderate improvements	control
Integrated	major increase	major improvements	overruns

with a wide range of train services and lines. As mentioned, this is a major difference compared with road investments. As an alternative ex-post evaluation and comparison between ex-ante and ex-post, all railways related investments in a given part of the railway system could be evaluated as a whole with certain intervals, e.g. every 5 years.

Conclusions

Key success criteria for travel time reductions from railway investments appear to be the combination of infrastructure development and acceptance for timetable adjustments. Investments executed as integrated projects appear to be more likely to achieve such acceptance for timetable adjustments compared with investments built and decided upon section by section. A critical mass of potential improvement is needed to justify a timetable change that uses new infrastructure. In contrast, sequenced decisions appear to provide a better cost control compared with integrated projects. Regarding the location of railway constructions, this study particularly points to difficulties in realizing travel time reductions when there are single tracks on both sides of the new lines, and the train traffic also passes through an area with high-capacity utilization. In such a situation, extension of double tracks seems to be more likely to realize expected travel time reductions.

This study indicates a need to make it clear in the ex-ante project description of future investment projects that the estimates for travel time, frequency, punctuality and number of travellers are dependent on appropriate timetable adjustments. Such a practice would give a higher accuracy of the project descriptions. To state explicitly the relation between timetable adjustments and the realization of investment benefit can contribute to a tighter coordination between investment and timetable planning.

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Paper 6.

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Adjustments, effectiveness and efficiency in Norwegian hospital construction projects

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ABSTRACT

This paper presents a case study focusing on process analysis as input to the design of new buildings at a Norwegian university hospital. The process analysis was also intended to spur organizational change. We study whether the process analysis provided the necessary input to the design of the hospital while also facilitating organizational development. As a framework, four key success factors in hospital projects are identified: efficiency, effectiveness, user involvement and flexibility. Separate sets of research material have been used. The most important information sources are project documentation and quantitative information such as statistics along with participating observation. The process analysis appears to have been torn between different output needs. Other ongoing activities may also have reduced the impact of the process analyses.

KEY WORDS: Process analysis, Hospitals; Project Management

INTRODUCTION

Large hospital construction projects are planned up to ten to twenty years ahead and face the challenge of providing buildings for equipment, technology, activities and patient care that may be radically different in the future. High uncertainty and changing prerequisites, technology and treatment methods create a need for flexibility.

In 1993, the Norwegian government gave the go-ahead for the plan to replace the old regional hospital in Trondheim with a new one. The project was divided into two phases. On 28th of May 2002 the parliament decided to build the university hospital at it's current location based on the plans for Phase 1 of the building programme. The first phase of the construction of the new hospital in Trondheim is almost finished at the time of writing.

To obtain background information about capacity needs at the hospital, St Olavs Hospital chose to initiate an Organisational development project along the lines of Business Process Reengineering (BPR). The initiative of St Olavs was dubbed a process analysis project, and was influenced by a Scandinavian management tradition developed through the works of Trist and Bamforth (1951) and Emery and Thorsrud (1976), among others. In this tradition, user involvement is commonly regarded as a key success factor in projects involving organisational change. The process analysis at St Olavs Hospital had the dual purpose of spurring organizational change, efficient work processes as well as providing background data and material about future capacity of the hospital. Keeping in line with the terminology of this specific project, we use the term process analysis for the whole initiative. This differs from traditional BPR literature where process analysis refers to one step in a BPR initiative.

In this paper we use the process analysis of the second phase of the St Olavs Hospital project as a case study to address two research questions:

1. Did the process analysis provide the necessary input regarding future capacity needs for the new hospital buildings?
2. Did the process analysis facilitate user involvement and organisational development?

We discuss these two research questions in light of four key success factors in hospital construction projects: efficiency, effectiveness, flexibility and user involvement. A project's ability to produce its immediate outcome can be measured in terms of efficiency. It is a question of doing things right and producing project outputs in terms of the agreed scope, quality, cost and time. Hence, it is a measure internal to the project and restricted to the project management or contractor's perspective. The longer-term effects of the project can be measured in terms of effectiveness - or in other words doing the right things. In relation to the construction project, it is an external measure. Eikeland (2001) relates effectiveness to how the results of a project contribute to value added for owners and users.

Flexibility in a project can be associated with the project's decision process or the final product. The intention with flexibility in the decision process is to be able to incorporate new needs and prerequisites throughout the project. Flexibility in the product means that the physical design of the hospital facilitates changes in type of activity and required capacity, as well as other changes which might require changes in physical structures.

PROCESS ANALYSIS IN HOSPITALS

Like other enterprises, health care organisations such as hospitals can be viewed as a number of processes organised in many different process-hierarchies. Each process-hierarchy in an organisation has a specific purpose, with clear objectives, goals and methods, and may also have many variants, depending on the enterprise's needs to characterise, categorise and classify knowledge (Browne and Doumeingts 1997). In health care, patients, professionals as well as managers increasingly value aspects of processes as much as final clinical outcomes (Calnan and Ferlie 2003).

There are a number of different definitions and meanings of process. Badiru and Ayeni (1993) choose to define a process as "a collection of interrelated activities that are designed to generate specific outputs based on the application of specific inputs". A process can consist of only one task or a number of tasks in sequence. Such tasks are characterised by that people, tools, materials, and environment act together to perform one or more operations which cause one or more characteristics of a product to be altered or generated (Badiru et al.1993). Another distinctive feature of a process is that it is indifferent to departments and functional areas in that it may spread across several or be contained within one specific department.

With the development from the traditional focus on departments towards process-oriented organisations, process analysis has emerged as a tool for gaining organisational insight and for improving the performance of the organisation. Process analysis typically involves both quantitative and qualitative techniques. Visual graphical representations of process data are particularly useful in process analysis as they allow for simultaneous representation of a large

number of dimensions and are useful in showing precedence, parallel processes and the passage of time (Langley, 1999).

Enterprises embarking on process analysis need to strike a balance between quantitative and qualitative techniques in their approach. Moreover, they must choose to what extent the process analysis will be "bottom-up" and "top-down". Badiru et al. (1993) suggested that underlying processes must be improved bottom-up. Others, such as Henriksen and Myrbostad (2004) emphasised the importance of both leadership and employee involvement, suggesting that a combination of the two approaches may be appropriate in health care organisations and that it is necessary to evaluate to what extent one should focus on either in each specific case. Badiru et al.'s (1993) approach seems somewhat categorical, yet employee involvement is clearly important, as is leadership involvement. However, it is possible to have a committed and involved leadership even when resorting to a bottom-up approach. It seems both top-down and bottom-up approaches may be suitable for process analysis purposes in health care.

METHODOLOGY

This study is a case study based on trailing research (Finne et al. 1995). In the terminology of Yin (2003), this is a single case study. Separate sets of research material have been used, particularly a combination of personal qualitative experience and quantitative decision support information. The most important information sources are:

- Project documentation and quantitative information
- Participating observation during the process analysis

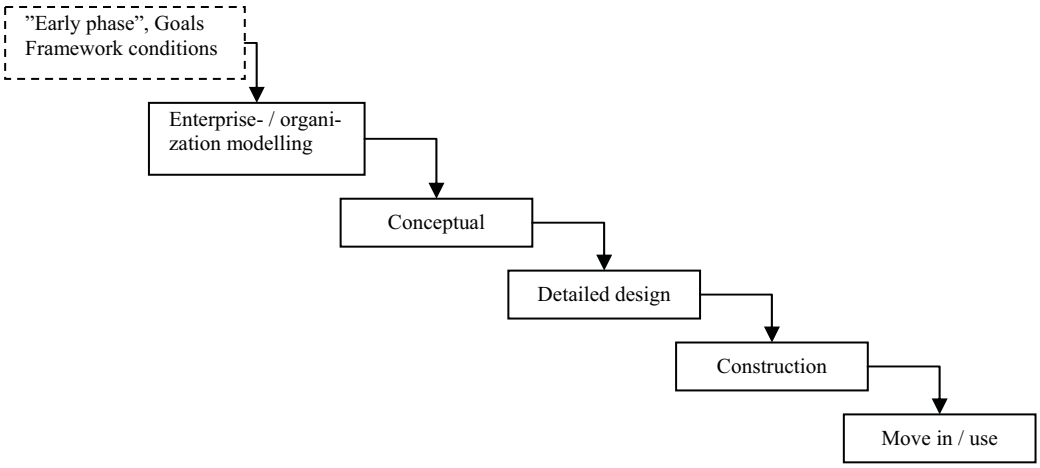
Participating observation was carried out during the process analysis, as two of the authors were involved as facilitators. Being involved as facilitators provided insight to the preparations, execution and the following use of results. The combined role as facilitator and researcher of the same phenomenon has strengths and weaknesses. The authors' involvement was separated in time, which provides an opportunity to reflect on each other's experiences, without the bias of direct personal involvement.

As facilitators for process analysis, the authors had access to a wide range of documentation, including presentations and minutes of meetings, formal reports, data that provided input to prognoses, aggregated decision support data and other types of supporting information. All this information was stored in a database, primarily to support the facilitation of process analysis. The database has also served as a reference database during the research, enabling the researchers to validate later claims against documentation from each phase of the process analysis. Such an approach was particularly important as personal experiences may be subject to judgmental subjectivity.

