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NPRA's Cost Estimation Method Assessment

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Abstract:

NPRA is responsible for preparing cost estimates through the different public road project phases in Norway. To do that NPRA has decided to develop its own cost estimation method that is used in the conceptualization and planning phases. The current version of the handbook 217, which gives the guidelines of the method, has been in use since 2005. Nonetheless, a Norwegian University of Science and Technology's publication in 2012 shows, from a selected group of projects, that the estimates tend to escalate since the first estimate until project conclusion. The main objective of this master thesis is to assess the method and investigate possible causes for such cost development and what can be improved, so the future estimates fluctuate less. The approach used is to assess NPRA's practices and compare them with the practices of a guide published by the United States Government Accountability Office (GAO), which may be adopted by any organization, and is seen as best practices to estimate the cost of public investments.

The chapter 1 of this master thesis consists of an introduction of the paper, where some background information is given, and objective and research questions are defined. The chapter 2 consists of a description of some existing methodology approaches for executing an academic paper such as a master thesis. On the third and fourth chapter a literature research is built. The chapter 3 covers literature that is related with project and cost management, while the chapter 4 refers to specifications of public projects in Norway. On the fifth chapter a guide published by the U.S. government and the 12 steps that make part of it are reviewed. On the chapter 6 the NPRA's handbook for cost estimation is studied. Finally, the chapter 7 and 8 consists of discussion and conclusion of the master thesis, respectively.

The main conclusion of the paper is that NPRA's estimation method is an easy method to understand and to implement, and meets to a certain extent those that are considered best practices. However it presents some flaws with regard to the issue that was one of the concerns of this paper, the cost growth.

Keywords:

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|---------------------------|
| 1. Cost-estimation method |
| 2. Road project |
| 3. Cost growth |
| 4. Cost management |

PREFACE

This master thesis, consisting of 30 ECTS, is part of the International Master Programme in Project Management held by the Norwegian University of Science and Technology. The thesis is conducted on the spring of 2014, the 4th semester of the programme, and has supervision from Olav Torp, associate professor of the Department of Civil and Transport Engineering.

The topic of this thesis was raised by the findings from a report with the title “Costs and Budget development in Road Projects” which was done at the department mentioned above. This report gathers information regarding cost from a series of public projects that were built in Norway and analyses their cost development since the earliest estimation until project conclusion. The report shows that there is an excessive increase on the cost through all stages. That issue that this thesis intends to address by studying the Norwegian Public Road Administration's (NPRA) cost estimate methods.

SUMMARY

The Norwegian Public Road Administration (NPRA) is the governmental agency that is responsible for the road infrastructure of the country. They are the ones who may have the initiative to start a road project, when a need is found. In addition, all the processes of planning, constructing and operating public roads are taken or supervised and controlled by them.

The available amount of funds for investments in roads in Norway has been increasing over the last years. However, the reason for that is directly related with the introduction of road toll and with the money that comes from it. That happened after late 1980s when road tolling became largely adopted around the country. On the other hand, the funds from the national budget have been decreasing, especially in the last decade.

Before becoming a reality, a road in Norway usually emerges from a necessity that originates a project that shall start its life time with a conceptualization study. Such study analyses different opinions and solutions that can meet the need and after an external quality assurance may or not be part of the National Transport Plan. The project matures and when defining the Plan of Action main characteristics of the project are set. The project continues its development until a budget is create and proposed in the parliament. Another independent quality assurance should be part of all the documentation that is provided to the parliament in order to fundament their decision.

The mentioned external quality assurances are part of the quality assurance scheme that applies to every major public investment in Norway above 750 million Norwegian kroner. For projects bellow 750 million kroner, the first quality assurance (QA1) at the conceptualization evaluation study may be necessary or not. That should be the Ministry of Transport and Communication and the Ministry of Finance deciding. The second quality assurance gate (QA2) applies for all the projects.

In parallel to all this legal procedures there is also a project to develop and to manage. A project's attribute that is aim of analysis by the quality assurance scheme is the estimated cost of the project. As mentioned before, NPRA is responsible for preparing cost estimates through the different project phases. To do that NPRA has decided to develop its own cost estimation method that is used in the conceptualization and planning phases. The current version of the handbook 217, which gives the guidelines of the method, has been in use since 2005. Nonetheless, a Norwegian University of Science and Technology's publication in 2012 the shows, from a selected group of projects, that the estimates tend to escalate since the first

estimate until project conclusion. In this master thesis, the estimation method is investigated in order to assess the possible causes for such cost development and what can be improved, so the future estimates fluctuate less. The approach used is to assess NPRA's practices and compare them with the practices of a guide published by the United States Government Accountability Office (GAO), which may be adopted by any organization, and is seen as best practices to estimate the cost of public investments.

Even though NPRA's estimation method is not as extensive and detailed as GAO's guide, it is a simple and easily understandable method that incorporates most of the recommended best practices studied. Nonetheless some critics and recommendations that could make the method better are given.

TABLE OF CONTENTS

| | |
|---|-----|
| Preface | iii |
| Summary | iv |
| Table of Contents | vii |
| List of figures | ix |
| List of tables | ix |
| 1. Introduction | 1 |
| 1.1 Background | 1 |
| 1.2 Motivation | 4 |
| 1.3 Objective | 4 |
| 1.4 Research questions | 5 |
| 1.5 Scope of work | 6 |
| 1.6 Outline | 6 |
| 2. Methodology | 9 |
| 2.1 Literature review | 9 |
| 2.2 Theoretical approaches to research | 10 |
| 2.3 Qualitative data collection methods | 10 |
| 2.4 Research strategy | 11 |
| 3. Project Development in an Organizational Framework | 13 |
| 3.1 Program and Portfolio management | 13 |
| 3.2 Project Selection | 15 |
| 3.3 Project Life Cycle | 15 |
| 3.4 Project Management Processes | 19 |
| 3.5 Cost management | 21 |
| 4. Road Investments in Norway | 31 |
| 4.1 Project initiation process | 31 |
| 4.2 Quality Assurance scheme through project life cycle | 31 |
| 5. Best practices for cost-estimation | 35 |
| 5.1 U.S. cost guide | 36 |

| | | |
|-----|---|-------------------------------------|
| 5.2 | The GAO Cost Estimation Process | 36 |
| 6. | NPRA's (Statens Vegvesen) cost-estimation practices | 51 |
| 6.1 | The Handbook 217 | 51 |
| 6.2 | Cost-estimation method..... | 51 |
| 7. | Discussion..... | 67 |
| 7.1 | Road project development..... | 67 |
| 7.2 | Cost development | 70 |
| 7.3 | NPRA's versus GAO's cost estimation practices | 71 |
| 8. | Conclusion | 75 |
| 9. | References..... | Erro! Marcador não definido. |

LIST OF FIGURES

| | |
|--|----|
| Figure 1.1 – Available funds for road investments from 1973 to 2009 (in 2009 NOK) (Torp et al., 2012)..... | 2 |
| Figure 1.2 - Road planning through NPRA's management process (NPRA, 2014)..... | 3 |
| Figure 1.3 - Cost estimation development. Adjusted for inflation using CPI (Torp et al., 2012) | 4 |
| Figure 1.4 - Research questions aiming the objective..... | 6 |
| Figure 4.1 - Quality assurance scheme along the project (NTNU, 2014) | 32 |
| Figure 5.1 – Cost estimation process (GAO, 2009) | 37 |
| Figure 6.1 - Structure of a cost estimate according to the method (NPRA, 2011b)..... | 54 |
| Figure 6.2 - NPRA's acceptance criteria | 56 |
| Figure 6.3 - General workflow of the estimation process (NPRA, 2011b)..... | 58 |

LIST OF TABLES

| | |
|--|----|
| Table 3.1 – Cost estimating classification matrix (Sabol, 2008)..... | 28 |
| Table 6.1 - Correlation between quality assurance of Estimation Reports and the size of the project (NPRA, 2011a)..... | 57 |
| Table 6.2 - Estimation process work sequences (NPRA, 2011a)..... | 62 |
| Table 7.1 – Summary of a road project stages (FHWA, 2014)..... | 70 |

1. INTRODUCTION

1.1 BACKGROUND

As part of country development, the transport infrastructures have been getting significant attention from the European governments. Each country has its own strategy for their transport infrastructures, but the different politics and orientations of each government of each country, in different economic contexts, result on distinct budgets and different strategies to use money.

There are many different approaches, being some strategies very ambitious, where big amounts of money are allocated to the development of new transport infrastructures. Other policies benefit other areas and the transports may only get money for maintenance of the existing infrastructures. Nevertheless, just a portion of the budget for transports is normally allocated for the roads infrastructures, but in this case that is the part of interest.

Other sources may increase the availability of funds for both, maintenance and new road projects. Tolls were introduced in many roads and highways and have been widely used as a way to finance investments. Moreover, some governments have been making partnerships with private parties (PPPs) where financial, technical and operational risk of the projects may be shared.

To what concerns Norway, public-private partnerships (PPPs) have not been much used, and the political perspective is that the public sector should be the main responsible for the public road system (Bråthen and Odeck, 2009). On the other hand, toll financing has been introduced in Norway for more than 70 years ago, as a supplementary source for funding public roads. However, just after late 1980s tolling gained relevance as part of the total funding availability for road investments (Torp et al., 2012). In the figure 1.1, it is illustrated in blue, the part of the total public financing which comes from road tolling.

Today, tolling money constitute a significant part of the total funds. Tolls have also considerable importance to the increase of the total funds for road investment that has been noticed on the last years. On the other hand, it is visible (in red and yellow on the figure 1.1) that the funds from the National Budget have been decreasing in the last years. The figure shows values in 2009 Norwegian kroner (NOK).

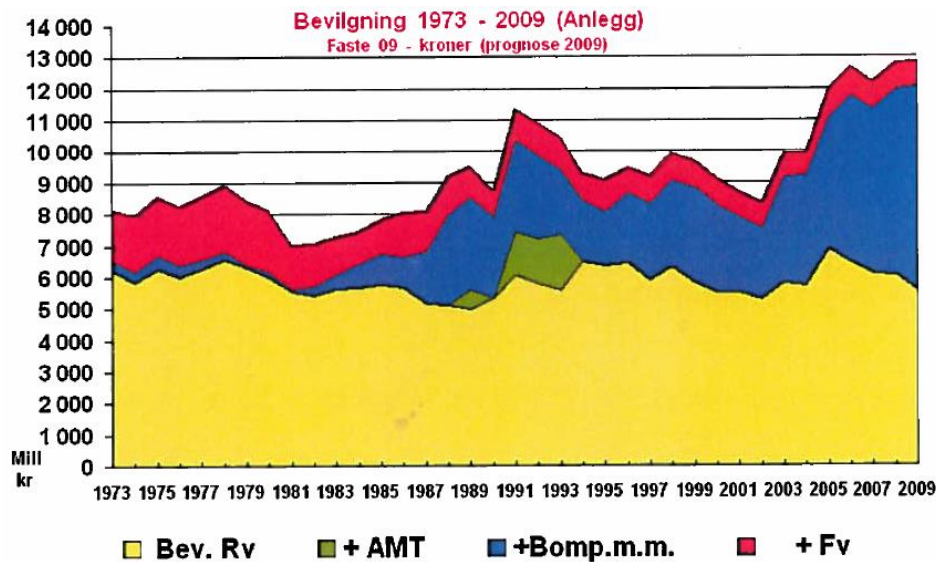


Figure 1.1 – Available funds for road investments from 1973 to 2009 (in 2009 NOK) (Torp et al., 2012)

Before funds being allocated to a road project, there is a procedure that must be followed, until approval is conceded at the parliament. The Norwegian Public Road Administration (NPRA), known in Norway as Statens Vegvesen, is the government agency which is responsible for the public roads in the country, having responsibilities to what concerns planning, construction and operation of the roads, among others. Is this public entity who makes the plans for the investments to be done around the country (NPRA, 2013). When a need is identified and a road project is considered, firstly a study for the concept must be done. The study can be executed by NPRA but it often happens that external consultants are asked to perform such studies, especially for big and complex projects. However the decision maker is always the NPRA. The conceptualization study is aim of an external quality assurance and therefore be the base for the authorities decision. The chosen concept may go forward, if approved, to form part of the National Transport Plan (NTP). In parallel, road planning takes place, the project evolves until an approximated cost for the project is proposed to the parliament. Throughout this process, there are three important milestones where an estimate for the project cost must be given. A first cost estimation must be present on the national transport plan, even though the accuracy at this stage is expected to vary within a great extent. When defining the Plan of Action (HP) a second estimation is performed, and this one is expected to be more close to the final budget but still with some uncertainty attached. Then, before the first allocation of funds could be done, a more detailed project cost-estimation is performed and presented to parliament for resolution to start-up and funding (Welde et al., 2013). The following figure summarizes the whole process.

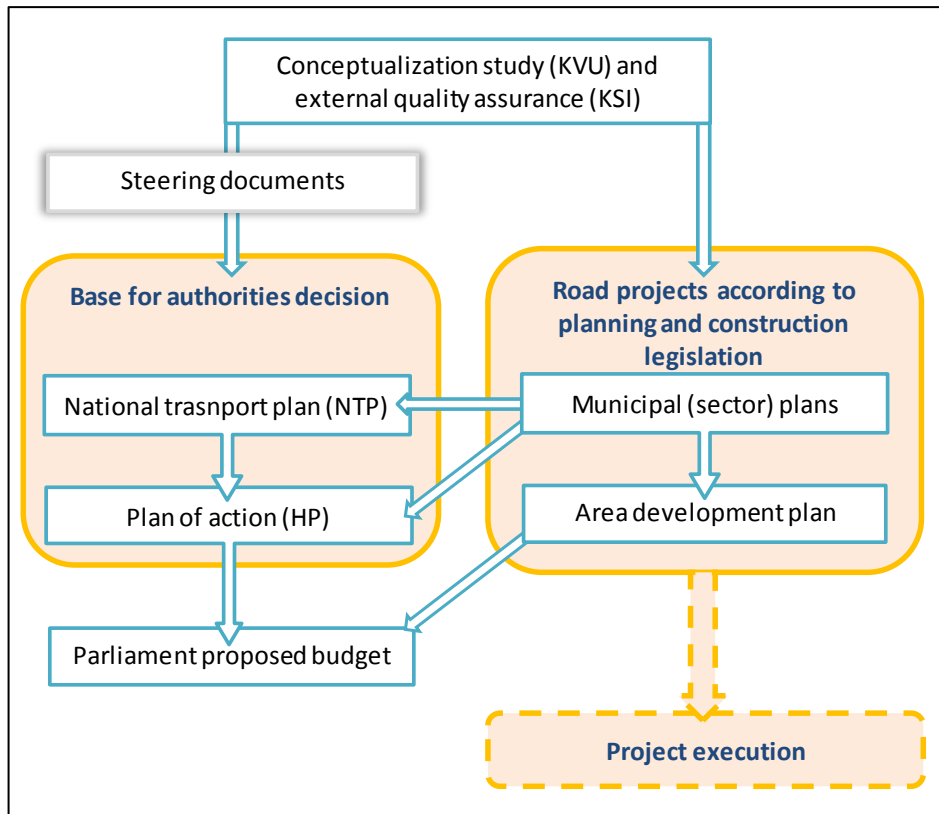


Figure 1.2 - Road planning through NPRA's management process (NPRA, 2014)

The National Transport Plan (NTP) is an official document elaborated with the contribution of the governmental transport agencies, where NPRA is included. This document is submitted to the Norwegian Parliament every four years and sets the Government's transport policy goals and strategies for the 10 upcoming years. (NPRA, 2014)

NPRA's plan of action (Handlingsprogram, HP) is the implementation plans of the NTP and has a validity of only 4 years. It sets the basis for the yearly budget elaboration. The main objective is to establish plans for investments on the national road network, oriented to meet the goals and strategies for the first four years of the NTP. It may also include major projects planned for the remaining six years of the plan. (NPRA, 2013)

In a report done at NTNU and prepared by Torp et al. (2012), a portfolio of road projects is analysed in order to understand the cost behaviour from the early phase of the project until project completion. The cost-estimations done throughout the mentioned phases, plus the project final cost, are assessed regarding their development. The results show that, in average, the cost-estimations escalate between every milestone. The graph from the figure 1.3 illustrates those results.

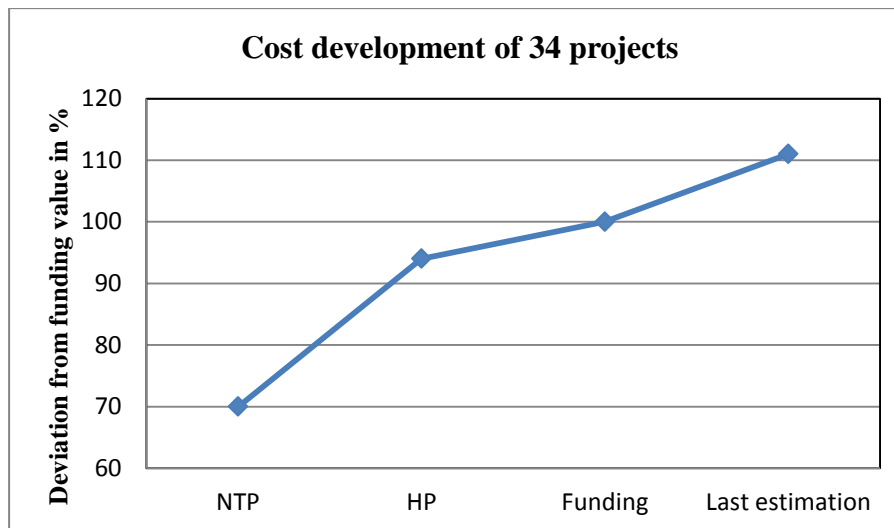


Figure 1.3 - Cost estimation development. Adjusted for inflation using CPI (Torp et al., 2012)

As stated before, it is expected that the earliest estimations result on significant deviations, due to the amount of uncertainty that must be managed at such early stage. However, the tendency for underestimation may not be only related to that. It is perceptible that there is a clear bias to too optimistic cost-estimations, even at the funding stage, when the level of detail is already quite developed, resulting in this case in cost-overrun.

