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A framework for assessing uncertainties in benefit cost analyses in the Norwegian road sector.

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Abstract:
Nowadays the limited project information in the early phases of projects leads to high degrees of uncertainty, which make cost estimation become a complex and challenging task that in some cases results in cost overruns in road projects. The estimates calculated during this task are later used in the so-called Benefit-cost analysis (BCA), which constitute one of the most common evaluation methods in the road sector. This means that the results of the BCA are also affected by uncertainties. In the case of Norway the problem is that this results are presented to the decision makers as one figure without due consideration of the uncertainties regarding their expected outcomes.

In relation to this, the present master thesis suggests a framework which simplifies the process of calculating confidence intervals referred to the benefit-cost ratio, alongside with a method for ranking projects that includes uncertainty parameters as a part of the considerations that must be taken into account when, due to limited government funds, there is a need to choosing between competing projects.

Keywords:

Road projects
Benefit cost analysis
Cost estimation method
Uncertainties

Preface

This master thesis is written as a part of the International Master Programme in Project Management held by the Norwegian University of Science and Technology. It consists of 30 ECTS and is conducted during the 4th semester of the programme, on the spring of 2015. Both the first supervisor, James Odeck and the co-supervisor, Olav Torp, belong to the Department of Civil and Transport Engineering at NTNU.

Based on the findings from a course called "Economics of Transport Infrastructures" where different techniques related to benefit-cost analysis and uncertainties during the project process were deeply studied and evaluated, the topic of the present master thesis was raised. Thus, this paper gathers all the necessary information related to different ways of evaluating projects and techniques for cost estimation, which will later allow focusing in one of the most important drawback in the Norwegian framework for benefit cost analysis: the lack of a systematic method for ascertaining confidence intervals for BCA results in relation to their uncertainty.

Trondheim, June 10th 2015

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MSc in Project Management

Abstract

In Norway, the governmental agency which is responsible of all the processes related to the planning, construction, and operation of the road infrastructures of the country is the Norwegian Public Road Administration (NPRA). This entity is the one that, every time there is a need for a new infrastructure, have the initiative to start a road project, alongside with the responsibility of supervising and controlling it. Moreover, the NPRA established in its handbook 140 most of the principles and considerations that must be fulfilled every time an evaluation of projects has to be done. For this purpose, it establishes not only different methods, but also differentiates between three types of impacts whose analysis should be included when evaluating project if the aim is to see how the implementation of a project can affect the society.

In relation to the Norwegian society, it must be also said that during the last years the amount of funds for investments in roads has been increasing due to the fact that road tolling has become a common practice which allows getting money from the road infrastructure. Nevertheless the funds from the national budget have been decreasing which has lead to the necessity of prioritizing projects.

One of the most common practices in Norway when considering a road project for investment is an evaluation method called the Benefit-Cost Analysis (BCA). This method consists in comparing a new construction alternative over the "do-nothing" scenario by analysing costs and benefits of both the alternatives. As it can be easily understood, both costs and benefits must be estimated when they are considered in the long term so it is at this point where the need for cost estimation arises.

Cost estimation is a complex process where major decisions must be made under high levels of uncertainty due to the lack of information about situations or happenings that can take place in the future. Thus, the accuracy of the estimations can vary from stage to stage in a project, being the level of uncertainty much higher during the front-end phases than in the end of the project.

In order to better understand how estimations are made in Norway the present thesis explains in detailed the process followed by the NPRA when implementing cost estimations, with the main idea of identifying how uncertainties are dealt in relation to those estimates. As it will be later explained, the consideration of uncertainties during the cost estimation process are succinct, but the considerations of those uncertainties when analysing the posterior BCA results are not enough, in some cases such considerations are not even taken into account. This drawback, which motivates the present master thesis, needs due consideration due to the fact that uncertainties regarding expect outcomes in a BCA may impact decision makers´ decisions.

This work presents a framework that can facilitate the procedure to calculate confidence intervals for BCA results; more specifically it defines, in a simple way, the steps that

have to be followed in order to get the confidence interval for the Benefit-cost ratio, a ratio used to prioritize projects when not all of them can be undertaken due to a limitation of the government´s budget. This framework will be later tested in a specific case of study, where 44 projects are analysed. Part of the analysis of these projects will consist in ranking them depending on different parameters such as the expected net present value (NPV), the benefit-cost ratio (BC-ratio), the standard deviation and the amplitude of the confidence intervals referred to the BC-ratio. Moreover, the programmed spreadsheet developed by Vatn J. (2013) will be used to model the results of that analysis. This programme, known as pRisk, will allow performing Monte Carlo Simulations and obtaining the S-curves of the profitable projects. Finally the aim, after analysing these projects, is to rank them according to uncertainty parameters. In this way, the proposed way of ranking can be considered as a solution that the present master thesis suggests to solve the Norwegian drawback related to the consideration of uncertainties that was previously explained. Even though the model proposed to rank has demonstrated to be consistent, its accuracy may be improved by more advanced research in areas as for example risk management.