PROCESS ANALYSIS IN THE PLANNING OF THE NEW ST. OLAVS HOSPITAL

The new hospital in Trondheim was originally planned according to a clinical centre model. Capacities and functions in each of the six clinical centres were planned based on ICD-10 diagnostic groups. Each centre was to a large extent meant to be self supporting in terms of clinical support resources and competence. The implementation of the project New St. Olavs hospital has been divided in to two planning and construction phases. Our experience is based on involvement in the process analysis for one centre in the second phase. Figure 1 illustrates different steps in a construction project such as the New St. Olavs hospital.

Figure 1. Generic steps in a construction project



The construction project together with the initiatives for organizational change and improvement were intended to give significant gains in productivity (including quality improvement), and the process analysis had goals to (Myrbostad 2003):

- Ensure a good quantitative and qualitative basis for hospital activity, capacity and organisation, as input for design and construction
- Identify improvement potential in work processes. Start up the planning and implementation of possible actions independent of the new buildings.
- Establish interaction between employees in the hospital, primary health care and the patient organizations. Process analysis was also intended as a tool for future improvements.

In the St. Olav hospital project, important premises were expressed in a conceptual design document, HFP (the Norwegian acronym). HFP documented activities, capacities, functional content and operational principles of the new hospital. During the process analysis of the second phase of the project, the HFP were under revision and main elements of the framework were still not finalised. This means that the process analysis was to a large extent carried out in parallel with the development of the conceptual design.

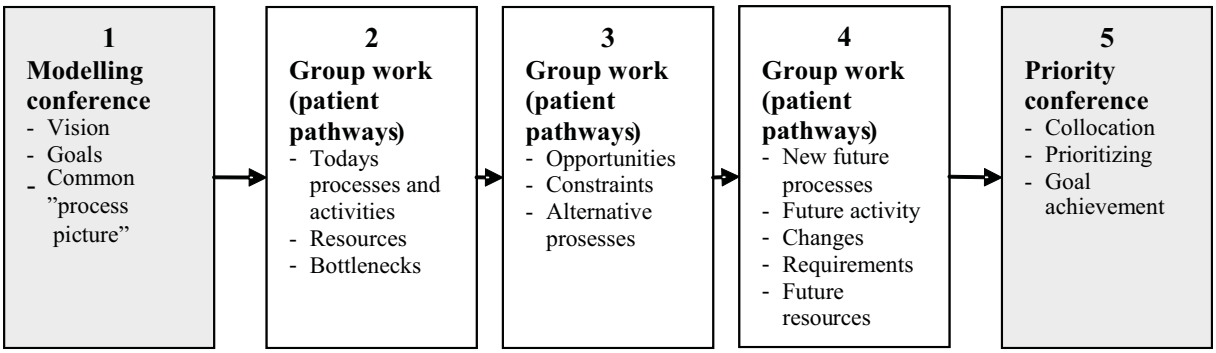
A project such as the new St. Olavs hospital has a need for specific and detailed knowledge of today's activities and capacities, as well as possible avenues towards improving conditions for the future. Obtaining such knowledge requires involvement of employees and specialists from different levels and places in the organization. This argues for a bottom-up approach to creating an enterprise map and to identifying areas for improvement.

On the other hand there is also a need to make decisions and priorities that trigger the relevant changes and ensure that the project is working towards common goals. Moreover, construction projects of the size of the St Olavs project (200.000 m2) involve important discussions on policy and strategy regarding e.g. the distribution of resources, implying the need for elements of a top-down approach.

In the process analysis of each of the clinical centres at St Olavs Hospital, different approaches were used. Initially, process analysis was largely along the lines of a bottom-up approach, where individuals from the higher organizational levels in the centres were engaged mainly at the early and the latest stages (stage 1 and 5 in Figure 2).

Figure 2 illustrates the plan for process analyses. As we see there were intensive group-work sessions where employees and experts on the relevant patient groups or patient pathways were the main resources.

Figure 2. Process analyses bottom-up



The modelling conference was a session assembling both leadership and employees at different levels in the organization aiming to get a common overall picture of the processes in the centre. Ambitions and goals related to the process analyses, and to some extent training/guiding in process approach, is also a part of the modelling conference.

The stages 2-4 represent much of "the traditional" BPR activities and produces much of the facts/basis for decisions in the future project work. In this model, the priority conference is the most important arena for decision making regarding new and/or improved processes

Our case was one of the first process analyses in the second phase and represented important learning for everybody involved. In the process analyses in this particular centre there were continuous discussions regarding the HFP that was under revision. The consequence of this was that the HFP was not regarded as an absolute constraint. The HFP 2 is regarded as the

final framework for expected patient volume for each centre as well as allocation of space. In the working groups, focus was on activities, functions, functional proximity requirements, other requirements and number of patients in the future. The translation into area, rooms and concrete specifications was mainly an exercise done by the facilitators as a part of the reporting from each group.

Table 1 illustrates the consequences in number of patients and area for some functions described at different stages of the process analysis:

PA 1= Results from the group work
PA 2= Results from the priority conference
HFP 1= functional strategic program from 1999
HFP 2= the revised strategic functional program from 2003

The figures in table 1 are indexed to the HFP from 1999. The main variables that influenced need for room and area in the new hospital were number of patients, lay time and whether the patients needed beds or could be treated at daytime, e.g policlinic. In the process analysis group work, a key issue was to identify enablers for reduced lay time and alternative pathways. Despite this the group reports all concluded in need for area that exceeded the HFP 1 by more than 78%. This was mainly caused by an increased estimate of number of future patients.

Table 1: Patients and needs for some functions expressed in the process analysis

	Number of patients				Area			
Functions	HFP 1	PA 1	PA 2	HFP 2	HFP 1	PA 1	PA 2	HFP 2
Beds	100	245	233	158	100	178	202	162
Day treatment	100	344	198	183	100	319	184	142
Policlinical rooms	100	211	92	220	100	-	-	134

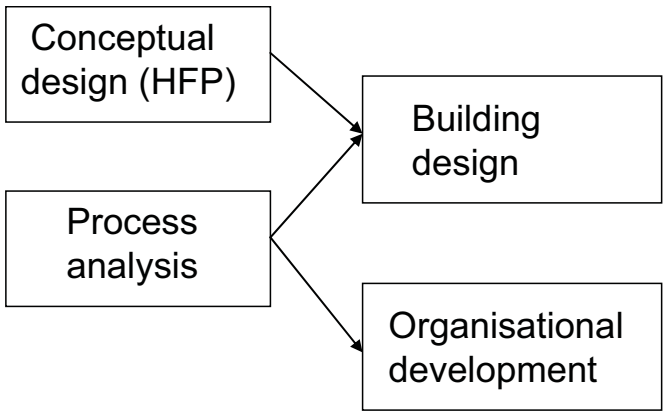
The priority conference represented an important arena for decisions regarding future activity in the hospital. The people involved has to focus on common goal and not only focus on own (short term) interests. There was naturally a need for facts and information of high quality from the earlier stages in the project (e.g the group reports).

As we see from Table 1, there was a reduction in need for beds and rooms during the priority conference despite an upward adjustment of the number of patients. This reduction was mainly a result of working with variables such as lay time and daytime treatment.

During this latter phase of the process analyses the revised HFP (HFP 2, from 2003) was presented. It represented a considerable upward adjustment of the number of patients and area compared to the previous HFP. Figure 3 illustrates that the conceptual design (HFP) were done in parallel to the process analysis. If we just study the number of beds and patients (hospitalization) we see that the number of patients increased by 58% in the revised HFP, but was still only 68% of the estimations from the priority conference. The priority conference was some extent was an arena for policy and strategy making, because both leadership and

employees at different levels in the organization were gathered. However, the conference was not intended as an arena for building consensus on quantifications of future hospital capacity.

Figure 3. Relation between conceptual design, process analysis, organisational development and the design of the hospital



The process analysis appears torn by different output needs. With reference to Figure 3, the process analysis should provide input to both building design and organisational development. To provide fruitful input to building design, results from process analysis were often too general. Efforts had to be made to quantify the output, using experience data and prognoses. As the results from process analysis were formatted to provide relevant input to the building design, they appear to have become less suitable to serve as a basis for organisational development. Finally, results from process analysis lost some of its edge when the conceptual design (HFP) were developed in parallel. Moreover, the HFP2 provided a more definitive output in terms of available area, standards and similar parameters.

CONCLUDING DISCUSSION

In this paper we discussed how the process analysis contributed to four key success factors in hospital projects: efficiency, effectiveness, user involvement and flexibility. The first research question was related to what extent the process analysis provided the necessary input to the hospital design. The second research question addressed to what extent process analysis facilitated user involvement and organisational development.

The process analysis should provide input to both building design and organisational development. Regarding input to building design, the conceptual design (HFP) delivered a more definitive output than the process analyse.

The process analysis did achieve user involvement. However, the experiences from the bottom-up approach pointed to the need to establish a strategic framework for the analysis.

User involvement also generated expectations. All desired features and volume of the new hospital building was not possible to combine within the allocated recourses. As a result of this the process analyses of the second phase had more elements of a top-down approach with more intensive involvement of leadership in the first steps to define goals, priorities etc, and an emphasis on providing more facts when starting the group work. The group work was also more focused due to a more defined mandate owing to focus on critical aspects and processes.

The learning curve for all parts involved in the process analyses in phase 2 was quite steep. One insight was that there was need of more defined direction, priorities and goals in the early steps of the process analyses. This also includes consensus related to facts and definitions such as in the HFP.