To estimate the project cost, the NPRA makes use of its own guidelines that are published in a form of a handbook and can be found in their internet page. Those guidelines are used for the first three estimates that are performed before parliament's project approval and they shall also be assessed in this master thesis.

1.2 MOTIVATION

Cost estimation is a vital task for any organization's success. Wrong cost estimates may result on low control on the financial resources and on other consequences that can affect the organizations' sake. In the private sector the most probable consequences are economic losses or waste of potential profits. When talking about public organizations the consequences are not less severe. In this case bad cost estimating may lead to miss usage of tax payers' moneys and to wrong prioritization of projects due to a misleading base for decision caused by incorrect estimates. The cost development showed in the figure 1.3 proves that the cost estimates of the Norwegian road projects can be improved as well as the NPRA's method for estimating.

1.3 OBJECTIVE

The main objective of the present master thesis is to assess NPRA's methodology for estimate projects' cost. This includes perceiving the whole process and getting a grasp of how project

management tools are used and put together, by the mentioned organization, in order to form a standard methodology that is used at their all divisions throughout the country. Such assessment should enable perceiving method's limitation and potential for improvements. To support that, other methodologies seen as best practices for cost estimation are also studied.

In addition, other learning objectives were formed. Given that a cost estimate is performed and used in different phases and decision making milestone through of a project, the fundamentals of project management are to be analysed in order to get an overview of how such milestones fit in the project life time.

Get a good understanding of a cost estimation process within a construction project and be able to recognize good practices for estimating is also part of main expected learning outcomes. Research questions, which are formulated in the next topic, should, when answered, allow achieving the proposed goals.

1.4 RESEARCH QUESTIONS

If considering countries' area, Norway is a considerably big country and attached to that comes a big need for communications infrastructures, including roads. A road project is in almost every case a public investment in Norway. It may take few years since project idealization until the construction of the road starts. That may be explain because, in addition to normal planning and development, it also needs to be aim of parliamentary consideration for funding. Q1: Which are the legal and management procedures that precede the execution of a public road project in Norway?

As rule, NPRA follows a step-by-step procedure to perform the estimation of their projects. That process is described in the Handbook 217, which is a guideline for its own estimation method and must be used through all planning phases for investments above 5 million Norwegian kroner. Q2: Is NPRA's method for cost estimating up to today's best practices?

The early phase is the most critical phase of a project. Here decisions have to be made based on little information and a lot of uncertainty. For public road projects, at its conceptualization phase early estimations must be done and uncertainty must be assessed and considered in a way that its impact is diminished as much as possible. Q3: What are the bigger challenges for such assessment and how NPRA addresses this issue?

The public investments for road projects in Norway must follow a procedure where they are assessed throughout a series of milestones. Here has been noticed a significant increase of their cost estimates from milestone to milestone, resulting on big gaps between the estimate

done on the earliest phase and the final cost of the project. This may be directly related to the project uncertainty or estimation errors, but a noticeable bias to underestimation makes it unclear what are the reasons for such deviations. Q4: What can be the causes of such underestimation and consequent cost increase, and how NPRA's estimation method tackles the problem?

The defined research questions are the base of the work that follows. An approach that allows answering them should lead to the thesis objectives.

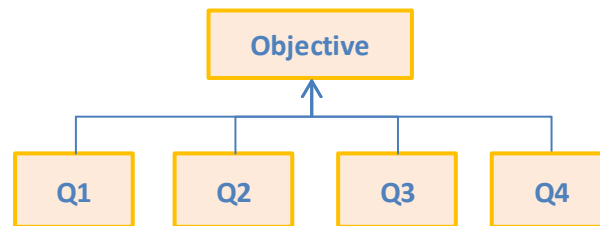


Figure 1.4 - Research questions aiming the objective

1.5 SCOPE OF WORK

This master thesis has its main focus on a methodology that is used in the process of estimating the cost of public project and executed by a public organization, NPRA always from the project's owner perspective. NPRA's method for cost estimation is therefore a specific method that may be compared with other methods use in the public sector. Methodologies for cost estimation used by contractor or other organizations in the private sector are disregarded. Such methodology is only used in the earlier stages of the project, still before all the design details are available, resulting that only preliminary estimates are possible targets.

1.6 OUTLINE

The chapter 1 of this master thesis consists of an introduction of the paper, where some background information is given, and objective and research questions are defined. Motivation, scope of work and some important definitions are part of the chapter as well.

The chapter 2 consist of a description of some existing methodology approaches for executing an academic paper such as a master thesis. The ones that are in used in this paper are further described and therefore explain how they are put in use.

On the third and fourth chapter a literature research is built. The chapter 3 covers literature that is related with project and cost management, while the chapter 4 refers to specifications of public projects in Norway, more specifically road projects.

On the fifth chapter a guide published by the U.S. government - that is considered to incorporate the best practices for cost estimation - and the 12 steps that make part of it are reviewed. On the chapter 6 the NPRA's handbook for cost estimation is studied and its main components are transcribed.

Finally, the chapter 7 and 8 consists of discussion and conclusion of the master thesis, respectively.

2. METHODOLOGY

This chapter intends to define the methodology used both for research and elaboration of the paper. In an initial phase, right after roughly defining the dissertation topic, the author delineated a strategy in order to build knowledge that could help to define a narrower research topic and the research problem to address. Moreover, this chapter shall address the different approaches used to assess information and analyse data that were considered in order to enable the author to follow a coherent methodology for data processing.

2.1 LITERATURE REVIEW

A literature review is a compilation of relevant available literature on a defined topic of research. A literature review is aimed to bring the reader up-to-date with current literature on the topic. The literature review starts with a research for relevant literature. Its content and richness depends on the quality of the information gathered. Diverse information from various sources is gathered in a flowing written text, where author's biases must not be included. (Cronin et al., 2008)

The performed literature review aims to provide comprehension on subjects that are important to acknowledge when executing the master thesis. This includes some project management fundamentals that intend perception of a project and its different phases and challenges.

Being the literature research scope defined, the first step is to decide upon the search keywords to use. The used terms such be cleverly chosen in order to generate relevant data and refine the search as much as possible. Wisely chosen keywords may result on a first filtration for relevant search results. If possible, the search may also be divided in categories.

Academic online search engines, libraries and institutional websites are often used for academic literature reviews, however there is a vast number of sources and databases from where a selection must be done, according to its scope and reliability.

During the search it is important to briefly evaluate the results regarding their relevance and if needed refine the search by changing or combining different search keywords. At this point, literature that is seen as appropriate is gathered. By reading the abstract and briefly looking through the source content it is possible to get the sense of what they are about and furthermore to determine those that may worth further assessment. (Cronin et al., 2008)

To conclude, a deeper evaluation must be done, in order to select the more relevant sources to be used when writing the literature review. Here, a more systematic and critical review of the sources content is done. In this screening process criteria such as reliability, objectivity,

accuracy and relevance of the sources are considered. Now the amount of sources should be smaller and contain enough information to build the literature review.

The body of the literature review consist of the gathered material in an organized and structured text and should fulfil its objective which is, as mentioned, to deliver a comprehensive and clarifying paper about the researched topic.

2.2 THEORETICAL APPROACHES TO RESEARCH

There are different approaches that are important to consider as a plan to conduct research. The research methods used for collection, analysis and interpretation of data along the elaboration of the thesis follow an approach, that depending on the nature of the problem and the strategy to tackle it may be a quantitative, qualitative and mixed methods approach.

The quantitative approach to research implies handling numerical data and is usually related to research based on quantitative data. It is an approach “for testing objective theories by examining the relationship among variables”. Such approach enables to generalize and replicate the findings, and makes it hard for bias opinions or alternative explanations (Creswell, 2014).

The qualitative approach is a process of research that relies on “emerging questions and procedures, data typically collected in the participant’s setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data” (Creswell, 2014). In contrary to quantitative, qualitative approach aims to understand non-numerical data in terms of the author perspective. Within a particular context, a qualitative approach tries to analyse and understand interpretations done to a specific topic.

The mixed methods approach combines both quantitative and qualitative data. Such approach may be beneficial for research works where the two types of data can be integrated. It may provide “a more complete understanding of a research problem than either approach alone”. (Creswell, 2014)

2.3 QUALITATIVE DATA COLLECTION METHODS

Data collection refers to gathering of data that is to be analysed, in this case with the purpose of elaborating a master thesis. However that should not be seen in such simple way. “Data collection must be tied to the research questions and epistemological perspective of the study” states Chism et al. (2008). There are three methods that are most commonly used for

collecting qualitative data; they are interviews, observation, and documents and materials. In the following each of the methods are briefly explained.

Interviews are a method that enables the researcher to collect data from specific participants about a specific topic. The data collected is reflected mainly on the participants' views on the topic. That allows the researcher to learn with the participants' experience, perceptions and feelings regarding the topic being studied. An interview does not reflect an authentic recreation of those experiences, they are rather filtered through the interviewees perceptions and personal views. Observations, in contrast to interviews, provide a view of a particular setting without being filtered by those who are being observed. (Chism et al., 2008)

Documents and materials may be as well a highly informative source to some studies. Documents consist of a variety of print sources, while materials may comprise things such as photographs, visual art, instruments or others products that may help to tell a story. Certain documents "can provide historical information that tells about how certain issues were perceive or dealt with in the past" (Chism et al., 2008).

2.4 RESEARCH STRATEGY

The main subjects of research of this master thesis are cost-estimation methods and practices used within public investment. NPRA's method, for instance, is described through guidelines given on the handbook 217, which is an official document that can be downloaded from the NPRA's website. With the objective of assessing the method, the document is studied so an evaluation can be done regarding its situation towards best practices for cost-estimation.

The task comprises understanding the cost-estimation method used by NPRA within the procedures and approving milestones and quality assurance gates for public projects in Norway. Differences between cost-estimation in the different project phases are considered and compared with other practices within a similar scope. The main sources for data collection are documents in the form of print sources. The assessment is done based on a critical examination of papers. The documentation used is mostly government guidelines, complemented with technical biography within the topic. Such documents provide much information about the studied subject with detailed description of processes and methodology, providing in addition a strong theoretical background of all the technical information that is given. Moreover, some documents are complemented by examples or case studies that allow further understanding. For this reason and also due to the time short available time, other possible sources for data collection were therefore not considered.

Interviews could, however have provided information to what concerns the consideration and applicability of the method in practice on NPRA's projects.

The planning and research strategy of the paper is built mainly on a qualitative approach. Such decision is not facultative and it is rather dependent on the type of data to analyse. The methodology used to assess the mentioned cost-estimation practices relies, basically on non-numerical data. The considered information is based on text resulted from human experience and the author role is to understand how the studied cost-estimation method is put in practice, in comparison to other methodology used in the same context of estimating the cost of public investments.

Due to the type of data utilized for the accomplishment of this paper, other approaches also introduced before are automatically discarded. The quantitative approach it is a method that would not fit such type of research. Moreover, it automatically eliminates the possibility of adopting the mixed methods approach, whereas such approach is a combination of two methods, based in numerical and non-numerical data.

3. PROJECT DEVELOPMENT IN AN ORGANIZATIONAL FRAMEWORK

This chapter aims to analyse a project development from the project management perspective. This includes a review to the different possibilities for using project management as a tool to improve organization's performance and how it fits on an organizational framework.

A project is a group of temporary actions that are taken by an organization to meet an established goal. That goal is to create something that may be for example a service, an event, a video game or a road. Even though it is temporary, a project can last for years. A road project is a good example of that, since the project do not finish when the road is open to traffic. There is still maintenance and/or commissioning throughout the life of the road. Although it is not common, a road may also go through a decommissioning or termination process if it is seen as not having more utility. On the other hand, short-term projects such as organizing a field trip may last only for days.

A project may be run by a single organization or involve different organizations that work in partnership (Samset, 2010). On road projects, joint ventures are commonly established on the execution phase, where two or more contractors join resources to carry out the project.

Each project is unique and in an organization is it common to run several projects at the same time. Project management is seen today as an indispensable practice to run such projects towards project success within time, cost and quality. In a broader picture, projects portfolio and program management may also influence project's performance.

Project management is about the application of knowledge, skills, tools and techniques to meet the project purpose and requirements (PMI, 2008).

3.1 PROGRAM AND PORTFOLIO MANAGEMENT

An organization with a mature project management culture may handle several projects at the same time. Depending on the size and resources of the organization, the number of projects may vary. There are strategic ways to organize projects that can optimize organization's resources and improve its project management performance.

Depending on the links between projects they may be organized in programs. These programs and other independent project may also form, in a superior hierarchy, another group of projects called a portfolio. This process, that is often called organizational planning, results from the relationships between projects, however the type of relationship is important to decide whether the project fits in a certain program or portfolio of projects. Such organization can help defining priorities for financing and supporting projects on the basis "of risk

categories, specific lines of business, or general types of projects, such as infrastructure and internal process improvement.” (PMI, 2008)

In this context, a program consists on a “group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually”. Projects with a common delivery are selected and managed by a program manager from a broader scope, with the purpose of meeting the program’s strategic objectives (PMI, 2008). The design of an electronic toll charging system and the placement of traffic signs that are going to be used in the new built highways (projects) are possible examples of what can be a program of projects. If the relation between projects is for instance a shared contractor so the projects may be considered for a portfolio of projects rather than a program.

The program manager has the task of monitoring the projects regarding “time, cost, quality, risks and issues, and interdependencies with other related projects, and delegate responsibility for the successful completion of individual projects to project managers.” (APM, 2006)

A portfolio comprises a set of programs or independent projects that are aligned in a way that facilitates analysis and collaboration between projects, with the goal of achieve the organization’s strategic objectives. (PMI, 2008)

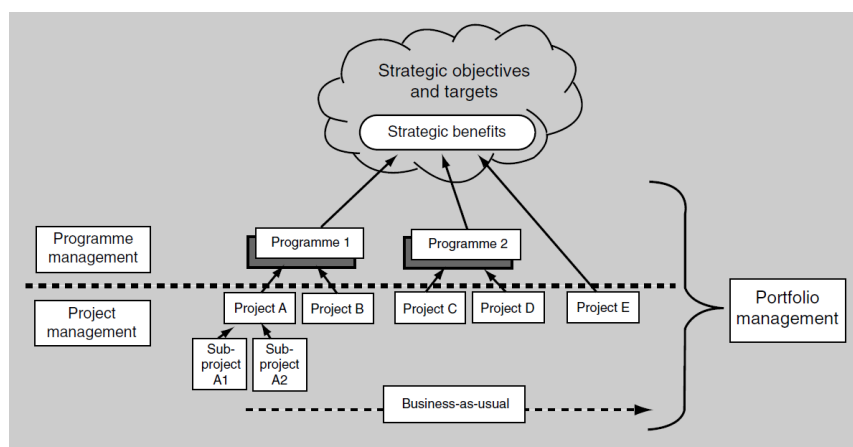


Figure 3.1 - Portfolio management (APM, 2006)

When resource availability is fixed, its allocation amongst projects and programs must be done respecting a priority list that is defined by the portfolio manager, allowing the more important projects to access the needed resources to succeed. By focusing on the project portfolio rather than an individual projects, issues such as poor coordination and erroneous choices may be avoided. Project portfolio management provides tools that help determining which projects to accept, prioritize, postpone, reject and kill. (APM, 2006) The figure 3.1 shows the relation between project, program and portfolio management.

3.2 PROJECT SELECTION

Due to strategic reasons and resource limitations, both human and financial, organizations must decide upon the project they are willing to undertake. When considering the existent opportunities, it is important to set choice criteria that lead organizations towards the most viable projects. Frequent bad decisions at this point may result on significant financial squander (Pinto, 2010).

For private organizations, those criteria are usually related with the capability to perform the project, the cost and duration, risk and potential return of the project. However, for a public organization profitability is not always a criterion of evaluation, which is the case of the investments for public road projects. Although decision making is done on other bases it still has to be substantiated.

A widely used method to aid decision making for infrastructure investment in the public sector is the cost-benefit analysis. Cost-benefit analysis allows taking into account the benefits to the society that a project might create when evaluating a project. The cost-benefit analysis monetizes the benefits of a project “on a socially accepted valuation system that transforms the inputs into monetary value”. This allows a comparison between the net costs and the net benefits of a project, and therefore evaluate the justifiability of a project or compare it with other alternatives. The analysis must result on at least two options, i.e. do or not to do the project (Jones et al., 2014).

Nevertheless, there are other evaluation techniques that may help the decision makers when deciding on which of project to assume. Techniques as for instance: inter alia, multicriteria analysis, cost-effectiveness analysis, regional economic impact studies and environmental impact assessment (Brucker et al., 2011) may also be applied to evaluate the feasibility of a project. In some cases, more than one technique may be used. Some of them can complement each other, but can also be used to provide more evaluation results and more information to base a decision.

3.3 PROJECT LIFE CYCLE

When narrowing to a less broad framework and focusing on the management of a project, there are some project characteristics that are important to acknowledge in order to situate in the project context, subjects that are to be addressed along this paper. The project life cycle is one of them. The project life cycle consists on the phases to which a project goes through since its beginning until its end. Those phases are not always perceived in the same way, but

generally a project follows a sequence of stages that starts with its conceptualization, evolving to a definition stage before starting its implementation. Finally the project is handed over and closed. Some authors also include the operational phase and termination of the project as part of the project life cycle, while others consider them as part of an extended life cycle.