Summary

Nowadays, every time there is a need of undertaking a project, different alternatives are considered. The differences between those alternatives can be related to technical or economical aspects, so in order to identify the best alternative a deep evaluation of both technical and economical aspects must be carried out.

According to this it is important to highlight that there exist different ways of evaluating projects depending on the impacts that are taken into account. For this reason, a big effort is needed to distinguish between impacts that can be considered when developing a benefit cost analysis and those impacts that due to the fact that cannot measurable in monetary terms must be considered as a part of another type of evaluation.

On the other hand, if the evaluation of the different alternatives focuses on the monetised terms, special factors must be considered when developing a benefit costs analysis. Some of those considerations are related to the fact that infrastructure projects have a long lifetime, which implies the need of using a long term perspective when analysing the project further in the future. In this moment is when uncertainty in relation to some of the estimates that are used when calculating cost or benefits during the whole life cycle cost of the project comes into play.

Cost estimations will highly influence the decision-making process regarding the selection of the preferred alternative to be implemented when considering several road projects. For this reason many governments have published their own standards or guidelines with the aim of including all the existing tools and knowledge that are available in order to create good cost estimations. However, it is the consideration of the uncertainties which makes the task of making good estimates more and more challenging. Thus, during the pre-investment phases, where there is a higher level of a uncertainty and a relevant lack of definition, the process of obtaining accurate estimations become very complex.

On the other hand, later on when cost estimations are used in the benefit cost analysis, there exist again a need to include those uncertainty factors as aspects that must be taken into account when choosing between different alternatives, but this is something that is not commonly applied in Norway.

For this reason, this work propose, by taking into account the stochastic nature of the project costs, a possible solution to this matter, which constitutes an academic effort to contribute to the improvement of the basis for the decision making process. It is important to notice that in some cases a reduction of the uncertainty in a project can be preferable instead of a project with a high profitability. For this reason what the proposed solution suggests is not only a framework to simplify the methodology used when calculating confidence intervals in relation to the BC-ratio, but also a methodology to rank projects where uncertainty factors can be considered with the aim of aiding decision makers to identify those projects with lower levels of uncertainty.

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1. Introduction

1.1 Background

Nowadays there is an increasing interest in relation to the different strategies that can be used to allocate funds when talking about transport infrastructures. Thus, different countries around the world are using different strategies to allocate money in this type of projects, always considering not only the different economic situations, but also the orientation and policies of the countries themselves.

Depending on the country policies, different methods of getting money can be used. The most common ones are the use of private public partnerships (PPP), where not only financial and technical support, but also operational risks are shared between both the public and the private sector, and the use of tolls, which allows to get money for financing the investments

On the one hand, it is important to highlight that the interest in public private partnership has been growing notably during the last few decades due to an increase in the need of new infrastructures where a higher level of expertise and new technology is demanded by the public sector. It is here where the private sector can contribute because, as it is known, all the major infrastructure projects have been typically undertaken by private companies, so their experience and way of solving habitual big problems that usually appear during the normal development of those projects is what the public sector really needs. (G.W.E.B, van Herpen., 2002) On the other hand, the public funds are sometimes not enough to implement huge projects, so in those cases the different governments consider as appropriate the implication of the private sector. The point is that the public sector seeks to invest the minimum amount of money in order to not incur in any borrowing. In this way the PPP can be understood as a new way of financing the new assets from the public sector´s point of view. (V, Tan. et al, 2012) In the case of Norway, this type of partnership has not been commonly used during the last years because it has been the government which takes the responsibility for the public road system. However it is starting to be one of the preferred alternatives when undertaking big projects in this country.