The transfer from analysis to decision making proved challenging for two reasons: Firstly, user involvement also generated user expectations. Secondly, the decision process required a higher level of detail, while the process analysis by nature was more conceptual. On a conceptual level, most stakeholders could agree on desirable solutions. As the level of detail increased, so did the awareness of different group interests. The pressure to summarise process analysis results into straight forward decision supporting facts was related to project efficiency. The design and construction project needed clarifications to be able to continue. Lack of clarifications meant delays and increased project-related costs. Project efficiency is a key issue when explaining why the process analysis was carried out as it was.

An overall objective of the process analysis was effectiveness in terms of a suitable future hospital building. One aspect of effectiveness of a hospital building project is the cost and quality level of the operation in the new building (the processes within a new hospital). The same cost and quality measures will be related to efficiency of the hospital, when the new buildings are taken into use. In other words, the efficiency in the hospital (once it is built and taken into use) is one dimension of effectiveness of the construction.

Effectiveness in the future hospital was measured and interpreted in many ways by the different involved stakeholders. Future cost of operation was one aspect. Ability to accommodate future patient volumes was another key issue. Suitable working conditions for hospital staff was yet a concern. Given the long time frame and present rate of change in health care, flexibility is another aspect of effectiveness in hospital buildings. Regarding flexibility, our experience is that extensive user involvement does not necessarily ensure future flexibility. Especially in the “locking phase” when the results from the process analysis were converted to hard facts for decision support, the reference point to most stakeholders was the present situation; do we get more or less than we have now; are present trends taken into consideration?

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Paper 7.

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FRONT-END MANAGEMENT, FLEXIBILITY, AND PROJECT SUCCESS

Nils O. E. Olsson

Knut Samset

A Project Management Paradox

Well-designed projects stand a better chance to succeed than inadequately designed ones. Investing more resources in the initial stages therefore seems to pay off. These are not controversial statements; they express common understanding and are supported by a great number of studies (e.g., Anderson & Merna, 2003; Berg et al., 1999; Morris & Hough, 1991). A study of 1,125 projects by the World Bank (1996) on the importance of quality-at-entry concluded that projects with adequate or better identification, preparation, and appraisal had an 80% satisfactory rate versus 35% for projects that were deficient in all these aspects. The study shows that the formal definition of the main characteristics of a project seems to matter, but also the project design in qualitative terms. In other words, a project design based on a thorough pre-study and appraisal is more likely to succeed than a project based on less systematic analysis of reality.

The distinction between design and planning is important. What really matters is to identify the key determinants that would be decisive in the final selection and design of the project. Many of these key determinants are predictable. Systematic scrutiny of these determinants and a probabilistic assessment of the risks and the opportunities they represent are likely to help produce a realistic design and increase chances of success.

Current practice is something else. Despite the fact that decisions made in the concept definition phase tend to have the largest impact on the final effect of the project, too little is done to ensure that these decisions are firmly based on analysis. Too many projects are initiated based a preconceived idea of the technical solution to the problem at hand. Genus (1997) showed that early and inflexible technology choices was one of the core problems in the Channel Tunnel project between Britain and France. In too many projects, the initial idea remains largely unchallenged and turns out to become the selected project concept. The predominant tradition is to apply "downstream" analyses of the consequences of an already given alternative, rather than "upstream" assessment of alternative concepts as seen in relation to needs and priorities.

The front-end phase of a project commences when the project idea is conceived—and it ends when the final decision to finance the project is made. The main aim of front-end management is to get the strategic perspective right. The potential to reduce possible additional and amendment costs during implementation and also to increase the projects long-term utility is higher in the front-end phase than during implementation. This is illustrated in Figure 1. It is therefore a paradox that textbooks in project management, as well as curricula in project management lectured in universities tend to restrict their focus on the more detailed planning and implementation phase where the potential for major improvements are

more marginal in relative terms. The authoritative *Project Management Body of Knowledge* (*PMBOK® Guide*) (Project Management Institute [PMI], 2004) is no exception with its relative marginal coverage of front-end management. Morris (2000) also points out that the *PMBOK® Guide* fails to recognize issues such as aligning project objective to business objectives of the project sponsor.

Söderlund (2004) discussed two main theoretical traditions in project management research. The first tradition has its intellectual roots in engineering science. Planning techniques and methods of project management, including the recent emphasis on uncertainty quantification and risk management, have been the major focus. This is in accordance with Packendorff (1995), who maintains that a number of authors trace the intellectual roots of project management research and knowledge to various types of planning techniques, such as PERT and CPM. The other tradition has its intellectual roots in social sciences and is especially interested in the organizational and behavioral aspects of projects. Söderlund (2004) terms these "the engineering tradition" and "the social science tradition," respectively. Another dimension on project management is noted by Engwall (2003), who claims that research on project management has been dominated by what he calls "the lonely project" perspective, with little emphasis on projects context.

The discussion on project management traditions can also be related to how "project management" is defined. PMI (2004) defines project management as "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements" (PMI, 2004, p. 368). In this terminology, project management is aimed at meeting project requirements, and not necessarily related to meeting overall objectives of projects. Provided that the requirements fully support overall objectives, such an approach is not problematic. In this way, project management does not include validating that project requirements are actually reflecting overall purposes of the project. What we have called front-end phase includes the initiating process group in PMI (2004) terminology. However, it is not clear if PMI (2004) considers selecting the right project as a part of project management. It is stated that "initiating processes are often done external to the project's scope of control by the organization or by program or portfolio processes, which may blur the projects boundaries for the initial project inputs" (PMI, 2004, p. 43).

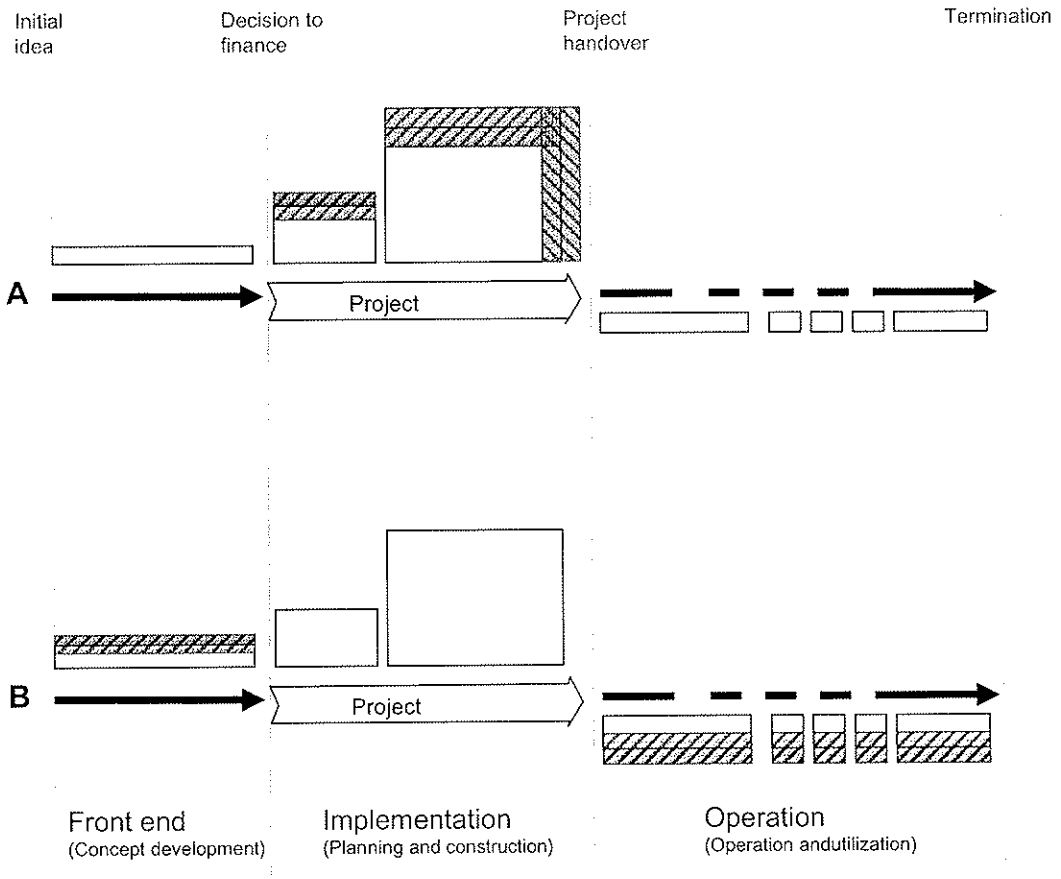

Figure 1: Schematic cash flow for a project over its life cycle. The project management approach (1) is to spend additional resources on planning in order to avoid cost overrun and delays in producing project outputs. More significant in terms of improving long-term utility (2) would probably be to spend additional resources front-end in selecting the most feasible project concept.

Efficiency versus Effectiveness

A project's ability to produce its immediate outcome can be measured in terms of efficiency. It is a question of doing things right and producing project outputs in terms of the agreed scope, quality, cost, and time. It is a measure internal to the project and restricted to the project or contractor's perspective. The longer-term effects of the project can be measured in terms of effectiveness—or in other words doing the right things. It is an external measure. Eikeland (2001) relates effectiveness to how the results of a project contribute to value added for owners and users. In Organisation for Economic Co-operation and Development (OECD) terms, effectiveness measures the realization of the project's purpose, or its first-order effects (Organisation for Economic Co-operation and Development, 2000). This is the perspective of the project owner or financing party, who in many types of projects might have a perspective similar to the users.