Samset (2010) in a simplified way, defines only three main phases for a project life cycle, namely: front-end phase, implementation phase and operational phase. The front-end phase starts with the initial idea that may fulfil an existent need. In this phase concepts are conceived and when funds for the project are granted starts the implementation phase. In the implementation phase detailed planning is done and the execution of the project itself is performed. The operational phase is defined as the period of utilization until the project is no longer need.

A different perspective has Pinto (2010). A simplified model for the project life cycle, with four distinct phases is considered, namely: conceptualization, planning, execution and termination. The model does not include an operational phase, and considers that the project finishes when transferred to the costumer, i.e. the termination phase, right after project execution.

Nicholas and Steyn (2008) present a four-phase model, which is constituted by conception phase (A), definition phase (B), execution phase (C) and operation phase (D), and to what it is called the systems development cycle. Following authors' opinion, the project life cycle incorporate only the three first phases. Moreover, it is stated that these three phases overlap with the three first phases of the systems development cycle but once the execution phase ends, upon implementation of the system, so does the project too. The main concept is shown on the following figure.

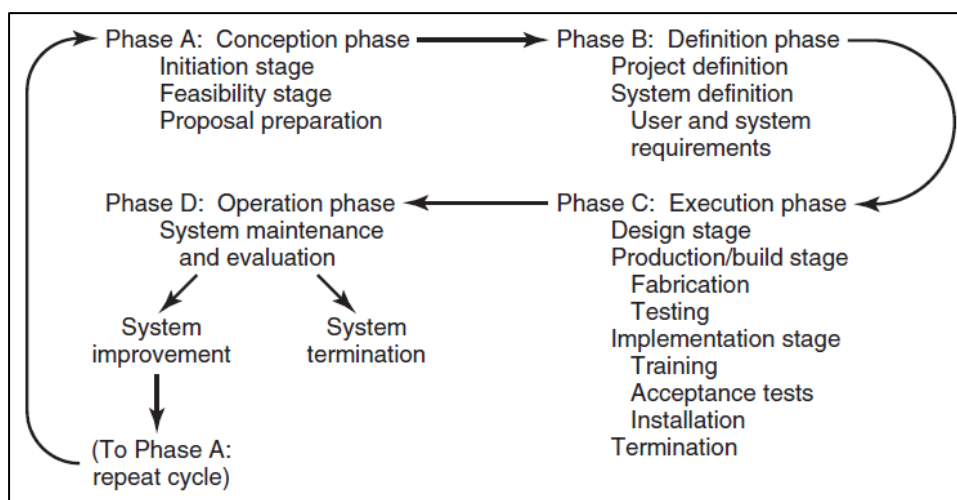


Figure 3.2 - System development cycle and project conception (Nicholas and Steyn, 2008)

A different approach shows the figure 3.3. It shows the phases of a project life cycle as it is perceived by the APM's book. Six main phases are seen as the phases of a called extended life cycle, which has two additional phases in comparison to the project life cycle. Those two last phases are seen as being part of the cycle only in specific circumstances. However, for road projects the operational phase is an important phase so it may be wise to consider such phase in the life cycle, but that will always depend on the approach used by the project team.

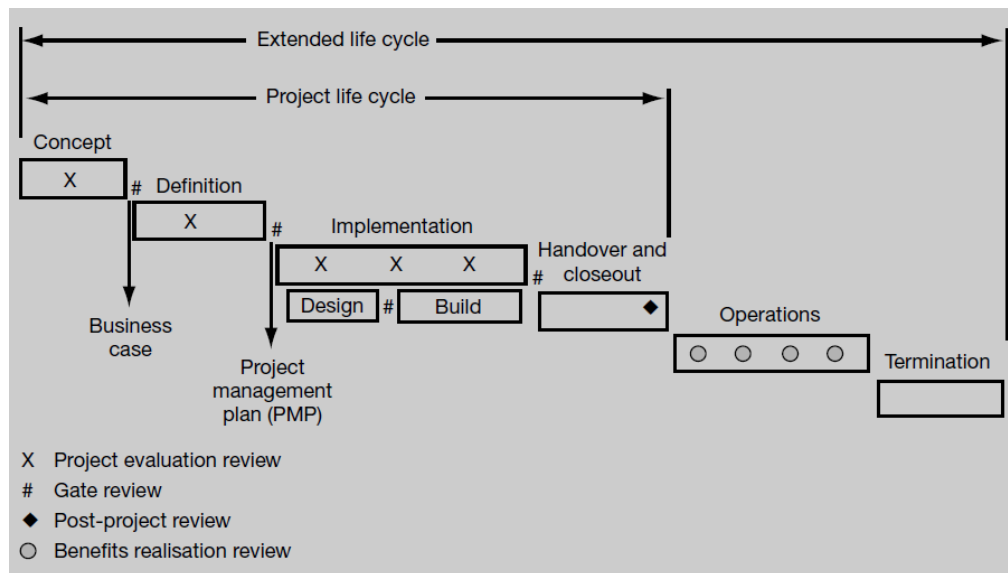


Figure 3.3 - Project life cycle (APM, 2006)

On the other hand, there are other sources that defend a much flexible approach for the project life cycle, not attributing any restrictive phases that a project should follow. PMI (2008), for example defines the project life cycle as “ a collection of generally sequential and sometimes overlapping project phases whose name and number are determined by the management and control needs of the organization or organizations involved in the project, the nature of the project itself, and its area of application”. It is added that it is the size, complexity, and potential impact of the project that will determine the number of phases, the need for phases and the degree of control applied.

Nonetheless, the majority of the sources rather interpret the project live cycle in phases, therefore some of the mentioned phases are, in the following described.

Conceptualization phase

The first phase of a project life cycle is the concept phase. Here the existing need, problem or opportunity is defined as a base for a feasibility study. The feasibility study shall identify possible solutions from where a preferred one shall be chosen. At this point, the alternatives resulting from the study should include technical specifications (Pinto, 2010). Even though

not so detailed, the specifications must clarify which kind of project is it, what is its goal and quantify the needed resources. In addition, the feasibility study must always consider the option of doing nothing.

Stakeholder identification and analysis is done in parallel with the feasibility study. Those who are going to be affected by a project must be considered since this stage. Stakeholders have expectations and in some cases potential to influence the project, so they cannot be disregarded at this stage where important decisions are taken (APM, 2006).

The financial aspect must also be considered as part of the feasibility study. Different methods such as net present value (NPV) and internal rate of return (IRR) are often used for profitability analysis of a project (APM, 2006). This appraisal is done based on rough cost estimations that are usually done by using costs from similar projects performed previously. To conclude, it is produced a business case where benefits, costs and risks of an alternative are stated. It should provide justification for undertaking the project and enough information for decision-making. If supported, resources are made available and the project continues to the definition phase. (APM, 2006)

Definition phase

In the definition phase the chosen solution on the conceptualization phase is aim of further work. The design is defined and detailed planning is done. These two components must allow producing estimates still within high tolerance levels.

At this stage, project specifications, schedules, work packages and processes for project construction are delineated. The level of detail is higher, since the executed elements are the based for project approval. Moreover, all the planning is to be the base for the next stage (implementation), and hence its importance regarding an increase of the detail. Plans such as risk management plan, health and safety plan and others are also included in this stage.(APM, 2006)

If approval is granted from owner and stakeholders who may have power to participate on that decision, the project may processed to the implementation phase.

As mentioned, this stage involves already a high level of complex decisions under a still large number of uncertainties and risks. This makes this stage susceptible to mistakes and outcomes not oriented to the project goal or organization strategy. Nevertheless, at this stage, big commitments have not been done and the costs of change or abandon the project are still not significant. (APM, 2006)

Implementation phase

The third phase on the project life cycle, the implementation phase, can be divided in to two stages, namely design and build. In the design stage, the design and engineering for all the disciplines of the project is completed (APM, 2006). This involves making ready drawings, specifications, materials and quantities at a level of detail that enables invite or start a bidding process for contractor selection. When the design is approved by the owner, project cost and duration is defined and contracts agreed. Hereupon the build stage can start.

In the build stage is where the actual 'work' of the project is done. Most part of the projects resources are used at this point, therefore is where project control actions are more frequent in order to ensure that project goes according to plan and the proposed scope, time, cost and quality objectives are achieved.(APM, 2006)

Handover and closeout

When the project is executed, and before entering the operational phase the project must be tested in order to ensure that the project deliverables meet the agreed acceptance criteria. If so, the project is ready to be transferred to the owner. When officially done, the owner takes the responsibility for the project. When handing the project, the contractor makes available documentation that may include "as-built" drawings, guarantees and warranties. (APM, 2006)

Operation

The operational phase is the phase that follows when the projects outputs are realized (Samset, 2010). The operational phase is very dependent to the type of deliverable of the project and to its need for maintenance and operation. In the operational phase contractors may or not remain involved. This phase is when the project becomes available to the users. In the case of a road, this would mean to keep the road within the needed quality in order to achieve the intended effects of the road on the society. Generally, that can be assured through two different ways: an agreement to maintain/repair the system or a new project to enhance that same system (Nicholas and Steyn, 2008). Once the project no longer fulfils its goal and is seen as no longer needed the project may be terminated.

3.4 PROJECT MANAGEMENT PROCESSES

A process in this context refers to the actions and activities performed in a project in order to achieve the aimed result. A process consists on the tools and techniques that a project management team decides to apply throughout a project or a project stage. Five processes are usually identified on project management literature as initiation, planning, execution, control

and closeout processes. They may take place on each of the project life cycle stages and they aim to provide guide line and criteria on how to treat project inputs and achieve the proposed project and project stage outputs (PMI, 2008).

The level of activity of the overlapping processes is shown on the following figure. The processes in the illustration from Samset (2010) match the processes that are suggested in other project management literature, as for instance the book from PMI (2008) which is therefore seen.

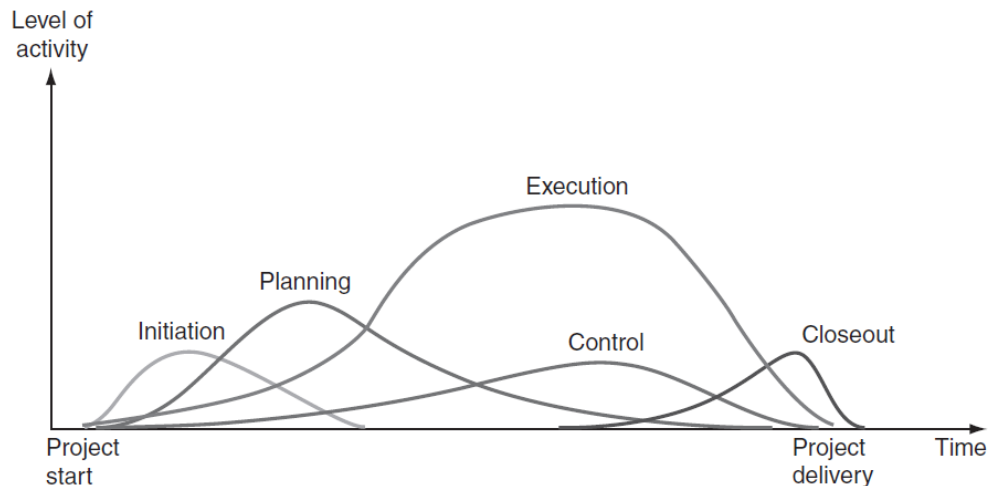


Figure 3.4 - Project management processes level of activity (Samset, 2010)

In order to keep the project goals aligned PMI (2008) defines a group of processes which allow coordination through all projects stages.

According to PMI (2008) these process groups are as follow:

- Initiation process group. Those processes performed to define a new project or a new phase of an existing project by obtaining authorization to start the project or phase.
- Planning process group. Those processes required to establish the scope of the project, refine the objectives, and define the course of action required to attain the objectives that the project was undertaken to achieve.
- Executing process group. Those processes performed to complete the work defined in the project management plan to satisfy the project specifications.
- Monitoring and controlling process group. Those processes required to track, review, and regulate the progress and performance of the project; identify and areas in which changes to the plan are required; and initiate the corresponding changes.
- Closing process group. Those processes performed to finalize all activities across all process groups to formally close the project or phase.

This process groups should not be confused with the project phases mentioned in the previous topic. The project stages may be seen as a sequence of sub-projects where overlapping processes are repeated. Although repeated, the processes are not exactly similar. On the more mature phases of the project the processes narrow the scope and while the information increases and the uncertainty decreases, the project stages demand for more accurate and precise outcomes, and so different tools and techniques are used on the corresponding process of each project life cycle stage (PMI, 2008).

3.5 COST MANAGEMENT

Cost management of a project involves all the processes that are related with estimating the cost of each activity to be performed in order to complete the project, the creation of a project budget and finally controlling costs and updating and managing possible changes on the project budget. These processes may occur several times during the project, one on each project phase for example. In less demanded projects they may occur only once and integrated in a way that they may be perceived as only one process. (PMI, 2008)

Project management teams, on a planning measure, may define the cost management processes by selecting which tools and techniques are to be used through the project life cycle. As part of the plan, criteria for planning, structuring, estimation, budgeting and controlling project costs should be established as well. The plan may, for instance, define levels of accuracy, units of measure, rules of performance measurement and report formats. (PMI, 2008)

3.5.1 COST-ESTIMATION PROCESS

The process of developing a project cost estimate it is a long process that goes through different phases of maturation, where different approaches and methodologies may be used. It is, in other words, closely tied to the project's life cycle phases. The whole process consists of several cost estimates that continuously evolve regarding its maturation and information that contains and to what it is built upon. (Nicholas and Steyn, 2008).

PMI (2008) defines cost-estimation as “the process of developing an approximation of the monetary resources needed to complete project activities”. It is the process of creating an estimated value at a certain point of the project. The cost estimation process is dynamic and tends to be closer to the real project value as long as the project matures.

An estimate may be defined as “a realistic assessment based upon known facts about the work, required resources, constraints, and the environmental, derived from estimating

methods” (Nicholas and Steyn, 2008). The value of an estimate should not be seen as the value of a project. Depending of the project stage, the cost estimate can be more or less accurate and used for different purposes, as for instance consider project feasibility or create bid values for a project or work packages. A cost-estimate is aim of constant update and refining during the course of the project in order to reflect recent information that is constantly made available. It should include all the costs related to the project, not only resources, materials, equipment, services and facilities but also other obligations such as financing, inflation or contingency costs. (PMI, 2008)

3.5.2 COST-ESTIMATION INPUTS

The inputs are basically the information and limitations that should be considered when producing a cost-estimate. They may vary according to the type of business, project and organization and on which stage of the project the estimate is being developed. The level of definition and maturity of the information that constitutes the inputs is however, what will have the greatest influence on the estimation outcome. Some of the inputs may originate from the project processes and may be controlled by the project management team, while others are introduced by external factors in the project context but away from project management team control.

Six major types of information inputs are defined by PMI (2008), namely:

- Scope baseline;
- Project schedule;
- Human resource plan;
- Risk register;
- Enterprise environmental factors;
- Organization process assets;

The scope baseline is in other words the description of the project, what it is about and what are its boundaries and limitations. A statement of the scope should provide all this information, describing “the product description, acceptance criteria, key deliverables, project boundaries, assumptions, and constraints about the project”. It should also define which costs will be part of the estimate, this is which indirect costs must be accounted or not by the project. Other constraints such as project budget limitation, delivery dates, available resources and organizational policies are other inputs introduced by the scope limitations of the project. The project work breakdown structure provide information regarding project deliverables that are as well defined regarding description of the type of work to be performed for each of

them. Contractual requirements and legal implication may also be part of the project scope baseline. (PMI, 2008)

The project schedule has major influence on the project cost. The project schedule defines the quantity and quality of resources, and the amount of time they are needed during the project. In addition, information regarding duration of the activities that constitute the project deliverables, and the materials associated to them are quantified. The estimation done for the duration of the activities may affect the cost estimation, so that is usually done in close coordination in the cost estimator. The human resource plan is related to project staffing, salaries, bonus and other expenses with personnel. (PMI, 2008)

After project risk being duly analysed, its outcome, the risk register, is considered during cost-estimation in order to contemplate costs with risk mitigation actions. Risk analysis identifies opportunities or threats that may influence some activities of the project. (PMI, 2008)

The enterprise environmental factors are related to the market conditions that the organization is involved. The contracts or agreements made with suppliers will define the terms and conditions do purchase something, and what are the possible additional costs associated.

The process of estimating costs must respect the internal organizational process assets. They may be, among others, cost estimating policies and cost estimating templates, historical information, and lessons learned. (PMI, 2008)

3.5.3 METHODS FOR COST ESTIMATION

One project, through its life cycle may be aim of several cost estimations that are most likely done by using different methods, depending on the project stage where the estimation is being performed. There are different methods and approaches to accomplish a cost estimate and the project management team must decide which one would fit better the estimate purpose. PMI (2008) points out tools and techniques to estimate costs, which are seen in the following.

Expert Judgment

Experienced and trained experts who hold historical information regarding earlier similar projects contribute with their judgment in order to achieve meaningful estimates. In addition, their knowledge may help deciding which methods or combination of methods would offer a better estimation process and outcome. (PMI, 2008)

Analogous Estimating

Analogous estimating is a technique that uses as a base for estimate a cost, costs of previous projects that have close similarities with the one being estimated. The same can be done on a narrower scope in order to estimate costs of a parameter or an element of a project. Besides the cost, on the same bases, duration for activities may be estimated as well. Such technique is often used on the early stages of the project, when information is still scarce and little detailed. It is a little expensive and little time consuming technique when compared with other techniques, but it is in the same time less accurate. The closer the projects are regarding similarities the more accurate the analogous estimate will be. (PMI, 2008)

Bottom-up Estimating

Bottom-up estimating is a method of estimating individual schedule activities or components of work. This type of process allows producing estimates for a particular component of work in a more refined and detailed level. Aggregating the estimates for the smaller components, results on estimates for complete tasks. They may be therefore added together to build a total estimation for the project. The accuracy of the estimate is connected to the accuracy of the estimates done at the lower level packages, which are in turn influenced by their size and complexity. (PMI, 2008)

Three-Point Estimates

Three-point estimates allow considering uncertainty and risk to an activity by estimating three costs, a most likely, an optimistic and a pessimistic cost that represent the range of uncertainty of how much the activity might cost. A PERT analysis enables calculating an expected cost that results from a weighted average of the three estimated costs, providing in many cases more accuracy results. (PMI, 2008)

Project Management Estimating Software

Cost estimation software that can aid project managers have become more and more common tools to create estimate. Software application such as computerized spreadsheets, simulation and statistical tools are examples of tools that have eased the cost-estimation process (PMI, 2008). These tools can fast the process, reduce the amount of repetitive task and therefore reduce human error.