Clearly, initial decisions regarding the choice of concept need to be based on thorough evaluation of ways and means to achieve the perceived project's overall purpose and goal, and not only its outputs. The project's purpose is directly related to user satisfaction and is best evaluated from a user perspective—which

is commonly addressed within the so-called engineering tradition of project management. The project's long-term goal is related to the socioeconomic benefits of the project, and will have to be considered in a broader socioeconomic perspective. This would require the skills and insight represented by the social science tradition.

Strategy versus Tactics

The traditional approach in front-end management of projects is to strive for increased predictability and robustness, by managing details and attempting to bring all variables under control. However, the merit of detailed strategic planning at an early stage is subject to much debate as discussed by for instance by Slevin and Pinto (1989), Christensen and Kreiner (1991), Kreiner (1995), and Mintzberg (1994). Not surprisingly, experience shows that the chance of realizing a plan without major amendments decreases with increasing time horizon. This was supported by Flyvbjerg, Holm, & Buhl (2004), who pointed out that cost escalation of major transportation investments is highly dependent on the length of the project implementation phase. Longer implementation causes higher cost escalation.

Because we neither have full predictability nor control over all variables, attempts at detail management may easily result in the opposite; reduced manageability. Flexibility to be able to handle situations that might occur along the way, might be equally, if not more important. Morris and Hough (1991) have studied large engineering projects and highlighted the need for clarity of project definition but also the drawbacks of premature over-commitment. Based on experiences form the Channel Tunnel project, Genus (1997) advocates flexible and incremental decision-making in large engineering. According to Genus (1997), inflexible technologies are characterized by long lead time, high capital intensity, large unit size, and dependence upon specialized infrastructure. Genus (1997) argues that technologies that do not have these characteristics should be favored.

An interpretation of this is that thorough preparations in the front-end phase are useful for determining the direction and the strategic framework for a project. It is also important for predicting the difficulties that might occur in order to keep ahead, in identifying options and possible tactical moves when necessary. Sufficient tactical leeway is needed to achieve the expected benefits of a project. However, if the basic project concept is wrong, appropriate tactical implementation cannot compensate for faulty strategic choice.

Terms like adaptability and robustness are often used when discussing issues related to what is termed flexibility. Note that flexibility is not seen as an alternative to strategic management, but as a means to help realizing a strategy; in the way that Samset (2001) argues that successful projects are characterized by a distinct strategy in combination with sufficient tactical flexibility. Olsson (2004) showed that flexibility often is a means of improving effectiveness rather than efficiency in projects. Well-performed front-end assessments involve a consistent focus on the original decisions made in the concept definition phase of the project. This will provide the project's stakeholders with a common framework when the project subsequently is planned and implemented. Iterations are not necessarily negative, depending of timing, type, and size. It is assumed that iterations are less resource consuming in the early phases than later, and that planned or prepared iterations require less management resources than those that are not prepared for.

Norwegian Major Public Projects—Case Studies

This paper is based on multi-case research over a number of years. Three data sets have been used. The first data set includes 18 projects. The prime source is reports written as a preparation of the quality-at entry regime. In addition, personal experience and public evaluation reports of governmental projects have been used.

The second source of information consists of 48 quality-at-entry reports carried out between 2000 and 2004. As a part of the Norwegian quality-at-entry regime, a forum was established consisting of the involved

consultants and ministries. A key issue of this forum was to ensure a uniform structure and terminology of the quality-at-entry reports. As a consequence, the research data used in this study has a uniform and quality-assured structure. Both these data sets have been codified and entered into a research database. The purpose of the database was to provide proper storage of all relevant data regarding the projects.

Finally, a multiple case study of four projects was done using both quantitative and qualitative data. Traffic impact of four Norwegian railway investment projects was analyzed, which focused on the development of punctuality, frequency, travel time, number of travelers, and construction cost. The main purpose was to follow-up benefit realization in the studied projects.

Measures to Improve Cost Control

The cost of major public investment projects in Norway amounts to the equivalent of about U.S. $3 billion per year totally. Funds are mainly channeled through the Ministries of Labor and Public Administration, Finance, Defense, and Transport and Communications (Ministry of Finance, 2001). In 1998, the Norwegian Ministry of Finance made an analysis of a number of such projects (Berg et al., 1999). Effective from 2000, the ministry introduced mandatory quality assurance and uncertainty analysis of all major public projects exceeding NOK $500 million (U.S. $60 million), the so-called quality-at-entry regime.

The regime was introduced in response to a situation with large overruns. The responsible ministries are now required to commission consultants to undertake assessments prior to the Parliament's appropriation of funds. Aims of such assessments are to review cost estimates and major risks that might affect the projects when implemented. Such analyses are termed "quality assurance 2" (QA2). The aim of the regime is to establish realistic cost and time frames for large governmental projects. A limited number of consulting groups are commissioned to undertake the assessments. The responsible ministry in these cases is seen as the project owner. Neither the project users nor the contractors are involved in the quality-at-entry analyses. The QA2 reports provide the ministries with a third-party opinion of the projects before they are submitted to Parliament.

Olsson, Austeng, Samset, & Laedre (2004) and Langlo and Olsson (2004) point out that the quality-at-entry Regime has had a prime focus on budget. To achieve maximum benefit from such an analysis, the project organizations themselves need to address the uncertainties identified in the analyses and continuously monitor these and other uncertainties that might affect the project. From a learning point of view, the research revealed a need for ensuring ownership of the results from the quality-at-entry analyses, while at the same time obtaining the benefits from an independent review. The responsible ministries report that they have got a better understanding of the projects and a better decision base.

To make sure that governmental projects do not require additional funding, project reserves are allocated. The QA2 reports include a budget recommendation for the project. Reserves are not intended for expanding the scope of the projects, but solely to cover unexpected expenses. Specific rules for the management of reserves have been established. During the period from the first QA2 in 2000 to mid 2002, QA2 was under development to find a suitable form, accepted definitions, and more uniform cost estimation process between the consultants. Compared to the agencies' cost estimates, the consultants' estimates were on average 9.5% higher. Subsequently, a more uniform cost estimation practice has emerged. Since mid 2002 the average difference between the cost estimates of consultants and agencies is reduced to 1.6%. From 2000 to 2005, cost overruns for Norwegian road projects has dropped from an average of 17% in 2001, to 4% in 2005 (Jordanger, 2005), indicating that a structured approach to cost estimation and control can result in reductions of cost overruns.

Need for Effectiveness Improvement

Even though a structured approach to cost management in the late front-end of projects can contribute to cost control, this does not ensure project success or optimal use of available resources. Our experience indicates that successful projects are characterized by a distinct strategy in combination with sufficient tactical flexibility and that both these key features are to be established in the front-end phase. It is therefore surprising that neither strategy nor flexibility is defined as focus areas in project management, but left to other disciplines.

Although effectiveness is important for project success in a strategic perspective, it is challenging to obtain, predict, and manage. Experience from the Norwegian quality-at-entry regime indicates that a structured approach to cost management in the late front-end of projects can contribute to cost control, illustrated by the effect of the QA2 exercises. Project management as an academic and management field possesses tools and techniques for this type of cost control and efficiency support. This does not ensure that existing tools and techniques are properly used and taken into account, depending on management tradition and other characteristics of organizations, but the enablers do exist and the project management community is constantly improving in taking them into use. In contrast, our studies indicate an improvement potential for tools, techniques, and experiences to secure effectiveness of projects. To a certain extent, this means utilizing practices from other disciplines than projects management.

To illustrate the challenges regarding project effectiveness, and particularly the benefit side of investment projects, Flyvbjerg, Bruzelius, & Rothengatter (2003) documented that estimated number of travelers on new transport infrastructure rarely matches the estimated numbers. Olsson (in press-a) made an in depth-analysis of the effect of four Norwegian railway investment projects. The results showed than it was a major challenge to obtain a combination of cost control and achieving expected benefits. Projects that were carried out as large-scale "mega projects" suffered cost overruns. However, they did achieve considerable benefit improvements, such as travel time reductions and an increase in the number of travelers. Projects that were decided upon section by section had better cost control, but benefit improvements were limited.

Measures to Improve Effectiveness

In the following, we discuss some approaches to achieve a combination of a distinct strategy in combination with sufficient tactical flexibility for projects. In addition, results from analyses of some of the proposed approaches are presented.

Quality-at-Entry Analyses at an Early Stage

The experiences from the first 54 quality assurance studies were that QA2 only addresses part of the major problems the projects are confronted with. Three years of trailing research served as input to the revision of the quality-at-entry regime. Olsson et al. (2004) as well as Magnussen and Samset (2005) have presented the results from this research. Figure 2 shows a summary of observations from the first four years of the quality-at-entry regime. There is a need to focus on the basic rationale of projects as to satisfy needs. The quality-at-entry regime was therefore revised in 2005, and extended to include an external assessment of the initial selection of the project concept. This new part of the regime is called quality assurance 1 (QA1), and was introduced with the view that it might have considerably more impact on the projects' long-term utility.

Problem	Observations
Cost overruns	Too early for conclusions—Positive indications
Tactical budgeting	Third-party reviews creates awareness
Different front-end routines in different agencies	Improved and more uniform practices
Lack of overall view of projects	QA2 is too restricted
No review of alternative project concepts	QA2 too late in the project cycle
Uncertainty management	QA2 too late in the project cycle
Low long-term utility/profitability	QA2 too late in the project cycle

Figure 2: Issues and problems related to QA2.

The QA1 exercise includes an analysis of the prerequisites for a proposed project, a need analysis, analyses of the documented strategy and requirements, and finally, a comparison of alternative concepts. The Government is required to present at least three alternative project concepts, including the "zero" alternative—proceeding without the project. The QA1 exercise has a wide perspective and focuses on the project's response to future users and society as a whole. The purpose is to identify the right project.

Decoupling Robustness and Adjustment

Thomke (1997) discusses how techniques developed in a total quality management tradition are transferable to a project management context. He particularly points to the Taguchi model (Taguchi, 1987) where flexibility is achieved through a two-step model by decoupling robustness optimization and performance adjustment. In this connection, robustness is defined as the insensitivity of the product toward variation in uncontrollable (to the project) external variables. During the first step, functional robustness of the product is maximized independent of the final requirements. During the next step, the performance of the product is adjusted to meet customer and user requirements. Referring to the Norwegian quality-at-entry regime, the objective of QA1 is to achieve a robust project concept, for instance by making the essential choice between different alternatives to improve transport between the mainland and an island (bridge, tunnel, ferry, etc.). QA2 makes a review of the final adjustments of the selected project, including its specification, cost and management structure, cost estimate, and risk exposure. Thomke (1997) pointed out that decoupling of robustness and adjustment has significant implications on design flexibility. Early design of project concept can focus on robustness alone. Changes to meet evolving need can then be made quickly using a low-cost adjustment factor.

Modularization

Design modularity is a common approach to achieve flexibility (Hellström & Wikström, 2005; Thomke, 1997). Hellström and Wikström (2005, p. 394) defined modularization as "decomposition of a part of a product into building blocks (modules) with specified interfaces, driven by company-specific reasons." Modularization in product development projects is primarily a tool to improve project efficiency (Thomke, 1997).

We have studied a strategic kind of modularization in an investment project context, where commitment to large projects is done step-by-step, not all in one. An approach of minimal commitment at each decision stage is a part of the "anti-disaster methodology" proposed by Hall (1980, p. 267). According to Hall (1980, p. 272) "this would generally mean an incremental or adaptive approach to development of any kind, rather than a new major departure; it would suggest enlargement and adaptation of existing airports rather than building new ones." Another approach to incremental decision-making is found in real options, an approach

with roots in financial options theory (Amram & Kulatlaka, 1999; Brennan & Trigeogris, 2000). In a real options perspective, uncertainty can increase the value of a project, as long as flexibility is preserved and resources are not irreversibly committed. A real options approach to transport infrastructure investment means that the value of future flexibility and new information is included in the project decision process, as illustrated by Mehndiratta, Brand, & Parody (2000) and Brand, Mehndiratta, & Parody (2000). Decision-makers can wait to observe the outcome of initial investments before they commit to next steps of a major investment. However, studies of railway investment projects indicate that such an approach also has a cost, because it may result in reduced benefit of the project (Olsson, in press-a). Benefits materialize only when certain new levels of improvements are achieved.

Flexibility in Decision Process and Product

Project flexibility refers to how projects are executed and to how adaptable the final product will be, once it has been produced. According to Olsson (2004), flexibility in the decision process is based on an approach where decisions and commitments in the projects are made sequentially over episodes. Flexibility in the product means that the design of the final product (what the project shall produce) has taken into consideration possible future changes in use or requirements. If requirements are altered, no changes are needed because the design can accommodate the revised requirements. Gill, Tommelein, Stout & Garrett (2005) also discussed flexibility in the process and product in a similar way.

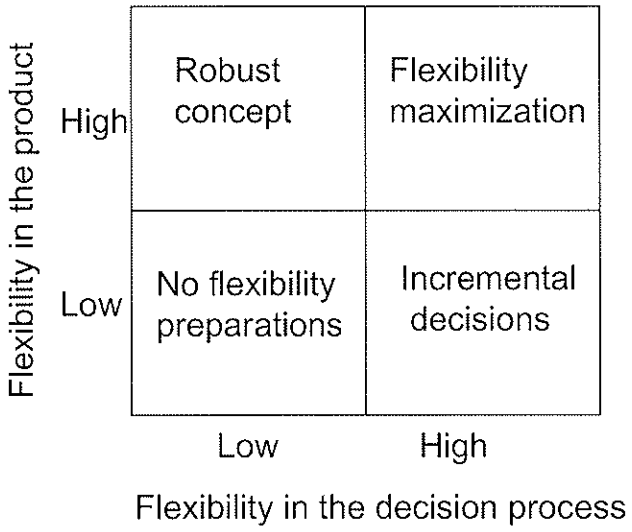

Figure 3: Flexibility in the product and the decision process (Olsson, 2006).

Different strategies for project flexibility management are depicted in Figure 3, each characterized by high or low flexibility in the process and product, respectively. With high flexibility in the product and low in the process, the decision process related to the project may be fairly straightforward because the result of the project is prepared for alternative use. High flexibility in the decision process in the study includes changes, extensions, and iterations in the project preparations.

Flexibility in the product and the decision process was analyzed in 18 projects. Figure 4 displays the number of projects found in each category reacted to flexibility in decision process and product. In addition, average cost overrun for the projects is shown in parentheses. The results indicate that flexibility in one dimension only to a limited extent could compensate for lack of flexibility in the other dimension. Projects with high flexibility in the product also had high flexibility in the decision process, even though it was not necessarily

prepared for. Regardless of the flexibility in the product, a high flexibility in the decision process resulted in more than 100% cost overrun, compared to the initial budget. Few projects had prepared for flexibility in the decision process. The number of projects in this study is too restricted to allow firm conclusions. However, the findings might illustrate challenges related to flexibility that could be explored further. Most projects were subject to changes, extensions, and iterations (summarized as "flexibility in the decision process"), few had prepared for flexibility. Finally, when flexibility is not properly managed, it is expensive.

		Flexibility in the decision process		
		Low	Medium	High
Flexibility in the product	High	0	0	2 (106%)
	Medium	1 (0%)	5 (5%)	2 (121%)
	Low	1 (1%)	1 (13%)	6 (117%)

Figure 4: Flexibility in the product and decision process (number of projects and mean cost overrun in percent).

Room for Maneuvering

Many textbooks on project management present models that illustrate how project attributes change during different project phases, often similar to Figure 5. These have in common that the uncertainty, significance of decisions, and the degree of freedom to maneuver are typically high in the beginning of the project, and low in the end. At the same time, variables such as the accumulated cost and available information begin at low levels and end up at a high level at the end of the project.

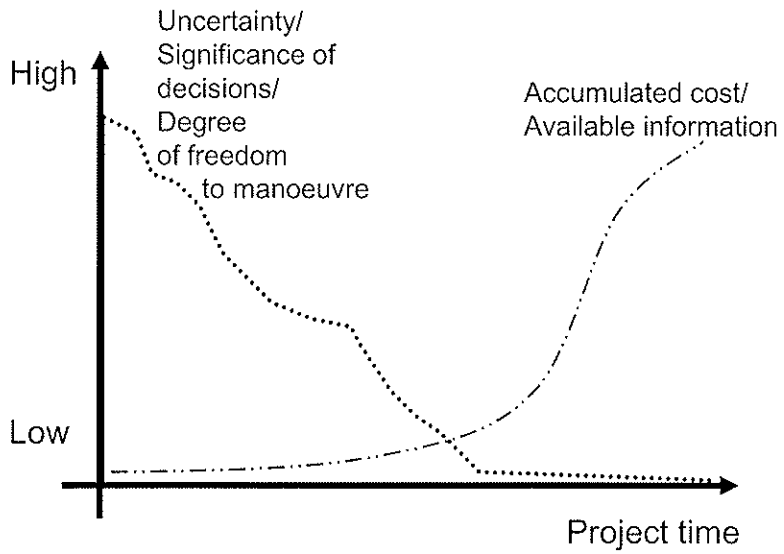

Figure 5: Uncertainty, significance of decisions and the degree of freedom to maneuver are typically high in the beginning of the project, and low in the end. Accumulated cost and available information have a reverse development through the project, beginning at a low level and ending at a high level. Based on Christensen & Kreiner, 1991, p. 40; Mikkelsen & Riis, 2003:, p. 7; Midler, 1995, p. 369; Samset, 2000, p. 32).

Midler (1995) linked the decreasing degree of freedom to maneuver with a rising degree of irreversibility in project decisions. Mahmoud-Jouini, Midler, & Garel (2004, p. 361) describes the descending curve as "possibilities of action in the project."

Figure 6 provides a similar model to illustrate a project's flexibility. A decision is within the room for maneuvering if it does not violate the consequences of previous decisions. The need of room for maneuvering is within the actual room for maneuvering in the early phase of projects (area A), but not during later parts of projects (area B). A major challenge in project management is that the need of room for maneuvering is typically at its highest when the actual freedom for maneuvering already has decreased significantly. Area B represents situations when some stakeholders (for example, users or project owner) have a desired room for maneuvering that is larger than the actual room. To satisfy the need for adjustments, changes have to be made, because the adjustments violate previous decisions. This generally reduces efficiency in the project. With reference to Figure 6, adequate front-end management means utilizing area A and minimizing area B. The project is not closed prematurely (utilize area A), an approach similar to the late locking advocated by Miller and Lessard (2000). Stakeholder alignment reduces the "desired room for maneuvering" after the project is finally decided upon (minimizing area B).