Vendor Bid Analysis

The vendor bid analysis method refers to the creation of an estimate by examining and putting together prices of individual deliverables that are given by vendors or sub-contractors. It may

be based on responsive bids as well. When the project team has a cost for all the deliverables a final project cost may be estimated.

3.5.4 COST-ESTIMATION OUTPUTS

The outputs are the results of the cost-estimation process. It is the created material that shows the estimated project cost, explains and fundamentals the result. Activity cost estimates, basis of estimates, and project document updates are three cost-estimation outputs defined by PMI (2008).

Activity cost estimates are the predicted costs of each activity that constitute the project. Here, direct and indirect costs must be estimated, in order to consider all type of resources that involve costs related to the project which is aim of estimation. Direct costs may include labour, materials, equipment, services, facilities, information technology, and special categories such as inflation allowance or a cost contingency reserve (PMI, 2008), and if indirect costs are taken into account on the project estimate, they may be part of the estimate at the activity level or at higher levels (PMI, 2008), depending on the used approach for the estimation.

The basis of the estimate corresponds to the additional details that support the cost estimate. As supporting documentation, it should provide clear information that allows complete understanding on how the process leads to a specific cost estimate. (PMI, 2008) The level of detail may change by application area but it may be consisted by:

- Documentation of the basis of the estimate that explains how it was developed,
- Documentation of all assumptions made,
- Documentation of any know constraints,
- Indication of the range of the cost estimate,
- Indication of the confidence level of the final estimate.

The project document updates are related to estimates that are performed outside the main estimate and that have to be included to the main document, so it remains updated. Their execution should rely on the same basis as the main estimation and include similar documentation.

3.5.5 COST-ESTIMATES MATURATION

Throughout the project's life cycle, cost estimates are prepared in many different stages. The estimates are approximated predictions to what the project may cost, and may be more or less realistic depending on the level of definition of the work and the extent of risk and uncertainty

(Smith, 2008). While the project develops it is to expect that the same happens to the estimates, and that as long as the project approximates termination the estimate becomes more and more accurate (Table 4.1). That is directly related to the increase of information available and reduction of the uncertainty.

The project uncertainty is usually defined as “a lack of relevant information for valid decision making” (Samset, 2010) and is greater at the earliest project phase (Figure 3.5), therefore it is understandable that estimates at this phase are quite uncertain. At this stage efforts should be done in order to obtain all the available relevant information, and so reduce project uncertainty and possibly increase accuracy of the estimates. As the project approximates the final decision more information is available. Studies allow defining design and planning works, reducing project uncertainty and consequently decreasing cost estimates uncertainty.

There are several methods that allow analysis the uncertainty in the cost estimation. The selection of the appropriate technique depends on the type of uncertainty and the available data. To calculate the uncertainty of parametric or analog-based cost models and when statistical information about previous similar costs is available, the statistical analysis methods are the most appropriate. When such kind of information is not available, the cost estimator may express his “global feeling” regarding the uncertainty of a cost item, by estimating a probability value of occurrence and add it to item's potential cost (Bellos et al., 2004).

It is in the front-end phase that the possibility to influence the project is greater. As the number of decisions increase such possibility reduces gradually, therefore it is important to map uncertainty as soon as possible, so that information can be used in project favour, reducing negative consequences of uncertainty and avoid late changes during project execution that may have great costs. Nevertheless, there is consensus that the front-end phase of the project is when the most important decisions are made (Samset, 2010). So, regardless the project phase, the aim must be to predict the most likely cost of the project, however it is wise to recognize that the range of possible costs may be bigger on the first estimates (Smith, 2008).

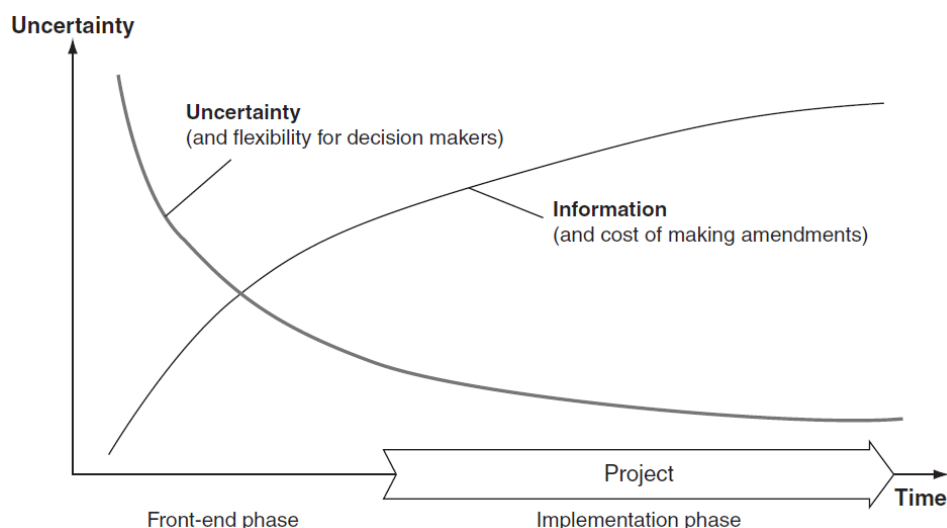


Figure 3.5 - Uncertainty and information through project time (Samset, 2010)

Although the first estimates are not the most reliable they may have big importance on project's future since "it is the base for releasing funds for further studies and estimates" and "it becomes the marker against which subsequent estimates are compared" (Smith, 2008). In addition, the decision to go further and invest in the project is usually based on preliminary and feasibility studies that consider such early estimates as one of the evaluated factors. However, an estimate, in a sense, is never completed. It is not static but has to be reviewed continually to be kept current and updated (CA.GOV, 2007).

The preliminary estimates are done in a very early stage, where design is likely to not exist. The project definition is low and this kind of estimate may be based on information such as project type, size or purpose. Estimate outcome is based on existing data from previous similar projects and the expected accuracy is low. On the feasibility studies, where few project alternatives may be under consideration, if the project is more defined it may result on better estimates but still on a high range of cost estimate values (Smith, 2008).

Then, when entering on the definition phase project design starts to be developed and estimates become more accurate. It is on this phase that the project and its budget will be considered to approval so usually owner demand a low range for total cost of the project. However, and since the design may not be fully defined, the accuracy may be still low, depending also on organization's requirements (Smith, 2008).

When design is fully defined new estimate is done in order to start a tender. At this stage accuracy is higher but once the tender is answered the estimate should reach its more accurate point before build starts. Work packages, its materials and quantities are defined in detail resulting on the estimate that will decide the value of the awarded contract. Deviating from

this estimate may result on cost overrun so during project implementation, the estimate is frequently updated in order to control the project cost (Smith, 2008).

Thus, as the project moves into middle and later stages, with more information and work being completed, cost estimates become more and more certain. The table 4.1 from Sabol (2008) shows how accuracy of the estimates may develop throughout different project stages and level of definition.

Table 3.1 – Cost estimating classification matrix (Sabol, 2008)

| Estimate Phase | Conceptual | | | Detailed | |
|---|--------------------------|------------------------------|----------------------------------|-----------------------|------------------------------|
| | Budget | | | | |
| Estimate Class | 5 | 4 | 3 | 2 | 1 |
| Level of Project Definition <i>% of complete definition</i> | 0% to 2% | 1% to 15% | 10% to 40% | 30% to 70% | 50% to 100% |
| End Usage <i>Typical purpose of estimate</i> | Screening or Feasibility | Concept Study or Feasibility | Budget, Authorization or Control | Control or Bid Tender | Check Estimate or Bid/Tender |
| Expecting Accuracy Range* <i>Typical variations in low and high ranges</i> | Hi: +30% to +100% | +20% to +50% | +10% to +30% | +5% to +20% | +3% to +15% |
| | Lo: -20% to -50% | -15% to -30% | -10% to -20% | -5% to -15% | -3% to -10% |
| Preparation Effort <i>Typical degree of effort relative to least cost index of 1</i> | 1 | 2 to 4 | 3 to 10 | 5 to 20 | 10 to 100 |

3.5.6 COST UNDERESTIMATION

As the project evolves and work is planned it is expected that cost estimate's uncertainty decreases. Together with the increase of the accuracy, estimates usually experience a cost increase with time in the front-end phase of the project (Figure 3.6). This increase is partly due to inflation but other factors such as addition of new elements in a phase when the project is still being developed and incorrect estimates may also be causes for such behaviour. Such cost development has been noticed to happen more often and with bigger deviations especially on public project (Samset, 2010). Torp et al. (2012) reports a study done to the development of different estimates done through life cycle of a group of projects that confirms that such behaviour is current in Norwegian public road projects. Other publications refer to the same fact. Kolltveit and Grønhaug (2004) analysis a group of projects from the Norwegian construction and building industry. Deviations up to 160% are noticed and only one of the projects does not see its starting cost estimate rising until project completion.

This matter that is usually called systematic underestimation has been aim of diverse studies. Those studies have investigated which reasons may contribute to explain the cost escalation on the earliest phases of the project.

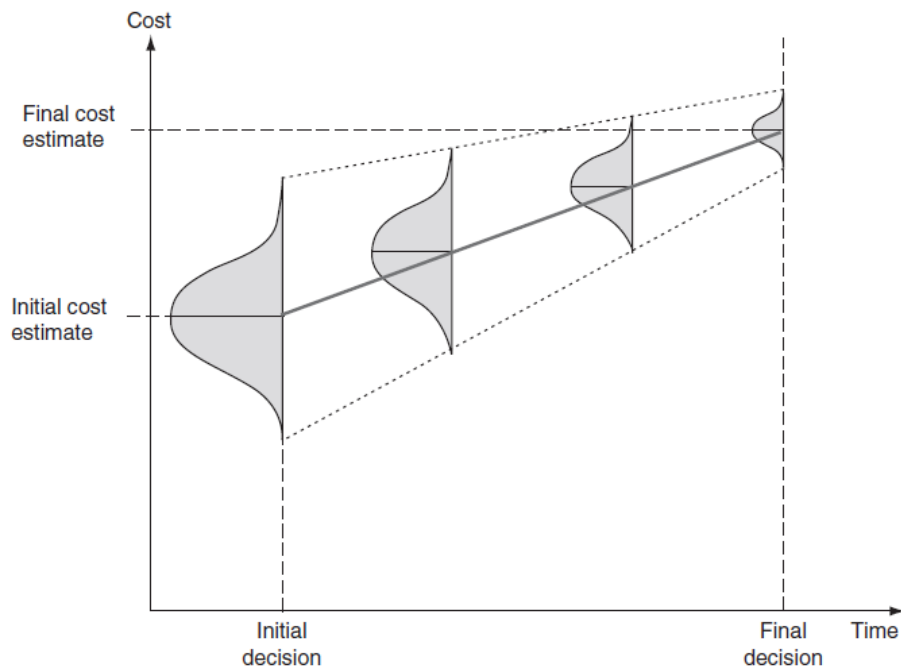


Figure 3.6 – Estimates maturation process (Samset, 2010)

Flyvbjerg has been very active on this topic investigation and have published many articles that may be somewhat controversial. Nevertheless, this author has good reputation and many other authors have based their studies on his investigations. Therefore, when analysing estimates it is, without a doubt, wise to consider some of his studies' conclusions.

Flyvbjerg et al. (2002) points out some reasons for cost underestimation. Four different types of explanations are given in order to clarify what those reasons may be and how they may be the cause of such situation, namely: technical, economical, psychological, and political explanations.

The technical explanations involve the use of wrong technics that may result on errors when forecasting costs. Errors such as “imperfect techniques, using inadequate data, honest mistakes, inherent problems in predicting the future and lack of experience on the part of forecasters “ may contribute for an increase of the uncertainty of the estimates, increasing the probability of ambiguous results. Although such facts may contribute to explain forecasting errors, they however do not explain biased distribution of errors. Such kind of technical errors are expected to decrease with time, as long as the organizations improve their processes and gain experience performing such tasks (Flyvbjerg et al., 2002).

There are two different economic explanations, one in terms of economic self-interest and other in terms of public interest. The first explanation consists on the willing of engineers and contractors to maximize profits. If costs are underestimated and benefits overestimated the likelihood of the project becoming a reality increases, increasing stakeholder's chances for

profits. It may occur in the state and city level as well, but in a different context. In that context the aim is to show that their projects are cheaper than other cities or countries, granting funds over the others. This can lead to start projects that are afterwards perceived as not being economically viable and secondly, to start a project over another that could have generated better returns. The economic public interest of underestimating cost is related with the intention of incentive to reduce project cost and save public money (Flyvbjerg et al., 2002).

Psychological explanations derive from promoter's and forecaster's optimism regarding project outcome in the appraisal phase that can result on low estimates (Flyvbjerg et al., 2002).

The political explanations concerns to whether intentional underestimated forecasts are created in order to "serve interests of project promoters in getting projects started" (Flyvbjerg et al., 2002). This issue deals with a sensitive topic such as lying, and if it really happens is not likely that this is going to be admitted to researchers. Therefore, it is hard to confirm and be able to clearly suggest that this reason may explain cost underestimation on public project or not.

4. ROAD INVESTMENTS IN NORWAY

4.1 PROJECT INITIATION PROCESS

When elaborating the Norwegian National Transport Plan (NTP) a number of projects are studied and evaluated into a level that makes them suitable to be included in the plan. Those projects are either selected by the NPRA or included as a result of detected limitations on the national transport system. Some of the project ideas can also result from local initiatives based on their perception of traffic needs. They may rise due to pressure from the private sector or from municipal and/or county plans for road transportation in the area. Local planning develops the idea and the decision to go forward with it into a preliminary study must come from the local NPRA department. This means that the projects that are selected to integrate the NTP result from both, the NPRA assessment efforts and a process of political involvement. (Welde et al., 2013)

A road project in Norway results, mainly, from local initiative rather than overall plans and project prioritization. This means that a permanent procedure for identifying new and necessary projects does not exist. The NTP forms a structure for project planning and execution, and preliminary studies are usually performed from the Ministry of Transport and Communication initiative. However, it is common that the project initiative is raised at the municipal and county level and later taken further by the NPRA. (Welde et al., 2013)

4.2 QUALITY ASSURANCE SCHEME THROUGH PROJECT LIFE CYCLE

The quality assurance (QA) scheme was introduced in Norway for major public projects in 2000 with the then labelled 'mandatory quantity-at-entry' regime, which was performed before submission to parliament for approval. The system was then extended in 2005 with the introduction of an earlier quality assurance that concerns the early choice of the project concept (Christensen, 2011). In 2005, the system included two quality assurance exercises that should create a base for decision making, firstly for the choice of the concept (QA1) and secondly for the budget, management structure, contract strategy and others for the chosen concept (QA2) (Samset et al., 2006).

For big projects (>750 million NOK) a conceptualization evaluation study and an external quality assurance (QA1) must be performed. The conceptualization study assesses the different possible alternatives to solve the need that are therefore analysed by an external organization. The main objective is to decide on which of the alternatives will be the base for the project definition. For smaller projects, it is the Ministry of Transport and Communication

together with the Ministry of Finance that decides if conceptualization study and a quality assurance must be performed (Welde et al., 2013). In the case of upgrading projects there is no need for a concept study, therefore this kind of public project may be exempt from QA1, but not from QA2 (NTNU, 2014).

Finished the conceptualization phase the project moves forward to the next phase where the project is defined regarding engineering and planning. This phase runs already in a municipal level and the level of detail of the project should increase. The NPRA may invite external engineering companies at this phase where, following the Norwegian legislation for planning and construction, the project is defined and made ready to present to the parliament. During this stage, conditions that may have big importance for the project total cost must be clarified, namely, alignment, number of intersections and roundabouts, type of cross-section and need for bridges and tunnels. In addition, an impact assessment of the project is also done, allowing performing a cost-benefit analyses that must include other variables than the financial. The cost-benefit analysis may include the financial consequences of the project and its contribution to local development and therefore compared them with non-monetary impacts such as impact on the landscape/cityscape, environment, culture and natural resources (Welde et al., 2013). The project shall in addition, right before entering the parliament, be aim of a second quality assurance (QA2) external review. After getting approval the project is completely defined and a contract strategy established. A tender process is initiated and the awarded contractors/contractors may initiate the project construction. The figure below represents graphically where the milestones for quality assurance are within project stages.