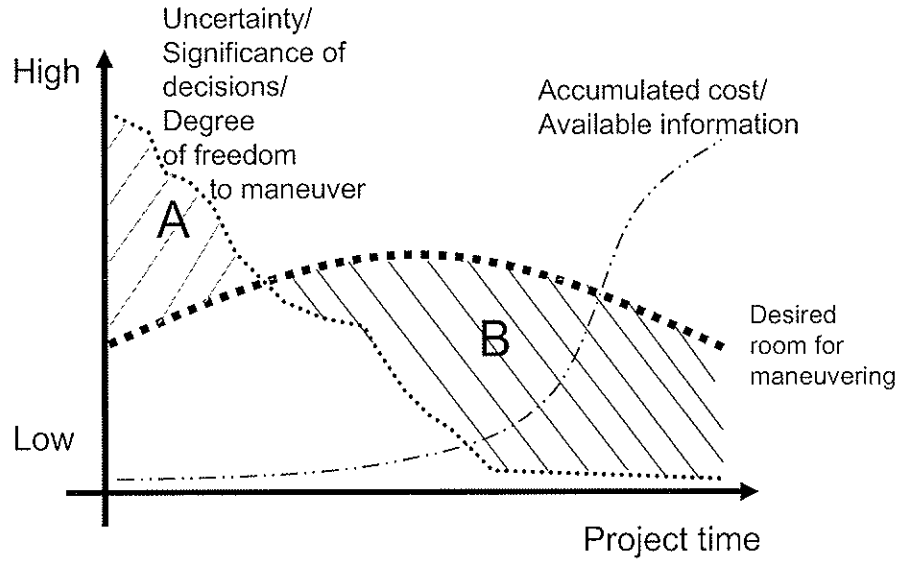

Figure 6: Consequences of different values on the uncertainty, significance of decisions and the degree of freedom to maneuver compared to the desired room for maneuvering in different project phases. (Based on Eikeland, 2001, p. 40).

Midler (1995) and Verganti (1999) identified strategies to increase the area A and reduce the area B in Figure 6. The purpose is to avoid changes but to keep options open to satisfy as much as possible the anticipated need for maneuvering. Midler (1995) described a management strategy where early commitment is prevented while as much information as possible is gathered on the project. This increases the area A. In the second phase, the project is locked as precisely as possible. Finally, at the end of the project, progress is given maximum priority in order to solve the remaining technical obstacles.

Targeted Room for Maneuvering

Another approach implies that front-end analyses identify areas where there is substantial uncertainty related to one or a limited number of issues that might affect the scope of the project. In such a case, the bulk of the project could be locked in the front-end phase, while some issues remain unsettled until later stages, as illustrated in Figure 7. This approach is routinely used in hospital construction, where the final decision of medical equipment typically is made later than decisions regarding the physical construction.

Based on data from QA2 analyses, Olsson and Magnussen (2005) estimated that at the time when projects were finally approved, it was considered appropriate that an average of 6% of the projects' total budget consisted of deliveries that where not finally specified or decided upon. Also, the analyses recommend that 9% of the project's budget were allocated as reserve, to cover unexpected expenses. An approximation of the relative size of projects that can be left open is therefore estimated to be in the range between 10 and 15% of total budgets.

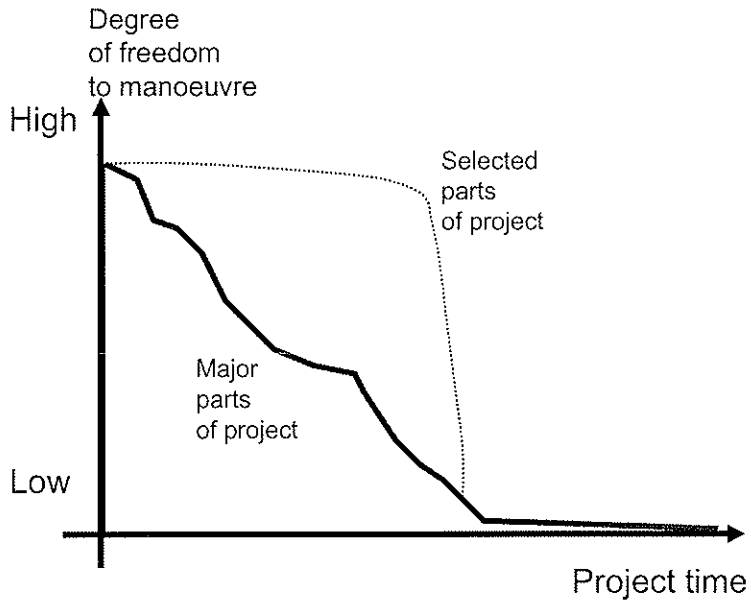

Figure 7: Locking the major part of a project, but keeping selected items in the specification open.

Concluding Discussion

The paper emphasizes that successful projects are characterized by a clear and well-founded strategy in combination with sufficient tactical flexibility. Establishing a strategy that provides a distinct direction but leaves room for maneuvering is arguable the most essential part in front-end management. In ensuring flexibility, the study suggests some measures that may be of use in front-end preparations of projects:

- Late locking of projects can be applied either for the whole or part of a project. Late locking of parts means that selected parts of the specification can still be open when the project is finally decided upon. Findings presented in this paper indicate that project content equivalent to some 10–15% of the total project budget can be finally specified even after the decision to go ahead with the projects as a whole.

- Splitting or modularizing major projects offer flexibility for decision-makers. There are indications that such an approach contributes to better cost control but reduced benefit realization, compared to major projects with an irreversible final commitment.

Project management as an academic and management discipline is essentially applying tools and techniques for efficiency support by focusing on cost control, progress, and quality of the output. In an engineering tradition, the objective of front-end management is to provide a well-defined framework for efficient project implementation. The purpose is to a large extent to minimize the need for flexibility. This does not mean that flexibility is undesirable; it is usually considered useful for adjustments within the strategic framework, and especially regarding how requirements shall be met. This perspective is often held by project managers and contractors. It was also the dominating perspective in the early phase of the Norwegian quality-at-entry regime.

Based on what is termed a social science tradition, an objective of the front-end phase is to align the content of the project to objectives of stakeholders. This is also the essential part of the current, revised Norwegian quality-at-entry regime. Objectives may be drifting; implying certain needs for flexibility. However, a strategic focus is needed and this is supported by a robust project concept. A final conclusion is that neither front-end management nor flexibility is properly emphasized in the curriculum of project management. As a consequence, these issues are largely left to other disciplines.

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Paper 8.

Olsson, N.O.E. 2006.'Flexibility and Front-End Management; Key to Project Success and failure' Paper accepted for presentation by ProMAC International Conference on Project Management, 27-29 September 2006, Sydney, Australia.

Project flexibility and front-end management: Keys to project success and failure

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Abstract
Project flexibility means a capability to adapt to new, different or changing requirements. The paper proposes a framework for understanding project flexibility. The framework for analysis consists of project flexibility categorisations, perspectives of analysis, flexibility drivers and enablers. The proposed framework can serve at least two purposes. First, it can work as a checklist for aspects that are to be included in an analysis of project flexibility. Such analyses may be carried out as a part of *ex-ante* project preparations, *ex-post* project evaluations or during projects. Second, the relation between different aspects in the framework can be analysed to gain an understanding of interaction between the aspects.

1. Focused and flexible - a project management dilemma
Traditionally, projects tend to strive for increased predictability and robustness, by managing details and attempting to bring all variables under control. However, experience shows that the chance of realizing a plan without major amendments decreases with increasing time horizon, which point to a need for flexibility, or adaptability. A key message in this paper is that successful projects are characterized by a firm and realistic strategy in combination with sufficient tactical flexibility. Strategy and tactical flexibility need to be carefully addressed in front-end management of projects.

Project flexibility is part of a fundamental dilemma in project management. On one hand, projects need stability and control to be executed efficiently, typically measured by time, cost and meeting specifications. In this perspective, flexibility shall be minimized. On the other hand, important decisions in projects must be taken based on limited information in an unpredictable world, creating a need for flexibility options.

The results presented in the paper are based on a diverse sample of large public investment projects. Several different information sources have been used and analysed, including both quantitative and qualitative information. The main data set used in this paper covers 18 Norwegian large engineering projects, which have been analyzed regarding project flexibility.

The paper proposes a framework for understanding project flexibility. Like previous researchers, this research has documented that the potential drawbacks of flexibility, both on efficiency and effectiveness, are substantial. However, the main drawback of project flexibility that has been observed in our research is not flexibility itself, but flexibility applications in projects that lacked structure and preparation for flexibility. This indicates that if a structural framework for a project is established, flexibility options could be utilised without destabilising the project organisation.

2. Project flexibility
According to the Merriam-Webster dictionary, being flexible is “characterised by a ready capability to adapt to new, different or changing requirements". This means that project flexibility includes preparations to manage both internal and contextual uncertainty, such as: scope change management, iterative decision process, adjustments related to uncertain funding in general and budget reserves in particular. This paper does not aim at covering the issue of uncertainty in a broad perspective. However, the distinction between the two types of uncertainty that Karlsen [1] and Christensen & Kreiner [2], among others, discuss has implications on the analysis of project flexibility. This paper will use the terms contextual uncertainty and internal uncertainty. Internal uncertainty is related to operational uncertainty [2] or task uncertainty [1].