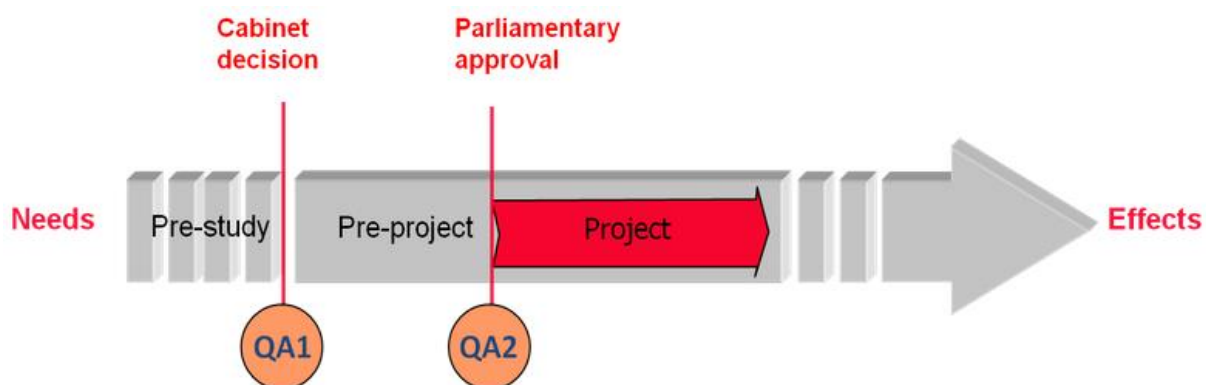


Figure 4.1 - Quality assurance scheme along the project (NTNU, 2014)

4.2.1 QUALITY ASSURANCE OF THE CHOICE OF CONCEPT (QA1)

The main purpose of submitting a project to the QA1 is “to ensure that the choice of concept has been subjected to a political process of fair and rational choice”, and consequently ensure that the chosen concept is the one with the highest economics return and with the best

possible use of public funds. The role of the external consultants is to provide with documents that may help the Cabinet to support a political decision that is solely taken by them (NTNU, 2014).

The concept evaluation study is prepared by the responsible ministry/agency and shall work as the basis for the consultant review during QA1. NTNU (2014) defines each of the chapters that should constitute the document. They are as follow:

- Needs analysis mapping all stakeholders and affected parties, and assessing the project's relevance in relation to societal needs and priorities.
- Overall strategy defining the project's goal and purpose (first order and long-term effects), with emphasis on consistency, realism, and verifiability.
- Overall requirements specifying important requirements which need to be fulfilled when the project is implemented. These requirements may follow from the project's own goal/purpose, or they may be non project-specific purposes within the overall strategic framework. The focus is on effects and functions, not on technical solutions and details.
- Possibility study. Needs, goal, purpose and requirements will together constitute the 'opportunity space'. It is essential to ensure that the opportunity space is not too narrow.
- Alternatives analysis which should include the zero-option and at least two alternative main concepts. If the zero-option lifetime is very short, a 'zero-plus' option should also be developed. For all alternatives, outputs, uncertainties, and a fiscal plan should be specified. The alternatives should also be subjected to a Benefit-Cost analysis.
- Guidance for the pre-project phase, including an implementation strategy for the chosen concept.

The consultant shall review all the documentation. Its role is to assess the methods that were used when considering possible alternatives and that the opportunity space was fully exploited. Those alternatives must be aim of an assessment regarding their capability of attaining goal and purpose; compliance with overall needs/requirements; and whether they capture the most interesting and feasible alternatives within the opportunity space (NTNU, 2014).

In addition, to each of the alternatives a benefit-cost analysis and an independent uncertainty analysis must be executed, and therefore quantify uncertainty related to the long-term flows of costs and benefits. Finally, based on the overall result of the assessment, the alternatives must

be ranked and recommendations regarding decision and implementation strategy must be given (NTNU, 2014).

4.2.2 QUALITY ASSURANCE OF THE MANAGEMENT BASE AND COST ESTIMATES (QA2)

The purpose of the QA2 is “to ensure the quality of the decision basis including cost estimates and uncertainties associated with the chosen project alternative before it is submitted to parliament for funding”. It has great focus on control aspects of the project but should also put emphasis on challenges related to project management in the implementation stage.

The responsible ministry/agency must prepare and submit to the consultant the documents that shall be used as the base to perform the quality assurance. Those documents shall include: overall project management documentation; a complete base estimate for costs and (if relevant) incomes; and an assessment of at least two alternative contract strategies.

The main tasks of the contractor is to “review these documents, and undertake and independent assessment of success factors and pitfalls, and quantify the uncertainty related to total cost”. This assessment shall result on formulated recommendations regarding (NTNU, 2014):

- Total cost frame for the project, including necessary contingency reserves to account for uncertainty, and cost frame for the responsible agency.
- How the project should be managed to maximize the probability that the cost frame will hold.

5. BEST PRACTICES FOR COST-ESTIMATION

In the construction industry there are many different methods that may be implemented in order to estimate the cost of a project. Both in the private and public sector, estimating a project cost is one of the most important activities. Public investments often make use of big amounts of public money, being state authorities responsible for making sure that those moneys are well spent. One way to do that is by encouraging organizations to systematize and document their practices, so it is assured that the most updated and recognized techniques for cost management are in use. Many governments have published standards or guides that intend to engage the public agencies to exercise cost estimation in the mentioned way.

To estimate a cost of high investments such as a road project is a complex task where many variables have to be considered. Therefore, it is expected that the governmental agencies which are accountable for the estimates that are usually the base for authorities' decision for financing the project, make use of the best practices that include all the existing knowledge and tools that are available out there for cost-estimation.

Setting standards for cost estimation provides the project owner a uniform guidance to produce and document an estimate. A project manager or a project team may have their own way to apply those standards, but such kind of guidance can provide governance across the projects in order to lead the estimates to authorities' requirements. In addition, it may make easier to the public agencies to train and integrate new employees (GAO, 2009).

Such type of guidance or standards may foment improvements on the cost estimating practices of all agencies that deal with public projects and at the same time improve authorities' capacities to monitor and audit project cost estimates (Evans&Peck, 2008).

The Authority for Total Cost Management (AACE) is widely recognized and their recommendations are seen by many as the best practices, however there are many recommended methodologies for cost estimating that are also seen and self-proclaimed as the best practices. Nevertheless, there are other models - such as AACE's model (Lavingia, 2004), Department of Infrastructure of Australia's model (Evans&Peck, 2008) and Norwegian Ministry of Finance's model (Finansdepartementet, 2008) - that are certainly accounted by cost estimators and could have been as well, aim of a review in this master thesis.

However, in this chapter is the cost estimating guide published by the Accountability Office of the Government of the United States (GAO, 2009) that is to be assessed, as it is also seen as complying with the best practices in cost estimation for public investments.

5.1 U.S. COST GUIDE

The guide with the title “GAO Cost Estimation and Assessment Guide – Best Practices for Developing and Managing Capital Program Costs” published by the U.S. Governmental Accountability Office (GAO) has the main goal of establishing “a consistent methodology that is based on best practices and that can be used across the federal government for developing, managing, and evaluation capital program cost estimates”. Public in general and public authorities expect that government programs achieve the proposed goals within reasonable costs. To evaluate that, reliable cost information is need, therefore a guide was issued in order to standardize the way to prepare the base information for decision-making (GAO, 2009).

The guide is an extensive book that gives guidance for all the cost management process for public invested programs. Methods for estimate the future cost of a program are established, but big part of it is dedicated to continuous updating of the estimate, estimate revision and monitoring of the estimate, with strong emphasis on earned value management.

Here the focus is on the method of creating an estimate until authorities' evaluation for funding.

5.2 THE GAO COST ESTIMATION PROCESS

This chapter aims to provide an overall perspective of the estimation process, and go through and briefly describe the main steps that constitute it. The guide is to be adopted by all of governmental agencies that handle public projects or acquisitions, also called programs.

The cost estimation process defined in the guide is considered as being a process that includes the best practices in this discipline. The process consists of repeatable methods that are to be performed through four main phases: Initiation and research, Assessment, Analysis, and Presentation. That process should result in “high-quality cost estimates that are comprehensive and accurate and that can be easily and clearly traced, replicated, and updated” (GAO, 2009). The following figure shows roughly the overall process.

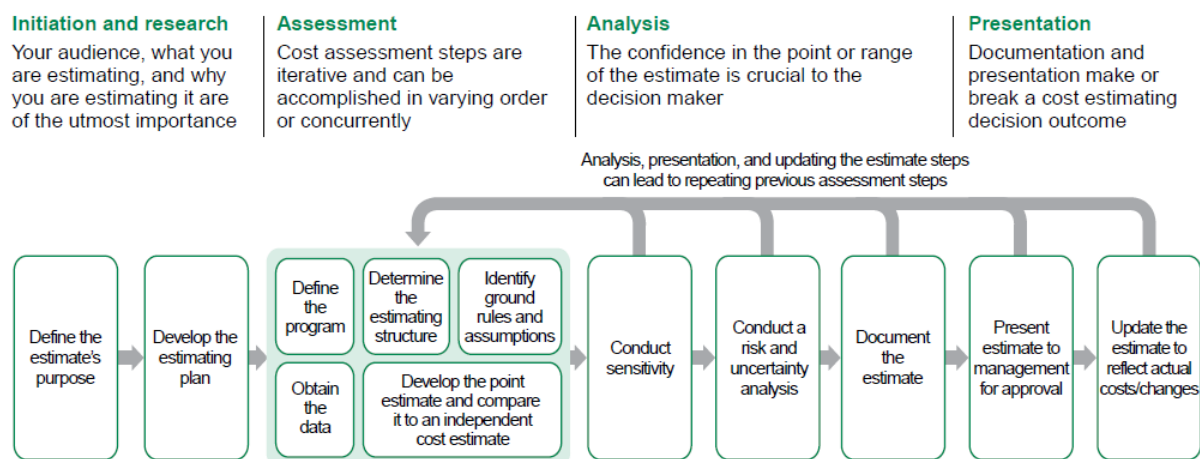


Figure 5.1 – Cost estimation process (GAO, 2009)

The process is divided in 12 main steps that are important to be performed in order to ensure a reliable estimate is developed and delivered in time to support important decisions. Estimates performed by agencies that do not incorporate the 12 steps are considered to be unreliable. In the following, the main tasks associated to each step are seen and the most important guidance information concise.

DEFINE ESTIMATE'S PURPOSE

An estimate is not just a compilation of values. In addition to a final estimated cost there is important documentation that follows in order to define the estimate framework. This step involves determining the estimate's purpose, the required level of detail, and the overall scope of the estimate.

The general purpose of a cost estimate may be: to help managers evaluate affordability and performance against plans, as well as selection of alternative systems and solutions, and to support the budget process by providing estimates of the funding required to efficiently execute a program. It should be link to the agency's mission, goals, and strategic objectives and state the intended benefits along with the appropriate performance measures for benchmarking progress.

The scope of the estimate is determined by locating the estimate within legal or requested requirements. For example laws or policies may require an independent estimate before a project start and which stage of the life-cycle cost should be included in the estimate.

Delimit what elements are to be estimated, the level of detail of the estimate, the need amount of data collection, the amount of work and the time available are examples of factors that are important to determine when defining the scope of the estimate.

DEVELOP ESTIMATING PLAN

The second step includes choosing the cost estimating team and determining the estimation process schedule. If necessary an independent cost estimate, it must be determined who will do it.

It is important that enough and adequate time is given to the estimating team to develop a competent estimate. The time frame to develop an estimate may vary from days to months, depending on the project phase, the detail required and type of project. A first-time estimate would require time to prepare the process, acquire data, choose estimation team, between others things that add to be done and the estimating process may last months, while a simple estimate update may be done much faster.

When the tasks are defined a detailed schedule should be created, including the key decision points and milestones, with margins for unexpected works but not delays. The project team must ensure that the schedule is reasonable avoiding overly optimistic plans.

Time to collect data should also be scheduled, including visiting contractor sites to understand the strengths and limitations of the collected data. If there is no time available that should be stated on the estimate rules and assumptions so it can be attached to estimate's quality and confidence.

An estimating team must possess a variety of skills that cover all the disciplines and concepts that are to be managed throughout the 12 steps of the process. Many decisions tend to be subjective and the cost analyst's judgment has great influence on the quality of the estimate, therefore the amount of expertise in the group is vital for the estimate result.

The disciplines and concepts present in a cost analysis are:

Economics

- Break-even analysis
- Foreign exchange rates
- Industrial base analysis
- Inflation
- Labour agreements
- Present value analysis

Budgeting

- Budget appropriations
- Internal company (industry)
- Program specific

Engineering

- Design
- Materials
- Performance parameters
- Production engineering
- Production process
- Program development test
- Scheduling
- System integration

Computer science/mathematics

- Analysis of commercial models
- Analysis of proposals
- Development of cost estimating relationship
- Model development
- Programming

Statistics

- Forecasting
- Learning curve applications
- Regression analysis
- Risk/uncertainty analysis
- Sensitivity analysis

Accounting

- Cost data analysis
- Financial analysis
- Overhead analysis
- Proposal analysis

Interpersonal skills

- Approach
- Estimate
- Knowledge

Public and government affairs

- Appropriations process
- Auditors
- Legislative issues
- Outside factors

When possible, members with experience with all the cost elements should be included, but that may be difficult so the project leader must be familiar with the team's capabilities and limitations when assigning tasks. The team may also include members from other organizations.

The best practices advise for centralization of the cost estimating team and process. GAO guide states that it facilitates the use of standardized processes, the identification of resident experts, a better sharing of resources, commonality and consistency of tools and training, more independence, and a career path with more opportunities for advancement

The professional credentials of the project team are aim of audition when reviewing an agency's cost estimate, and although there are not mandatory levels of training it is expected that each agency has its own criteria. In addition some certification programs are recommended and continuous training encouraged.

DEFINE PROGRAM CHARACTERISTICS

To develop a credible estimate an adequate understanding of the acquisition program is essential. This means understanding the acquisition strategy, technical definition, characteristics, system design features, and technologies to be included in its design.

To identify the program characteristics the following should be defined:

- In a technical baseline description document, identify the program's purpose and its system and performance characteristics and all system configurations;
- Any technology implications;
- Its program acquisition schedule and acquisition strategy;
- Its relationship to other existing systems, including predecessor or similar legacy systems;
- Support (manpower, training, etc.) and security needs and risk items;
- System quantities for development, test, and production;
- Deployment and maintenance plans.

The technical baseline should provide in a form of a single document a common definition of the program, including a detailed technical, program, and schedule of the system, from which all the life cycle cost estimates will be derived.

A best practice is to assign an integrated team of various experts that are responsible for developing the technical baseline at the beginning of the project. The expert team should include system engineers, design experts, schedulers, test and evaluation experts, financial managers, and cost estimators.

The first drawn technical baselines are as expected imprecise or incomplete. They should however evolve as more information becomes available. Therefore, it should be updated for program reviews, milestone decisions, and major program changes.

The technical baseline must be available in time for all cost estimation activities be able to proceed on schedule, after being approved by management.

DETERMINE ESTIMATING STRUCTURE

The main task in this step is to build a work breakdown structure (WBS) for the project or program to be estimated. A WBS reflects the requirements, what must be accomplished to develop a program, and provides a basis for identifying resource and tasks for developing a cost estimate. The WBS provides a broad picture of what the project consist of, what needs to be accomplished and the work to be done.

The associated tasks to this step are:

- Define a work breakdown structure (WBS) and describe each element in a WBS dictionary (a major automated information system may have only a cost element structure);
- Choose the best estimating method for each WBS element;
- Identify potential cross-checks for likely cost and schedule drivers;
- Develop a cost estimating checklist.

The best practice is to establish a product-oriented WBS since it allows tracking cost and schedule by defined deliverables. Moreover, it allows the program manager to more precisely identify the cost and duration of each component.

The WBS diagram divides the deliverable into smaller elements, showing how each one relates to the others and to the program as a whole. The lowest level elements are defined as work packages.

The number of levels of a WBS depends on the required detail of the estimate and the complexity and risk of the project. The level of detail is expanded to a level that is considered to be sufficient for planning and managing the full scope of work, however it should at least include three levels. The first level contains only one element that should represent the program – name of the project/program. The second level contains the major program segments, and level three contains the lower-level components or subsystems for each segment. However each WBS is done to fit the program, and not the opposite.

The WBS should be developed as early as possible to provide an idea of the program size and scope. As the project matures, the WBS will include more details and smaller elements will be added. That will allow more insight into the program's cost, schedule, and technical relationships. The WBS should be considered a living document.

A dictionary should follow the WBS. The document should describe what work is to be performed in each WBS element. Each element is presented in an outline to show how it relates to the next higher element. In addition, the dictionary may also describe the resources and processes needed to deliver each of the elements. The WBS dictionary can be the base for the creation of the statement of work.

It is also recommended as best practice to standardize the WBS. That enables an organization to collect data and make it available for other and future projects/programs. Standardized WBS results in more consistent and efficient cost estimates, due to its ability to share common cost measures across programs. A standardized product-oriented WBS can help define high-level milestones and cost driver relationships that can be repeated in future applications.

The WBS can also be used to flag elements that may encounter risk. That can be used as a tool to identify and monitor risks, leading to a better contingency planning.

IDENTIFY GROUND RULES AND ASSUMPTIONS

The fifth step of the cost estimating process is characterized by the following tasks:

- Clearly define what the estimate includes and excludes;
- Identify global and program-specific assumptions, such as the estimate's base year, including time-phasing and life cycle;
- Identify program schedule information by phase and program acquisition strategy;
- Identify any schedule or budget constraints, inflation assumptions, and travel costs;
- Specify equipment the government is to furnish as well as the use of existing facilities or new modification or development;
- Identify prime contractor and major subcontractors;
- Determine technology refresh cycles, technology assumptions, and new technology to be developed;
- Define commonality with legacy systems and assumed heritage savings;
- Describe effects of new ways of doing business

The ground rules are set when the technical baseline is created. By comprehending the technical baseline the analysts have the necessary ground rules for conducting the estimate. If there are no ground rules, then is necessary to make assumptions. Assumptions represent a set of judgments about past, present, or future conditions that are considered as true in the absence of information that allows creating a proved judgement.

Analyst should consider only expert judgment from experienced and technical personnel. They must be documented in a way that allows the management to fully understand the conditions the estimate was structured on. It should include historical data the rationale behind the assumptions. The risk attached to the assumptions should be considered and reflected on the estimate, regarding both time and cost. The risk associated to the assumptions should be determined by the cost estimators after meeting with the technical staff.

OBTAIN DATA

The quality and reliability of the data have great influence on the credibility of an estimate. Depending on this factor, an estimate can range anywhere from a mere guess to a highly accurate cost. Collecting valid and useful data is an important step for the creation of a rigorous cost estimate. To successfully perform this step the following tasks must be performed:

- Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data;
- Investigate possible data sources;
- Collect data and normalize them for cost accounting, inflation, learning, and quantity adjustments;
- Analyse the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data;
- Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy;
- Store data for future estimates.

There is a variety of sources for data collection. Data is the foundation of an estimate and it may be collected from databases of past projects, engineering build-up estimating analysis, interviews, surveys, data collection instruments, and focus groups. A cost estimating must be fed continuously with new relevant data so it can remain credible. Therefore all the obtain data must be well documented, protected and stored so it can be used in upcoming projects. When documenting the data it should be stated the source, content, time, units, assessment of accuracy and reliability and circumstances affecting the data.

The data should be managed by estimating professional that are able to assess if the data has value for future predictions and make part of the corporate history.

The data should be gathered and made available to the team as early as possible, so analysts can understand and question the data when participating in site visits.

Before the start of the actual built of the cost estimate, the data should be fully reviewed so their limitation and risks can be considered. Having historical data as reference and in order to validate the data, a benchmark should be done.

Since a variety of sources is used, and in order to compare the data is it necessary to normalize it. That improves data consistency and makes the comparisons and projections more valid. The normalization should account for cost and sizing units, mission or application, technology maturity and content. In addition, it should be normalized to constant base-year dollar to remove the effects of inflation.

DEVELOP POINT ESTIMATE AND COMPARE IT TO AN INDEPENDENT COST ESTIMATE

In this step, the number 7, is when all the information is put together in order to create the point estimate. A point estimate can be defined as the best guess at the cost estimate, given the underlying data. A cost estimate usually falls within a range of possible costs that can vary depending on the distribution of the cost of the elements, which are related to its uncertainty and risk. To perform a point estimate the following activities should be performed:

- Develop the cost model, estimating each WBS element, using the best methodology from the data collected, and including all estimating assumptions;
- Express costs in constant year dollars;
- Time-phase the results by spreading costs in the years they are expected to occur, based on the program schedule;
- Sum the WBS elements to develop the overall point estimate;

After developing the overall point estimate done, the cost estimator must:

- Validate the estimate by looking for errors like double counting and omitted costs;
- Compare estimate against the independent cost estimate and examine where and why there are differences;
- Perform cross-checks on cost drivers to see if results are similar;
- Update the model as more data become available or as changes occur and compare results against previous estimates

There are different methods for estimating a cost and to select which one to use, the stage in the live cycle where the estimate if going to be performed play important role. Few methods are suggested and a rough overview of them is given. Three methods are commonly used for

estimating cost. They are analogy, engineering build-up, and parametric. Each of them has its strong and weak points, and adapts better to different types of estimates.

The cost estimator should consider the various cost estimating methods and decide which one fits better the purpose of the estimate that is to be developed.

The analogy estimating method should be considered in the early life cycle, when little is known about the system being developed. It is a method that uses actual costs from similar programs with adjustments to account for differences between the requirements of the existing and new systems.

The engineering build-up method suits a later stage, when the scope of work is well defined and a complete WBS already determined. The overall cost is calculated by summing detailed estimates done at the lower levels of the WBS. Labour and material costs of the smaller elements are summed and a fee added to them.

The parametric cost estimating method may be used if a database of sufficient size, quality, and homogeneity is available for developing cost estimation relationships and normalize data. The relationships form a model that may be used to estimate a cost of a new program by editing its characteristics to match the system of the estimated program.

In addition to the three methods already mentioned the following methods should also be considered:

- Expert opinion, which relies on the subjective opinion of experts to give their opinion of what an element should cost. May be considered in a very early stage in the life cycle and there is no other way to estimate.
- Extrapolation, which uses actual costs and data from prototypes to predict the cost of future elements;
- Learning curves, which is a form of extrapolation costs.

For validation of the cost estimate there are characteristics that must be evaluated. The cost estimation should be documented in a comprehensive way and include source data, clearly detailed calculations and results, and explanations of why particular methods and references were chosen.

The best practices for validating an estimate should ensure that the estimate is comprehensive, includes all possible costs, ensures that no costs were omitted or double-counted, and explains and documents key assumptions. The estimate should be unbiased, accurate and not contain

major errors. It should be based on an assessment of most likely costs, adjusted properly for inflation.

CONDUCT SENSITIVITY ANALYSIS

The best practices for cost estimation should always include a sensitivity analysis. Such analysis allows identifying the more uncertain cost elements and take measures for mitigation of the risk that they represent. Conduction the analysis includes the following tasks:

- Test the sensitivity of cost elements to changes in estimating input values and key assumptions;
- Identify effects on the overall estimate of changing the program schedule or quantities;
- Determine which assumptions are key cost drivers and which cost elements are affected most by changes.

CONDUCT RISK AND UNCERTAINTY ANALYSIS

In addition to a sensitivity analysis a risk and uncertainty analysis should be performed. Although a sensitivity analysis allows perceiving effects of changing, it applies only to one parameter at a time. This is a limitation because in reality, many parameters can change at the same time. A cost estimate is composed by several elements, each of them with the respective source of error, that when added together results on a much bigger uncertainty.

A risk and uncertainty analysis is best practice and its goal is to quantify the risk and uncertainty so it can be quantified when estimating the project cost.

Risk and uncertainty are related and usually are together but in statistics they have distinct definitions:

- Risk is the chance of loss or injury. In a situation that includes favourable and unfavourable events, risk is the probability that an unfavourable event will occur.
- Uncertainty is the indefiniteness about the outcome of a situation. It is assessed in cost estimate models to estimate the risk (or probability) that a specific funding level will be exceeded

Performing such analysis involves:

- Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element;
- Analyse each risk for its severity and probability;
- Develop minimum, most likely and maximum ranges for each risk element;

- Determine type of risk distributions and reason for their use;
- Ensure that risks are correlated;
- Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate;
- Identify the confidence level of the point estimate;
- Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate;
- Recommend that the project or program office develop a risk management plan to track and mitigate risks.

A risk and uncertainty analysis allows assessing the variability of the point estimate, allowing to define a range of costs where the point estimate lays. That is useful information to the decision makers given that it expresses the level of confidence in achieving the most likely cost.

DOCUMENT THE ESTIMATE

A part of best practices is to document the cost estimates. That allows having track on all the estimation process and recall in the future. Documentation is essential for validating and defending a cost estimate. Good documentation may allow a person that is not familiar with the project to recreate it or update it if needed. Moreover, documentation may provide future programs with technical data and cost and support future estimates.

If the estimate is aim of an independent review, documentation shall be the bases for the analysis. If the estimate is to be seen as valid and credible the documentation should be well structured and allow the reviewers to effectively evaluate it.

This step consists on producing the following tasks:

- Document all steps used to develop the estimate so that a cost analyst unfamiliar with the program can recreate it quickly and produce the same result;
- Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date;
- Describe the program, its schedule, and the technical baseline used to create the estimate;
- Present the program's time-phased life-cycle cost;
- Discuss all ground rules and assumptions;

- Include auditable and traceable data sources for each cost element and document for all data sources how the data were normalized;
- Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less);
- Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified;
- Document how the estimate compares to the funding profile;
- Track how this estimate compares to any previous estimates.

The documentation should include:

- Cover page and table of contents
- Executive summary
- Introduction
- System description
- Program inputs
- Estimation method and data by WBS cost element
- Sensitivity analysis
- Risk and uncertainty analysis
- Management approval
- Updates reflecting actual costs and changes

It should include access to an electronic copy, and accessible for authorized personnel.

PRESENT ESTIMATE TO MANAGEMENT FOR APPROVAL

A cost estimate is considered valid only after management approval. The management should be briefed on how the estimate was developed, especially regarding the risks associated to the data and methods used. The management may have in hand many estimates from different alternatives, from where they have to make a decision so information transmitted should be enough detailed to enable proper defence. This may include showing how accurate, complete and high in quality the estimate is. These are the tasks that constitute this step:

- Develop a briefing that presents the documented life-cycle cost estimate;
- Include an explanation of the technical and programmatic baseline and any uncertainties;
- Compare the estimate to an independent cost estimate (ICE) and explain any differences;

- Compare the estimate (life-cycle cost estimate (LCCE)) or independent cost estimate to the budget with enough detail to easily defend it by showing how it is accurate, complete, and high in quality;
- Focus in a logical manner on the largest cost elements and cost drivers;
- Make the content clear and complete so that those who are unfamiliar with it can easily comprehend the competence that underlies the estimate results;
- Make backup slides available for more probing questions;
- Act on and document feedback from management;
- Request acceptance of the estimate

UPDATE THE ESTIMATE TO REFLECT ACTUAL COSTS AND CHANGES

Even after approved, the process of cost estimating is still not finished. The programs should be monitored continuously for their effectiveness. As the program is maturing the cost estimate should be updated with the actual costs so it remains relevant and current. That should allow perceiving which elements or work packages were incorrectly estimated and incorporate lessons that will be useful in future estimates. The main tasks to perform in this step are:

- Update the estimate to reflect changes in technical or program assumptions or keep it current as the program passes through new phases or milestones;
- Report progress on meeting cost and schedule estimates;
- Perform a post mortem and document lessons learned for elements whose actual costs or schedules differ from the estimate;
- Document all changes to the program and how they affect the cost estimate.

6. NPRA'S (STATENS VEGVESEN) COST-ESTIMATION PRACTICES

6.1 THE HANDBOOK 217

The Norwegian Public Roads Administration has issued a book which is a guideline for performing a cost-estimation for their investment projects. All the estimates must be conducted following those guidelines that were published in a form of a handbook. The handbook is part of a series of numbered books that are prepared and issued by the NPRA. The handbook now in use as guidelines to conduct cost-estimates is the Handbook 217 named Estimation Method (and with the Norwegian original name anslagmetoden), which is a revised version of the first guidelines used by NPRA since 1995. The present version published in October 2005 was already updated after a new estimation tool, called Anslag 4.0, and adopted in this last version in 2010 (NPRA, 2011b).

The guidelines intend to lead to “a quality-assured cost estimate that is to be presented to the decision-makers and used as a basis for subsequent financing, project management and uncertainty management” (NPRA, 2011a).

The handbook is divided in 7 sections and starts by presenting the implementation requirements and background theory. Section 4 and 5 describes the workflow and the needed preparation prior to the actual implementation of the estimation method. On the section 6 the estimation execution is described and finally the resulted documentation and subsequent follow-up is discussed. Attached with the handbook comes also 3 examples of the use of the tool Anslag 4.0 for 3 different projects (NPRA, 2011b).

6.2 COST-ESTIMATION METHOD

In this chapter a review of the mentioned handbook is done. The main aspects of the method are here briefly described with the intention to assess the NPRA's practices and create a background that enables a comparison with other practices used in the public sector framework that are seen as the best practices for cost-estimation.

6.2.1 IMPLEMENTATION REQUIREMENTS

The established requirements stipulated by the handbook define the scope of the handbook pointing which projects require an estimate according to these guidelines, and among others delimit the accuracy requirements for the estimated cost.

COVERED PROJECTS

All the cost estimates for investment projects taken by the NPRA above 5.0 million Norwegian kroner must be performed according to the estimation method from the handbook 217.

PLANNING LEVELS

For all the planning phases of the project a cost estimate should be performed. The estimates at the later phases shall have a greater degree of detail and be within a narrower accuracy requirement. These phases are 3 and they are as follow:

- Initial study level / concept planning: At this phase the project is still very little detailed and therefore only rough estimates are possible. Usually the produced estimates are based on metre prices of comparable projects, however the accuracy and resource utilization requirements are limited.
- Municipal (sector) planning level: The level of detail at this stage is higher so a standard estimation process shall be carried out. The project definition is bigger so accuracy and resource consumption requirements are higher.
- Area development planning level: The area development plans require the most detailed estimates. At this phase, the estimate must be mature enough to include detailed quantity estimates and description of the project. The cost estimate shall provide the basis for approval prior to start-up, management of the project, and non-compliance reporting.

EXECUTION

Some small project may be an exception, but in general the estimation method is based on work group. In the group there are 2 persons that take bigger responsibility, they are the project manager and the process manager. The project manager is responsible by the preparation of the cost estimate while the process manager shall lead the estimation process. The process manager, who should be a certified process manager, must be someone neutral and with no interference with the project.

The size and composition of the estimation group must be deliberated on a case-by-case basis. It positive to form a broad-based group, therefore persons within a diverse background and expertise, and from within and outside of the project should be considered to be part of the group. There are no requirements regarding where the participant comes from or if it is NPRA employee or not.

The planning note and background material should be given to the participants of the estimation group in advance. The material should not be more detailed and extensive than necessary and should be sent with enough time to be assessed by the participants. The material shall include information about:

- scope and objective of the project, including the principal quantities
- preconditions of the project and cost estimate
- decision and plans that are relevant to the cost estimate
- progress and organisation

In order to provide more information and in a way to stimulate ideas on the participants, an on-site inspection should be done prior to the estimation meeting.

To produce an estimate at the area development level is challenging and resource and time consuming, regardless their size. In order manage the resources it is important to define priorities among regions and make good use of the available resources. The used estimation tool (anslag 4.0) allows choosing a template that reflects the complexity of the cost estimate which is to be elaborated, in the case of small projects the “Simple Estimation Process” template, which has a limited scope, may be used. In such cases it may be effective to gather a small estimation group and prepare several cost estimates on the same date, at the same meeting.

For medium-sized project, the meeting lasts for two days, while for big projects, those which require external quality assurance, the meeting last a minimum of three to four days.

STRUCTURE OF THE COST ESTIMATE

The estimation method proposes a structure for overarching the cost estimate breakdown. Depending on the project stage and the level of detail of the estimate the used structure may be more or less broken-down. Each calculation should analyse which structure is more suitable, but all should observe and consider the proposed structure when breaking down the cost estimate. The structure purposes the following levels:

- Open roads
- Bridges and quays
- Rock tunnels
- Technical installations
- Other measures
- Project owner costs

- Land acquisition
- Factors of uncertainty
- Incidents

Then, it may be further broken down if necessary.

To estimate the total project cost all the elements cost and the uncertainty attached to them is calculated. The project cost estimate is built by putting together the different elements cost and their associated uncertainty. The estimated cost should consist on the sum of the following:

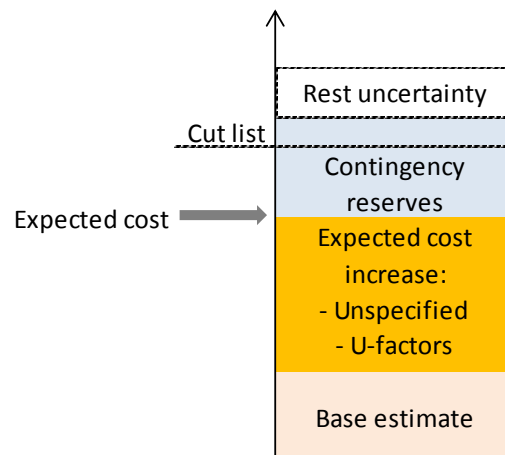


Figure 6.1 - Structure of a cost estimate according to the method (NPRA, 2011b)

The base estimate is the sum of all individual expected costs of the elements that were defined on the breakdown structure. The value of each cost element is estimated through a triple estimate. The project owner's cost estimates shall include the value-added tax, however this value must be calculated as a separate percentage markup for the main elements such as roads, bridges and tunnels.

In order to achieve the expected cost there are two additional costs that are called expected supplements. These expected supplements consist of the element "unspecified" and the expected supplement from internal and external influences and incident uncertainty. Unspecified includes costs that are expected but not possible to estimate at the time of calculations. The item value corresponds to a percentage markup of the base estimate that varies according to the planning phase.

- For initial study: 15-20 %
- For the municipal (sector) plan: 10-15 %
- For the area development plan: 3-7 %

There are internal and external influence factors that cannot be allocated to individual items, but that also result on uncertainty. This uncertainty factors called “U-factors” are usually determined through a brainstorming session at the estimation meeting, from where a list of the most common impacts are listed and accounted as factors that may result in costs. The U-factors and the uncertainty from the triple estimate on the base estimate constitute the project cost variability.

P-VALUES

The P45, P50 and P85 are automatically derived from the cost estimate in the estimation tool. P45 is the project manager's management framework. P50 is normally close to the expected value and it will be the management framework for projects that are aim of QA2. It is the median value of the estimate and considered project's original cost estimate.

From P85 taken from the estimation tool, the value from cutting costs is subtracted and the cost framework for the QA2 projects is derived.

CALCULATION ACCURACY REQUIREMENTS

All the cost estimates shall have at least 70% probability of lying within the intervals that were set as the accuracy limits for the estimate. Depending on the detail of the cost estimate and consequent project phase there were defined by the NPRA three different accuracy requirements.

- For initial study: +/- 40 %
- For the municipal (sector) plan: +/- 25 %
- For the area development plan: +/- 10 %

This means, for instance at the area development plan level, that the probability of exceeding or staying behind of the expected cost +/- 10% cannot be higher that 15%. The figure 5.2 shows in a graphic how the probabilities should be distributed.