Real options represent one approach to project flexibility [3], [4]. Real options illustrate the value of flexibility based on theory related to financial options. Flexibility is compared to owning an option - the right, but not the obligation to take an action in the future [3].

3. Research approach

In this paper, one phenomenon – flexibility – is analysed in a complex environment with several influencing factors. Investigating project flexibility from different angles has provided a multi-dimensional view of the subject. A combination of qualitative and quantitative information has been used. Case studies included in the paper apply a research methodology based on the works of Yin [5]. Three important principles in the research have been: (a) multiple sources of information, (b) use of case study databases to assemble evidence related to the cases, and (c) maintaining a chain of evidence with links between the questions asked, data collected and conclusions drawn.

This paper presents some analyses of 18 Norwegian large engineering projects, which have been analyzed regarding project flexibility. A main data source has been independent project evaluation reports of the projects. The same data set has also been used by Olsson [6] and Olsson & Samset [7]. These references provide additional information about each data set.

In addition, the paper has benefited from analyses of other data sets, which are listed below along with references for further information about each data set.

- Front-end assessments of 48 Norwegian governmental investments, related to transportation infrastructure, defence, public buildings and IT system implementation, [8] and [9].
- Two Norwegian hospital projects, [10], [11] and [12].
- Four Norwegian railway projects, [13].

While the proposed framework benefits from all information sources mentioned above, this paper also adds some new results from continued analysis of the first data set, the one which consist of 18 projects.

4. Analytical framework for flexibility in projects

This paper proposes a framework for analysis of project flexibility, shown in Figure 1. The framework for analysis consists of project flexibility categorisations, perspectives of analysis, flexibility drivers and enablers.

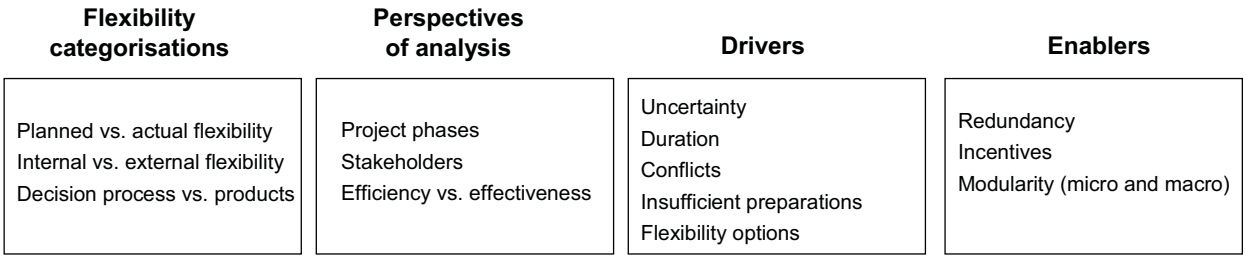

Figure 1. Framework for analysing project flexibility.

4.1 Flexibility categorisations

Four categorisations of project flexibility are; planned flexibility vs. actual flexibility approaches, internal flexibility vs. external flexibility, flexible decision process vs. flexible final products as well as modularity on macro and micro level.

Approaches to project flexibility has been analysed over time. In these studies, there was a need to make a distinction between planned and actual approaches to flexibility. Approaches to flexibility changed during the projects. Actual approaches turned out to be different from planned approaches.

Another distinction was also made between internal and external project flexibility. When flexibility is discussed in literature and in general, it is most often related to external flexibility, referring to adjustments of project scope. Project internal flexibility relates to flexibility within defined scope - how requirements shall be met. Particularly analyses of stakeholder approaches to flexibility are highly depending on whether internal or external flexibility is the subject of discussion. Internal and external flexibility are responses to contextual and internal uncertainty. However, internal flexibility is not limited to being a response to internal

uncertainty. External flexibility can be a response to contextual uncertainty, but all combinations of internal and external flexibility versus internal and contextual uncertainty can be found.

Project flexibility was divided into flexibility in the decision process and the product. Flexibility in the decision process is based on an approach where decisions and commitments in the projects are made sequentially over episodes. The use of decision gate models provides a successive commitment to a project, as shown by Eskerod & Östergren [14]. Flexibility in the product means that the design of the final product (what the project shall produce) has taken into consideration possible future changes in use or requirements.

4.2 Perspectives of analysis

Project flexibility is seen from the perspective of different stakeholders, in different project phases and related to efficiency and effectiveness.

The flexibility for one project stakeholder can be another's risk. According to McElroy & Mills [15], project stakeholders are persons or groups of people who have a vested interest in the success of a project and the environment within which the project operates. In a study of large engineering projects, Olander & Landin [16] found that it is important for a project management team to identify stakeholders that can affect a project, and then manage their differing demands throughout the project stages. Stakeholders may be organisations or individuals.

Project flexibility can be studied from both efficiency and effectiveness perspectives. A case in favour of flexibility emphasise the possibility to increase a project's effectiveness. Effectiveness is primarily addressed by external flexibility. Project scope is adjusted to utilise benefit opportunities. Regarding efficiency, such adjustment of project scope typically causes change costs. The net effect come form a balance between the values of benefit opportunities and incurred change cost.

4.3 Project flexibility drivers

In this context, drivers are factors that create needs or pressure on projects to be flexible. Uncertainty is the key driver for project flexibility, and arguable the only one. The other drivers mentioned below are in fact only highlights of selected types of uncertainty. In this paper uncertainty is defined as a gap between the amount of information needed to make a decision the amount of information available (based on Galbraith [17]). In order to manage this information gap, flexibility is primarily a way of reducing the amount of information needed. Other project management approaches may focus on increasing the available amount of information.

The longer duration a project has, the more likely it is that some pre-requisites are not longer valid. Long duration is likely to result in more or less suppressed need for scope changes. Both cost and demand estimates are more uncertain the longer the time perspective is. What is "long" duration is highly depending of the type of project. Experiences from previous projects of the same type provide indications of for how long prerequisites are likely to stay stable enough.

Flexible projects can contribute to conflict solutions. However, conflicts that arise during the preparation or execution of a project have also created a need for projects to be flexible, as a response to conflicts. Project flexibility can also be an issue of conflict. Stakeholders who benefit from the initial decisions are less likely to favour a continued flexible decision process. Flexible decision processes are likely to be valued by those who do not prefer an initial decision. In this way, availability of flexibility options and redundant resources can serve as an invitation to adjustments.

4.4 Project flexibility enablers

This paper refers to 'enablers' as factors that contribute to making it possible for projects to be flexible. Sager [18] presents redundancy as an enabler for flexibility. According to Landau [19], redundancy is created by repetition, duplication and overlap. Galbraith [17] points out that slack resources constitute an additional cost to an organisation. In a project perspective, redundancy can be applied for flexibility in both the product and decision process. Flexibility in the product may be achieved by over-specification of future functionality. A flexible decision process calls for redundant recourses and time to perform analyses of alternative project concepts. The rationality behind the use of redundancy is that this use of resources is cost effective compared to later major changes.

Incentives faced by stakeholders affect their approaches to project flexibility. Incentives for different project stakeholders are strongly related to the contracting structure of a project and other financial obligations. A common tool for achieving flexibility in projects in the use of option based contracts, which enables a continuous locking of the projects. Flexibility has a value for those that can benefit from adjustments, and it is a cost for those who have to adopt. The fewer restrictions on their part of the project, the better opportunities there are to any stakeholder to optimise the use of available resources.

Modularity is presented as an enabler for flexible project management. Modularity is related to the possibility to divide a project into more or less independent sub-units. On a micro level, design modularity is a tool for efficiency, because it may reduce negative effect of changes. Design modularity is a common approach to achieve flexibility [20], [21]. Thomke [21] claims that modularization in product development projects is primarily a tool to improve project efficiency. On a macro level, modularity can be an enabler for flexible decisions processes because decision makers can make the incremental commitments. An approach of minimal commitment at each decision stage is a part of the "anti-disaster methodology" proposed by Hall [22].

5. Applying the framework on selected aspects

The proposed framework can serve at least two purposes. First, it can work as a checklist for aspects that are to be included in an analysis of project flexibility. Such analyses may be carried out as a part of *ex-ante* project preparations, *ex-post* project evaluations or during projects. Second, the relation between different aspects in the framework can be analysed to gain an understanding of interaction between the aspects.

5.1. Modularity versus planned and actual flexibility in decision process

The relation between modularity and flexibility in the decision process has been analysed for 18 projects, as shown in Table 1 and Table 2.

		Planned flexibility in decision process		
		Low	Medium	High
Modularity	High	1	1	3
	Medium	5	0	0
	Low	7	1	0

Table 1. Modularity and planned flexibility. N=18

		Actual flexibility in the decision process		
		Low	Medium	High
Modularity	High	0	1	4
	Medium	0	2	3
	Low	2	3	3

Table 2. Modularity and actual flexibility. N=18

Table 1 indicates that a high modularity was related to a high planned flexibility in the decision process. Table 2 illustrates that highly modular projects frequently were related to a high actual flexibility in the decision process. A combination of high modularity and low actual flexibility in the decision process was not observed. Results support the suggestion that modularity can be an enabler for flexible decision processes. In this project sample, highly modular projects were likely to have highly flexible decision processes.