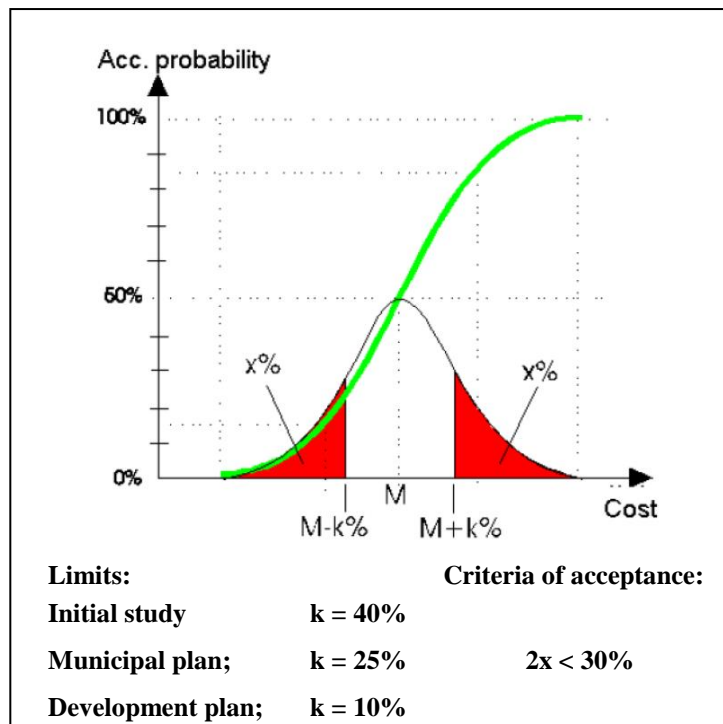


Figure 6.2 - NPRA's acceptance criteria (NPRA, 2011a)

CUT LIST AND ACTION PLAN

For project that require a QA it is necessary to prepare a cut list that should include a list of measures, and the associated costs, that may be implemented during the project execution phase to prevent cost overruns. During the estimating meeting, a list of proposals (or action plan) should also be prepared, with the purpose of proposing measures that may be useful for the project manager to reduce the uncertainty of further costs.

DOCUMENTATION REQUIREMENT

From the estimation process a report shall be prepared. The estimation report is an internal working document and should not be available to public. Only main items and aggregated cost table may be published. The report should contain:

- Prerequisites
- Participants/experience
- Reference projects
- Calculation results by item
- Results and interpretations
- Storage of data files
- Storage of an approved cost estimate

QUALITY ASSURANCE OF COST ESTIMATION REPORTS

Even though all the estimates done at the NPRA must follow the presented methodology, there are some differences regarding the quality assurance procedures. That is directly related with the project size value resulted of the estimate. Depending of the cost estimate value the results will be handled differently and go through a different process of quality assurance. The following matrix summarizes the process.

Table 6.1 - Correlation between quality assurance of Estimation Reports and the size of the project (NPRA, 2011a)

| Phase | Early planning phases/ concept | Area development plan | | | |
|--|--------------------------------|-----------------------|----------|-----------|----------|
| | | 5 -100 | 100 -200 | 200 - 500 | Over 500 |
| Size of the project Amounts in million NOK | All | 5 -100 | 100 -200 | 200 - 500 | Over 500 |
| Estimate review | x | x | x | x | x |
| Regional QA group | | | x | x | x |
| QA at the Directorate of Public Roads* | | | | x | x |
| External quality assurance (QA2) | | | | | x |

* All toll road projects shall be quality assured by the Directorate of Public Roads regardless of their size.

ADOPTION OF THE COST ESTIMATE

From the cost estimation meeting the cost estimate of the project should be decided, which should include the expected costs, including uncertainty. The NPRA has decided that it is the P50 value that should be used to officially state the cost estimate of the project.

The cost estimate resulted from the area development plan is called the original cost estimate, and is the estimate that will be the base for the initial funding. It is in addition the estimate that will be used as basis of comparison with the final cost when the project is completed.

6.2.2 WORKFLOW AND ROLES

WORKFLOW IN AN ESTIMATION PROCESS

The estimation process runs through a workflow that is suggested by the guidelines from the handbook. The resource group works systematically under the process facilitator supervision, respecting the following scheme.

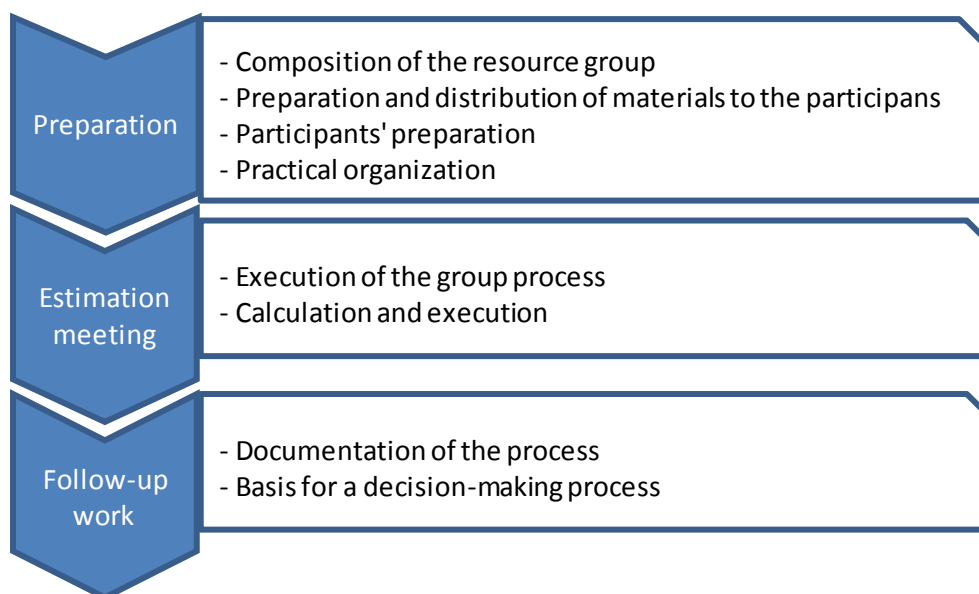


Figure 6.3 - General workflow of the estimation process (NPRA, 2011b)

After being done with the preparation works, the process group may start the estimation process itself. The first step is to define the goals and the scope of the project. The meeting framework and schedule is defined and project and cost estimates preconditions clarified.

Secondly, it is necessary to identify all the external and internal factors that affect the project, in order to ensure that the cost estimate is realistic. It is very important to identify the factors that may make the project special. Such factors may be found as uncertainty factors so they must be pointed out and added as a supplement to the cost estimate.

The next step is to create an appropriate breakdown structure for the estimate. The chosen structure should not include too many elements, and should be narrowed only to the required levels. In order to have a good overview of the elements to estimate, a too much detailed breakdown structure should be avoided. That would increase the volume of work as well. The calculation method requires, in principle, that the cost estimate is broken into statistically independent elements/items, but when not achievable covariance between them may be modelled into the estimation tool Anslag 4.0.

Having the breakdown structure done, the constituents may be estimated. To do so, a triple estimation must be given. This is, for each element a minimum value, a maximum value and the most likely value for cost should be given. The values are introduced in the computer so the tool Anslag 4.0 may perform the calculation.

The result must be assessed and the group must agree whether the results are acceptable or not and if satisfies the need for a decision-making basis in the relevant phase. If the assessment is not satisfactory and shows that the cost estimate is still no certain enough, then it must be

processed further. When the available information is enough to improve the result the session can go in. By doing some adjustments it may be possible to achieve a result that pleases the group.

At this point a conclusion is drawn based on the cost estimate result. A main conclusion is formulated, which should include important assumptions and recommendations. Expected project cost and uncertainty should also be included, pointing out the most uncertain elements and factors.

Finally an action plan is prepared. A list of measures that state how project opportunities may be exploited and how risk may be prevented/met should be done, where measures to reduce the project uncertainty may also be included.

GROUP WORK

The group work has its advantages but is not effective for the preparation of details or processing large volumes of data, therefore such kind of work should be avoided. The group work aims to fundament a well-documented decision-making but rarely has any decision-making power.

Team work is highly encouraged but there is the perception that conflicts and divergent view will occurs, so with the purpose of enabling healthy discussions meeting rules for the estimation process were created.

PROCESS FACILITATOR'S ROLE

The process manager is responsible for making sure that the group has all the means to obtain the best possible assessments. His task is to organise and supervise all the estimation process in a way that grants to the participants the opportunity to contribute with its opinion and expertise in the best interest of the project.

The process manager has not a managing role but has many responsibilities to what concerns the group meeting organizational decisions. Therefore, process manager's duties are clearly defined, together with rules that must be followed during the estimation process.

DATA SUPPORT

Alongside the process manager and the project manager there is a key person who is responsible for entering the information and numbers into the estimation tool Anslag 4.0. This person must have adequate training and knowledge, and have full control with a computer, specifically with the used computer software.

For the data support/secretary there is also a list of main rules and duties that should be followed during the meeting.

PARTICIPANTS' DUTIES AND WORK METHODS

The resource group is characterized by everyone being equal. Everyone should have the same opportunity to participate and interact with the group. Each participant must be compromised to the group work success, keeping a positive attitude towards an effective and pleasant meeting. High level of involvement is positive, and it is important that the participant stands to its point of views, but when an agreement cannot be achieved, a diplomatic attitude and willingness to compromise is equally important.

Everyone shares the same responsibility for the final result of the meeting, and if the estimation process has not been successful, that should be mentioned in the report.

COMPOSITION OF THE RESOURCE GROUP

Not only relevant knowledge and experience of the participants matter when composing the resource group. The group should have a broad-based composition with respect to gender, age and background. Regarding the participants expertise, persons with experience in planning, construction management, production, operations and maintenance may be prioritized to participate in the reference group. Persons with little expertise and experience should also have the opportunity to participate, and learn with the experienced.

The group should change and not use always the same persons. It is important to balance optimism and pessimism, avoiding systematic misjudgements in one direction or another. Specialists may be used if the project presents specialities that may be only assessed by them. Specialists are also often used on the later and more detailed estimation processes.

6.2.3 PREPARATIONS

DISTRIBUTION OF MATERIAL TO THE PARTICIPANTS

Before the meeting takes place, some material is distributed to the resource group so they can prepare themselves. Preparation allows avoiding wasting time with activities that could be done in advance. To do so it is also important that the material is sent enough time in advance. The material should not be more extensive and detailed than necessary. Irrelevant, old or over detailed material may turn preparation more difficult and make the process less effective. Typical documents that are sent to the participants in advance include:

- Maps

- Description of the road structure
- Main quantities
- Surplus or shortage of masses
- Short description of the soil mechanics/geology
- Any special conditions

A planning memorandum, which can be done directly in the software estimation tool, is also recommended to be distributed.

PARTICIPANTS' PREPARATION

Preparation is an important factor for a successful estimation process, and therefore those who will participate must be prepared. For all the participants there is a duties list with the preparation activities that must be performed by them. This applies for all the participants, that includes project manager, process manager, data support and price setters.

This preparation work is crucial, so time is not wasted on going through reports and informing all the participants about the project and the status of the project.

One of the most important tasks is to gather relevant cost data. The sources of relevant costs or other empirical data may include the Cost Bank, reports, plans and information from colleagues who have executed similar projects.

PRACTICAL ORGANISATION

Practical organisation is related with the necessary logistic to organize a meeting that can last for three long days. The working conditions must be appropriated and that means to prepare a room with all the facilities and with an environment that allow the participants to work without getting distracted or disturbed by surrounding factors.

6.2.4 ESTIMATION PROCESS

METHOD AND ESTIMATION TOOL (ANSLAG)

The internal system of the estimation tool was built according to the execution process described here. This means that the estimation tool is able to keep up with the work tasks in an estimation process, creating both calculation data and written documentation of the work done. The estimation software toll can manage all the information, and at the same time collect it all for future use in a structured and effective way.

The main items of the estimation tool are review in the following. The items respect the workflow already mentioned in this paper, which is constituted by preparations, estimation

meeting and follow-up work. The following table summarize the main items of each of the work sequence.

Table 6.2 - Estimation process work sequences (NPRA, 2011a)

| ESTIMATION PROCESS | | | | |
|-----------------------------|-------------------------|---------------------------|------------------------|----------------------------|
| Preparations | | Estimation meeting | | Follow-up work |
| Project information | Estimation process | Project review | Calculation | Result |
| Project data | Name and revision | Prerequisites | Calculation tree | Calculation result |
| Cover page image | Method and execution | Analysis limitations | -detail card | S-curve |
| Preface | Estimation schedule | Interface considerations | -calculation table | Uncertainty profile |
| Project description | Programme/agenda | Stakeholders | - (contract breakdown) | Risk assessment |
| Project limitations | Inspection | Ambition level | | Assessment of measures |
| Principal quantities | Objective | Complexity factors | | Cut list |
| Project history | Estimation participants | Situation map | | Covariance |
| Cost development | Reference projects | Maturity assessment | | Process manager's comments |
| Overview map | Documentation | SWOT analysis | | Conclusion |
| Existing planning materials | Checklist | Int./ext. influences | | Report |
| | | Assessment of uncertainty | | |
| | | Assessment of incidents | | |

The size of the project, planning level and purpose of the estimation determines to what extent each of the items should be assessed. In the estimation tool an initial guide allow to select a template that shall be used for the process execution. By selecting a template, the software automatically indicates which factors are relevant to assess. The estimation tool has defined three templates with different levels of complexity:

- Quick calculations
- Simple estimation process
- Formal group estimate

PROJECT INFORMATION

Initially, relevant material is required to be review in order to attain an overview of the significant factors of the project. To do so, text and information that concerns the project at a general level is collect and archived on the software under “Project information”. Such information will be part of the introductory part of the report, therefore a brief and clear introduction to the project is provided.

ESTIMATION PROCESS

The estimation process is planned and the information distributed should give to the participants the necessary background into their role and the need for preparation. All preparation, execution and supporting material are to be documented.

PROJECT REVIEW

In order to develop a good estimate it is crucial to constantly review and analyse the project status. The estimation tool has established a systematic approach that allows observing essential factors under the process.

A called situation map may be utilized to describe the project's potential of uncertainty. This is primarily a warm-up exercise that allows perceiving some project attributes. The attributes are chosen and ranked in a scale and therefore represented in a chart. The chart will be the base for a discussion and assessment for each of the attributes, but detailed descriptions should not be allowed at this level.

The maturity assessment aims to verify if the project maturity is at the required level to the corresponding planning phase. The assessment is also done through a diagram available in the estimation tool. Each of the diagram's sectors is evaluated with a colour that can be red, yellow or green. Red corresponds to not good enough, yellow to should be better and green to OK.

The SWOT analysis is a strategic planning tool that allows identifying project strengths, weaknesses, opportunities and threats. The aim is to provide the group insight on where the project should be further worked on. It is mandatory for projects subjected to external QA.

CALCULATION

The estimation tool has available a visual interface that allows working with figures and visual models of cost items. At the same time, that provides an overview of the scope and content of the project and makes it easier to establish the cost model and identify possible correlation between cost items.

The model is basically a breakdown structure composed by digital mathematical building blocks with different properties. The estimate tree must reflect the structuring of the works and other cost items of the project.

A good breakdown structure should allow a good overview of the project. To achieve that, it is important to insert only the necessary information, to the required level of detail. The

method employs a top-down approach in the structure of the calculation, so there is no more focus on the detail than that is necessary. Two reasons are given for choosing this approach, they are: reduces the probability of forgetting small elements and reduces the stochastic dependence to better management levels. Therefore, the breakdown starts at the general level and is further broken down into details as is required.

Main divisions for the structure are suggested and for each project is must be assessed which of them are relevant. For each of the division, items are assigned together with their values as described in the following section.

Seven types of blocks built the items that are part of the estimation tree. Each item has a different function and is included in the calculation base depending on where they are place in the estimate tree. They must be named and a number based on its placement should be attributed. On each of them it may be defined and described the following:

Item types:

- Total
- Specified
- Add-on
- Value-added tax
- Derived
- Uncertainty factor
- Incident

For each of the cost items and for the internal and external influence, assumptions have to be carefully assessed in order to give value for the triple estimation. The minimal value should be specified first, then the maximum value and finally the most probable value for the item cost. Usually the basic estimate is made first and only after the internal/external influences included.

When is not possible to eliminate covariance between items the estimation tool may be able to account it in the calculation.

RESULT AND EVALUATION

The final result of the estimate must be assessed in order to determine whether it meets or not the decision-making criteria of the phase where it is being produced. That should be done by the group before the conclusions are made. The group must agree that the result is acceptable and that the results are adequate and realistic. To do so, there is a checklist that must be gone through until the whole group is satisfied and ready to draw a conclusion.

The estimate results must refer to the follow key figures:

- Price level – year for the price level that has been used in the calculation
- Estimate accuracy requirements. Dependent on the planning basis.
- P50 cost – the cost for which there is a 50 per cent probability that it will not be exceeded. (NOTE! This is the cost that is presented for the budget/reporting).
- Expected cost – sum total of the basic cost and the expected supplements. Expresses the statistically expected cost for the project.
- Standard deviation – expresses the spread of the distribution.
- Relative standard deviation – specifies the standard deviation divided by the expected value, in other words how great the spread is in relation to the expected value.
- Accuracy requirements – acceptance criteria for the upper and lower limits in relation to the expected value.
- Probability of values lying within the limits defined under the accuracy requirements.
- Lower value – based on the range of the accuracy requirement.
- Upper value – based on the range of the accuracy requirement.

The main items from the estimate should also be stated so it can be perceived from where the main costs come. In addition, the most important calculation parameters are listed.

Factors for evaluation:

- Probability of values lying within the accuracy requirements (acceptance criteria): All cost estimates shall have a 70 per cent probability of lying within the given estimate accuracy requirements. Deviations from the acceptance criteria, or special conditions (for example, a value of 100 per cent) should be communicated.
- Standard deviation: Gives a measure for the spread of the distribution.
- Relative standard deviation: Standard deviation divided by the expected value.