5.2. Flexibility in decision process vs. flexibility in product

Olsson and Samset [7] analysed flexibility in decision process and flexibility in product. Figure 2 is a graphical illustration of such an analysis. Each project is represented by two marks; grey for planned flexibility and black for actual flexibility. The two mars for each project are connected with an arrow to illustrate any shift in flexibility approach. The arrows pointing to the right illustrate a shift from low planned flexibility in decision process, to medium or high actual flexibility in decision process. This shift was observed for projects with all degrees of flexibility in the product (low, medium or high).

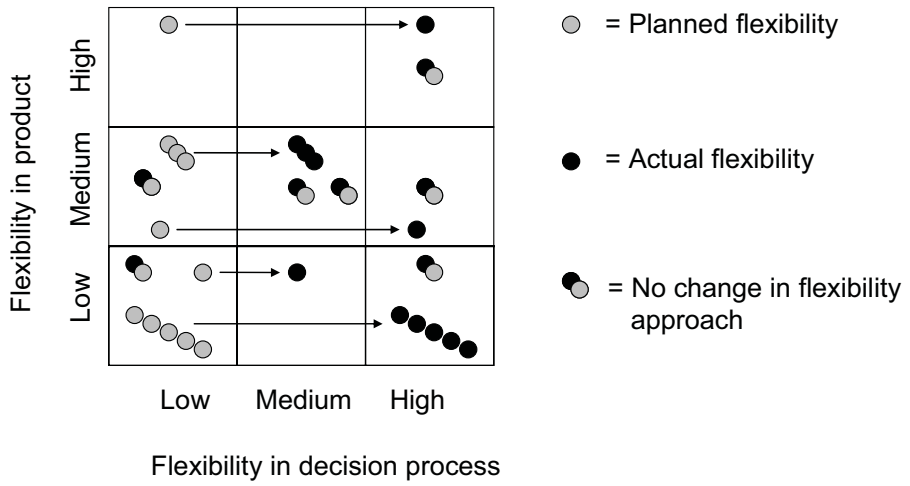

Figure 2. Flexibility in product versus planned and actual decision process.

The majority of the projects (16 out of 18) had medium or high actual flexibility in the decision processes. All three projects that were prepared for highly flexible decision process also experienced highly flexible decision process during the course of the projects. Seven projects did not have an observed shift in the flexibility approach (indicated in Figure 2 by a black and grey dot lying close to each other). Note that five of the seven projects had a medium or high planned flexibility in decision process. These projects where prepared for a flexible decision process. Of the 13 projects that had a low planned flexibility in the decision process, only two projects had also a low actual flexibility in decision process. None of the projects had lower actual than planned flexibility in the decision process.

Related to efficiency, Olsson and Samset [7] found that highly flexible decision processes resulted in more than 100% cost overrun, compared to the initial budgets, regardless of the flexibility in the product, Most projects were subject to changes, extensions and iterations (summarized as “flexibility in the decision process”).

6. Concluding discussion

A framework for understanding project flexibility has been presented. Based on the framework, the paper has discussed flexibility to selected aspects individually and in two-dimensional combinations. With larger samples, this type of analysis would benefit from regression analysis along the different aspects. In the following, the results presented in the previous section are briefly discussed and some implications for projects management practice are proposed.

6.1. Flexible decision processes – intended or safety valve?

In the beginning of this research, it was expected that the decision process related to the project can be fairly straight forward if flexibility in the product was high, because the result of the project was prepared for alternative use. Furthermore, it was assumed that a low flexibility in the product could be combined with high flexibility in the decision process because scope definitions could be postponed in order to gain as much knowledge as possible. These assumptions are only partially confirmed by the study.

Two explanations are proposed to this result:

1. If there are possibilities for flexible decision processes, they are highly likely to be utilised
2. Flexible decision processes can always be applied in response to unforeseen events

Regarding the first alternative explanation, possibilities for flexible decision processes may come from planned flexible decision processes. There are indications that flexible product designs also serve as enablers for flexible decision processes, not a substitute for.

The second alternative explanation means that even though it comes at a cost, and frequently at a high cost, plans can be changed. While the degree of flexibility in the product generally must be established at an early stage in a project, a flexible decision process may either be indented or ad hoc. Flexibility in the product is to a large extent an attribute that is designed into a delivery in the front-end of a project. On the other hand, a highly flexible decision process can be achieved even if it not prepared for. It may therefore work as a kind of "security valve" for unforeseen development. This is similar to Galbraith's [17] notion that if a firm fails to actively create other strategies to address uncertainty, a slack resources strategy will occur by default.

Even if Figure 2 indicates that projects are likely to apply both flexible product designs as well as flexible decision processes, the two dimensions of flexibility are of a different nature. This distinction can be valuable to have in mind when preparing a project.

6.2. Flexibility preparations

Several of the projects in Figure 2 experienced a shift from low to medium or high actual flexibility in the decision process. Projects frequently need to be more flexible than they have prepared for. This means that projects either cannot isolate themselves from contextual uncertainty in order to avoid iterations and changes, or have not mange to prepare for proper flexibility. As a response to uncertainty, projects can either isolate themselves in order to execute the defined task efficiently, or prepare the project to manage flexibility. A third, often unintended strategy occurs when projects plan for isolation, but cannot maintain the isolation. Projects are then forced to be more flexible than they have prepared for. Both of the first mentioned strategies have advantages and disadvantages. The research that this paper is based on indicates that this third strategy ("plan for isolation – experience forced flexibility") mainly is has disadvantages. The choices of flexibility strategy are to a large extent made during the front-end phase. This discussion points to both project flexibility and project front-end as key success factors for projects.

One indication from the analyses is that project flexibility requires a structure. In the referred studies, the potential drawbacks of flexible projects are substantial both on efficiency and effectiveness. It has also been shown that the drawbacks are the largest when projects did not prepare for flexibility. To avoid cost overruns, but also to obtain desirable benefit from a project, it is advised that flexible decisions are supported by a structural framework of strategies and guidelines. Such framework is preferably established in the front-end of projects. Related to the framework proposed in Figure 1, this means that the flexibility drivers shall be identified in order to judge the need, or likelihood, for flexibility.

The enablers proposed in Figure 1 are key elements in a structural framework for project flexibility. Figure 3 shows how one of these enablers; redundancy, can be seen in relation to either prepared for isolation and thus to avoid changes, or to prepare to manage changes. In Figure 3, '*precision*' is used to indicate low redundancy and '*slack*' to indicate high redundancy.

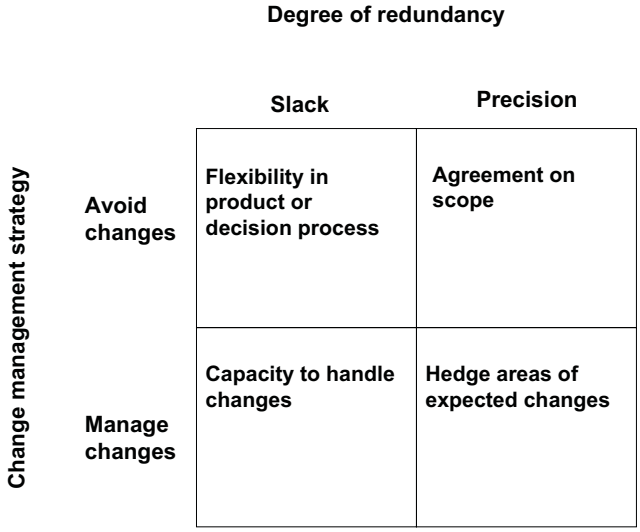

Figure 3. Flexibility strategies in relation to redundancy and change management.

Changes can be avoided by having slack resources in a project. Redundancy can be achieved by over-specification of future functionality, so that future needs may be met without physical changes. Such needs may emerge during the project execution, or after the project has been delivered. Redundancy can also enable front-end analyses of alternative project concepts, which require recourses and time but may avoid later changes.

Changes can also be avoided by precision in the project preparations, thus reducing the need for slack. Aiming at a clear agreement on scope represents a traditional project management approach – to zoom in on project scope and then execute. After establishing the scope, project management aims at minimising external flexibility.

Changes can be managed if there is slack in a project organisation. High redundancy indicates a general capacity to manage a wide range of changes. Such slack can include budget reserves, time slack in plans and organisation capacity to manage changes. On average, this increases project cost. However, it may still prove cost effective if the alternative is that the project will face changes which it does not have the resources to manage.

Finally, changes can be managed even with low redundancy, but it requires precision. In the process of locking specifications, certain parts are locked later than others. Low redundancy requires an ability to identify and hedge areas exposed to changes. The late locking items must therefore be well defined and of a limited relative size.

6.3. Flexibility options as flexibility drivers

In the framework proposed in Figure 1, flexibility options where listed as flexibility drivers. This is supported by the discussion above. Of the studied projects, projects with a high planned flexibility in the decision process also had a high actual flexibility in the decision process. Availability of flexibility options and redundant resources can serve as an invitation to adjustments. If there are possibilities for adjustments and iterations, it is likely that flexibility options will be utilised. This means that the presence (or knowledge) of flexibility enablers can work as a flexibility driver.

6.4. Front-end as a key phase

Flexible the front-end phases are the least controversial aspect of project flexibility. This is particularly related to external flexibility. Results presented in [7] indicates that minimizing external flexibility after the front-end phase increases the likelihood to deliver projects on time and budget and according to specifications. One objective of front-end management is to provide a well defined framework for efficient project implementation, including the identification of flexibility drivers, and appropriate introduction of flexibility enablers.

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