An S-curve of the estimate should be built. The curve represents project's cost uncertainty from where P values can be derived. From the curve the following factor may be evaluated:

- Management framework (P50): Specifies the management framework for the project manager.
- Cost framework (P85 cut): Is there a cut list that has been deducted?
- Slope of the curve: It gives an indication of the spread of the estimate (Steep curve for less uncertain estimates).

The uncertainty profile allows understanding which items have more contribution for the estimate uncertainty. To those items further assessment may be done in order to reduce that uncertainty.

All the identified incidents are listed and prioritized according to their probability of occurrence and respective consequences. These incidents are described and possible measures to be taken under the project execution defined.

FOLLOW-UP WORK

The Estimation Process generates raw material for several processes.

- Documentation of the result and assessments from the Estimation Process (transfer of experience)
- Basis for the subsequent decision-making process
- Basis for improvement and further development of the project
- Management signal – input for planning and focus for continuing work in the project

When the meeting is over and the estimate completed, the whole process must be documented. From the estimation tool all the input data and calculations results are printed.

To be used as a basis for the decision-making a report from the estimation process is build.

The report shall be evaluated regarding its fulfilment of the requirements of these guidelines.

7. DISCUSSION

7.1 ROAD PROJECT DEVELOPMENT

Unsuccessful projects resulting of public investments are in many occasions a very sensitive subject due to the attention they usually get from the media. Since such projects are mostly financed by tax and toll payers' money, and for being their money at stake they easily become a controversial topic. In Norway there is a general public opinion that road projects take longer that they should and that they cost too much. Norway has a difficult orography that makes some road projects in Norway very complex projects, making them consequently difficult to plan and to estimate. However, the NPRA must overcome such difficulties, and that is only possible by implementing the best methods and techniques to what concerns project management.

Organizations like the NPRA handle frequently numerous projects. Even though they are separated in few main divisions, the demand and need for new roads is still high throughout the whole country and the numbers of projects that run in each of the divisions is considerable.

Although it is expected that most of the executed projects are simple road projects, they are organized and prioritized according to the defined strategic goals. Moreover, road projects can be quite distinct and present different complexity levels, depending on the expected traffic of the road and the type of natural obstacles the road must overcome, resulting on different kinds of projects with different costs and risk levels. Therefore, projects cannot be treated equally and priorities must be defined. It is very common that one road project is divided in few projects to be executed in different phases, at the same time or not, therefore, resource allocation is crucial. Each of the projects may have its own project team, but a project team may have to manage few projects at the same time. Organizational planning plays an important role and the creation of programs and portfolios may allow optimization in a base of resource sharing between projects.

To choose upon each projects are to take forward, there are evaluation techniques, e.g. cost benefit analysis, that allows considering criteria and therefore substantiate a decision. Such kind of analysis enables a quantitative evaluation of the project where the social welfare created by the road has its weight. Increase of security, reduction of traffic accidents, decrease of the travel time and reduction of CO2 emissions and noise are for instance aspects that may be included on such evaluation. It is often used to justify political decisions that may not be understandable if only the financial side of the project is evaluated. Although selecting a

project involves doing and considering such analyses, the country's transportation strategy and political willing can and most likely will highly influence the final decision.

Once the decision of building a road is taken, a series of decisions and tasks are to be performed in order to deliver the project within requirements. The project goes through different phases that are known within project management environment as constituting the project life cycle. A road project and its more or less complex life cycle will always go through a phase of studies, planning and action that involves making use of engineering and project management capacities and tools.

On the conceptualization stage, a road may raise as one of few alternatives to fulfil a transportation need. At this early stage of a project, little is known and it is still not clear if the project will consist on a road project or if it will even take place, but if assuming that a road project became a reality so that alternative must have been surely studied, being so is the conceptualization stage the beginning of the life cycle of the road project.

The conceptualization stage may start with a stakeholder analysis in order to understand the willingness and expectations of those who will be, in a good or bad way, affected by the project (APM, 2006). It is important to perceive who might have the power to influence the project and who must be eared on this early project stage. The type of project must be idealized so road traffic numbers are estimated in order to provide information to fundament the decision on what type and size of road to build. It is also on the stage that must be defined if bridges, tunnels and other specific road element are to be used or not (Welde et al., 2013). By the end of this stage is when the first cost estimate is produced. As usual NPRA follows its estimation method to accomplish it, methodology which allows a still wide cost range at this phase.

A feasibility study should provide information regarding profitability, resources and capital financing needs. Other criteria as for instance environmental and economic benefits; decrease of traffic accidents; development of a certain region, and others may also be considered on the feasibility study. For instance, techniques as multi-criteria decision analysis and cost-benefit analysis may be used in order to consider all the mentioned factors and so, justify the choice of such alternative (Brucker et al., 2011). For the other proposed alternatives, it should run in parallel a similar study to enable fair comparison among them all.

Once the alternative is chosen, the project moves to the definition phase. At this stage design and engineering is put together. This phase usually experiments three different types of planning at a state, regional and local level. In this phase, design class and respective road

specifications are defined. That involves defining speed limits, number of traffic lanes and carriageways, tunnels, bridges, roundabouts, cycle tracks, and others. Work packages and construction processes are defined and a schedule for the project is created. A cost-estimate is produced being that, on the definition stage, it should be already expected a reasonable accuracy range, as required by NPRA's guidelines. Risk management, safety and security plans and others already mentioned before are created. The aim is to provide the owner with information that is closest possible to the final project outcome so the owner or sponsors can deliberate and decide if project should be built and funded it (Welde et al., 2013).

On the project implementation, the design is completed and, if it is the case, a base for a bidding process may be created. Consequently, the cost estimate performed here, should set the base price for the tender process. A contractor or a group of contractors on a joint venture agreement shall be selected and contracts are settled. So then, the actual work can start and the road is built. Most of the project resources are use in this stage so it demands constant control regarding respecting both planning and quality standards agreed (Pinto, 2010). The type of contract and how responsibilities are shared plays important roles here, but it is of the interest of both owner and contractor to avoid time or cost overrun.

Once the road is built, an expert inspects the quality of the project and if the infrastructure matches owner's request the responsibility of the road is passed and all the formal documentation transmitted and signed.

The project enters now on its operational phase, where the infrastructure is made available to the drivers. The owner or commissioners have now to secure the return of the investment. Usually this means to recover the financial investment directly from the project, but in a public projects such as a road project, this may stand for reduction of fatal accidents or increasing productivity in the transport industry.

During this period, maintenance activities take place regularly. Maintenance activities may be performed by the owner, but is more common that contracts are made with specialized companies to perform such works, especially for big infrastructures. Such activities imply costs for the owner and they aim preservation of the road, keeping it clean and safe. Big activities such repaving the road is done periodically and usually the period is agreed in advanced and can be done according to pavement live time or traffic levels (FHWA, 2014).

The operational phase continues until a point where the project is seen to be no longer needed or it does not fulfil the needs anymore. For a road the second reason is the more plausible, since traffic levels may increase through the years overloading the road, making it less safe

and too expensive to maintain. At a point the road may be substituted or see its scope changed, and may be the culmination of the road life cycle.

The following table shows a simple example of how project activities may be divided in stages and how to name them. It summarizes how the U.S. federal highway department perceives the first stages of the life cycle of a highway project.

Table 7.1 – Summary of a road project stages (FHWA, 2014)

| Stage | Description of Activity |
|----------------------------|---|
| Planning | Road authorities and local governments identify transportation needs and program project to be built within financial constraints. |
| Project Development | The transportation project is more clearly defined. Alternative locations and design features are developed and an alternative is selected. |
| Design | The design team develops detailed plans, specifications and estimates. |
| Right-of-Way | Additional land needed for the project is purchased. |
| Construction | The State or local government selects the contractor, who then builds the project. |

7.2 COST DEVELOPMENT

When comparing the study that originated this master thesis (Torp et al., 2012) with similar studies that analyse cost behaviour of transportation projects it is noticeable that the average cost overrun of the Norwegian road projects, from financing until project finalization, are actually the ones that perform better. Cantarelli et al. (2012) analyses the cost overrun during implementation phase of road projects in different countries. The data used for the Norwegian projects is taken from the study done by Odeck (2004). More than 600 projects analysed show an average discrepancy between estimated and actual costs of projects constructed by NPRA of about 8%. That value is close to the value achieved by Torp et al. (2012). For a smaller group of projects the results show a cost overrun, in average, just over 10%.

This reflection enables to conclude that the main problem with the cost estimates of NPRA's projects is before implementation, during planning phase. In such phase is harder to keep historical track of the estimate and much less information is available, nevertheless the cost increase from NTP until project financing achieved in Torp et al. (2012) is about 30%, which in authors' opinion is a substantial deviation. It is also observable that more than 20% of such deviation is between the estimate at the NTP and the HP (figure 1.3), thereby allowing to conclude that is the earliest estimate that is the main responsible for the total discrepancy. A publication that analyses Dutch road projects' underrun and overrun in two different project phases, pre-construction and construction phase, enables a comparison that complements such

conclusion. The mean deviation of the studied projects in the pre-construction phase is 17.6% overrun, confirming that the 30% is a poor result.

Such results confirm that in NPRA there is the knowledge and expertise to perform good estimates. The last estimates presented to the parliament, right before project funding proves that. That is because they experience reasonably small overruns until project conclusion, when compared with other countries. The estimation method and tools used are, or should be, the same in all the stages. That raises the question if the deviations are caused by the estimation method used or if there are other causes. One possible cause that could not be confirmed in this paper is that the method may not be used before NTP at all. Given the previously analysed results, it is believable that, in some cases, the project cost at NTP may be based on a rough value reached by guessing.

7.3 NPRA'S VERSUS GAO'S COST ESTIMATION PRACTICES

The handbook 217, which describes how every cost estimation process done by NPRA for investment project should be conducted, is a reasonably short manual, easy to read and provides direct information on how to perform each of the tasks that the method consists of and how the process proceeds. NPRA's method makes use of an estimation tool called 'Anslag', which is the Norwegian word for estimate. The guidelines are given in a way that would only make sense if the estimation tool in use is the mentioned. All the procedures of the estimation process account tool's capabilities and limitations. Moreover, it sets in advance the needed requirements to implement the method and some background theory that is useful to acknowledge to correctly interpreting the handbook.

The U.S. Governmental Accountability Office's cost estimating and assessment guide is, on the other hand, an extensive book that is recommended to all the organizations that estimate costs of public investments in the U.S., both on the public or private sector. It may also be used by the governmental authorities for auditing estimation processes of organizations to which they may work with. Does not always define clearly what a task involves, it states instead generally which parameters such task should comply with, using definitions for what each task should consist of. Since it can be used for all type of projects, it is not as specific as the NPRA method, which is a method to estimate road project's cost, but on the other hand addresses in a greater extension many other factors present on a cost estimation. For this reason it cannot be seen as a cost estimation method itself but firstly as a series of ground rules that an estimation process should adapt to.

When reviewing the process suggested by GAO (2009) and the steps that constitute it, many similarities with NPRA's method are found. The first step of GAO's estimation process - define estimate's purpose - is reflected on the NPRA's method on the requirements chapter, where things as for example planning levels and accuracy requirements are defined. The second step – develop estimation plan – is partly covered on the NPRA's method still on the requirements topic, where indications for who should take part on the estimation team, and further on the topic workflow and roles, where working plan and members' roles are defined. Since NPRA's methodology is only used through the planning phase, a phase when design is not fully developed yet, and always for road projects, the GAO's step called 'Define program characteristics' takes place on the NPRA method only by providing the participants materials that should provide a good overview on what consists the project.

The methodology to breakdown the estimate elements and the estimating structure proposed by NPRA's method puts in practice most of GAO's recommendations. It gives, for instance a standardized structure as is said by GAO as being best practice.

The step of collection data gets little guidance of the NPRA's method when compared with GAO's guide. Nevertheless the NPRA's method follows some of the best practices, but author's opinion is that more information regarding the data sources used could be given, as for instance how the data retrieved from the Cost Bank is treated regarding inflation.

NPRA's estimation method is used at the concept and planning level, stages where it has been observed a cost development that shows that the earlier estimates are frequently underestimated. The NPRA's guidelines for estimating fail by not making aware of such fact. This issue has been introduced before in this paper and is usually found in many textbooks, guidelines and standards that are related to cost management. The American cost guide approaches the issue and gives some recommendation in order to achieve more realistic point estimates. In addition some reasons that may explain why optimistic estimates are often developed are given. It is stated that "cost estimators may have ignored program risk, underestimated data outliers, relied on historical data that may be misleading for a new technology, or assumed better productivity than the historical data supported, causing narrow uncertainty ranges. Decision makers may add their own bias for political or budgetary reasons".

In order to determine whether a project is realistically budgeted, GAO (2009) recommends the execution of a uncertainty analysis to be reflected on a cumulative probability distribution know as an S curve. Such technique is also adopted by the NPRA's method but the U.S. cost

guide is flexible to what concerns the percentage of the confidence level to use. It is stated that management may analyse the data from the S curve to choose the most appropriated point of the probability distribution. It is added that “how much contingency reserve should be allocated to a program beyond the 50 percent confidence level depends on the program cost growth an agency is willing to risk”.

The Norwegian public road administration has decided that P50 is the value used to state the official cost estimate. The author's opinion is that a more flexible approach is more beneficial and may allow, especially on the earliest estimates, better estimates. That may be even more useful when projects that involve new technical solutions or are built in an unknown area are to be estimated, i.e. project with great uncertainty. Nonetheless, the stochastic approach that NPRA's method uses, the possibility of considering covariance between items and the calculation method adopted (Monte Carlo simulation) makes it consistent to what regards the best practices for considering uncertain quantities in cost estimation. In addition, it requires that all cost estimates have at least 70% probability of lying within the interval of the given accuracy limits, which vary depending on the planning level the estimate is produced. That allows having less spread results and steeper S curves, thus producing better results.

Other approach introduced by GAO's guide for dealing with uncertainty is the cost growth factor. The factor is “a percentage increase, based on historical data from similar programs, or an adjustment solicited from expert opinion and based on experience. This yields a revised cost estimate that explicitly recognizes the existence of uncertainty”. By using such factor, the estimator reflects on assumptions and judgments from the development of the cost estimate and if necessary makes an adjustment to the estimate (GAO, 2009). Given the history of cost development of NPRA's project, confirmed by Torp et al. (2012) this could be something useful to introduce on their methodology.

GAO's estimation process requires a comparison of the estimate with an independent one. The Norwegian approach, even though different should be also seen as best practice since it is reviewed by independent organization through the quality assurance scheme.

To conduct a sensitivity analysis is a requirement of GAO's process that is not fulfilled by the NPRA's method. A sensitivity analysis allows identifying the most uncertain items and further analyse them. That can help to reduce some of the estimate's uncertainty by attributing to such elements a wider cost range. However, the NPRA's process allows assessing uncertainty and incidents. They may be quantified and therefore considered on the estimate calculation. The NPRA's estimation tool enables uncertainty assessment through techniques

such as the SWOT analysis and another which is called maturity assessment. They allow scoring risk categories and perceiving, through a diagram, which of the categories are more or less uncertain. Internal and external influences are identified and rules for brainstorming are even given. That should allow the estimation team to identify a cost range and the respective probability of a cost element. Although none of these techniques are mentioned by GAO's guide, the used techniques are also based on scoring categories, and therefore based the same fundamentals.

The last three steps of GAO's guide and the main recommended practices are partly incorporated by NPRA's methodology on the chapter 'follow-up work' of the NPRA's handbook, where the generated material of the estimation process is handled.

NPRA's estimating method makes use of many practices that are found by GAO as being best practices for cost estimating. There is, on the other hand a step that constitutes GAO's estimation process, and is considered as part of the best practices activities, that is not part of the NPRA's method. That is the case of the sensitivity analysis.

It should also be considered that NPRA's method is only used for early cost estimates, being most of them simple estimates based on little detailed information. For that reason the author's opinion is that the method should always be kept simple as it is, even though some measures to tackle cost growth, as for instance the ones recommended by GAO's guide, could be introduced. With an easier approach, a chapter could be added to the handbook 217 where topics such as optimistic estimation and cost growth are addressed, and in that way create awareness about the issue among estimation team.

8. CONCLUSION

It is common that public authorities create guidelines or even standards for cost estimating, to which public organizations may account when dealing with public investments. The same happens in Norway since the Ministry of Finance published the guidelines number 6 which refers to cost estimation (original name: Veileder nr. 6: kostnadsestimering), but NPRA went further and produced its own cost estimation method which was published in the form of a handbook, that is therefore assessed in this paper. As the main objective of the master thesis, such assessment aims to enable the author to understand how the estimation process runs and on which techniques is based. Having the main objective in mind and the formulated research questions, the NPRA's cost estimation method was evaluated regarding its situation when compared with those that are considered the best practices for cost estimation, and its approach to cost increase control along the project planning phase.

The first part of the work gives theoretical information that builds a background that allows framing many aspects that are addressed in this master thesis. It allows, for example to situate in the life cycle the milestones that a road project in Norway meets and the course it takes since the NTP until parliamentary final approval for construction, including the QA scheme.

Further in the paper, the assessment both the NPRA's handbook and U.S. GAO's guidelines show that even though NPRA's method is easy to understand and to implement, and that mostly meets those that are considered best practices, it presents some flaws with regard to the issue that was one of the concerns of this paper, the cost growth. The method was last time updated already in 2010, so it may be recommended that in a next revision the used methodology is improved and new strategies are introduced in order to address some of the detected issues.

Given the research method used and the type of data analysed, the main conclusions of this paper are obviously influenced by author's interpretations and perspectives. Nonetheless the author reckons that they are valid, considering therefore that the objectives proposed are accomplished. In addition the author also feels that in general the learning process through the elaboration of the master thesis was positive and rewarding.

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