In relation to toll financing, it is important to notice that it has been a very common tool used to finance road projects in Norway since more than 70 years ago, when the Vrengen bridge located near the town of Tønsberg was financed using tolls. However, this method of funding has gained more and more relevance during the last 30 years and nowadays, when funds from the national budget have been decreasing, more than the 35 percent of the total annual budget for road construction is constituted by the net revenues from toll financing. According to this, the importance of making good estimates of the costs and net revenues can be better understood due to the fact that it implies not only the government budget but also the money that motorists spend on tolls. (Amdal, E., et al, 2006)

In Norway, the governmental agency which is responsible for the public roads is the Norwegian Public Road Administration (NPRA), known as Statens Vegvesen. This entity is responsible for everything that is related to planning, construction and operation of the roads and it is the one in charge of planning how the investments are going to be allocated around the country. (NPRA, 2013)

Every time a road project is considered, the NPRA has to develop a deep study of the concept, so this entity can be considered as the decision maker despite the fact that one or more external consulting companies can also help with that study in case of having larger or more complex projects

This study can be better understood with the following graph, where the whole process is represented.

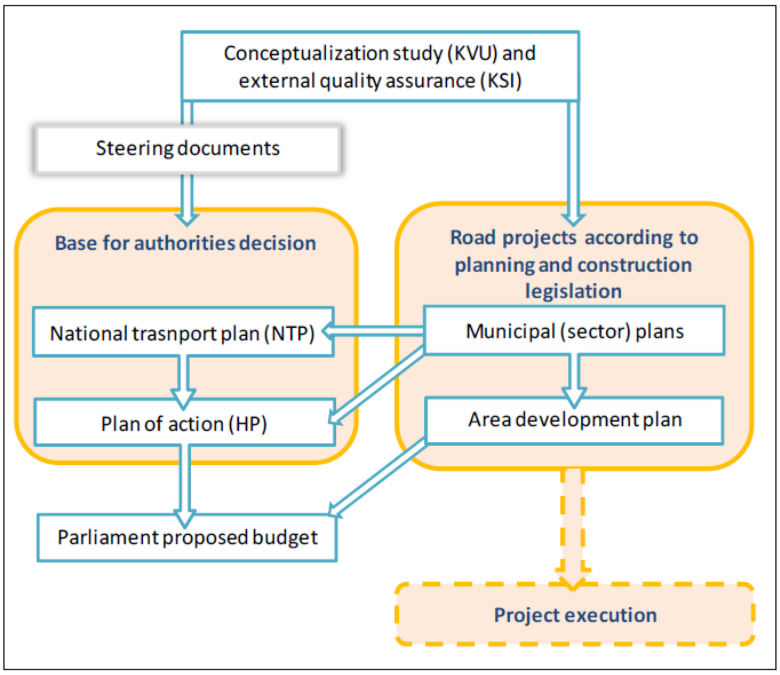


Figure 1.1 - Road planning through NPRA's management process (NPRA, 2014)

As shown in the graph both the conceptualization study and the external quality assurance can be considered as the base for the final decision that will be taken by the authorities. First of all, the chosen concept, after being approved, will become a part of the National Transport Plan (NTP), which is an official document submitted every four years to the Norwegian Parliament. This document is elaborated with the help of the governmental transport agencies, where the NPRA is included, and it establishes the main strategies, goals and policies in relation to transport projects for the following ten years. (NPRA, 2014)

At the same time while the project is evolving there is a process through which an estimation for the project cost must be given. This process includes three different estimations. The first one is established at the very early stages and it is included in the National Transport Plan. As it can be easily understood, this first estimation will result on significant deviations because of the great amount of uncertainty that usually characterizes these early stages. After that, a second estimation, which is closer to the final budget due to a lower uncertainty, is included in the Plan of Action (Handlingsprogram, HP). In this document, which is valid just for four years, the NPRA includes the implementation plans of the National Transport Plan, setting the base for the budget elaboration which takes place every year. The HP establishes the plans for investments on the Norwegian road network with the main goal of reaching the goals and developing the strategies for the first for years of the NTP. (NPRA, 2013). Finally, before allocating the funds, the third cost estimation is done. In this case, the estimation is more detailed and its uncertainty is much lower. It is this one, which is presented to the parliament with the main objective of being resolute to be able to start the project and funding. (Welde et al., 2013).

As mentioned before, all these three estimations are in most cases too optimistic, even when referring to the third one, which is performed just before the funding where the level of detail and information is supposed to be higher than in the previous phases. Thus, special attention must be given to these estimations in order to avoid cost overruns during the development of the project. It is in this context where the present thesis is going to focus, not only by developing a deep literature review and research, but also by analysing a specific case study where 44 road projects will be included.

1.2 Problem definition

As previously said, all the estimations that are done during the planning phase constitute one of the most important task within an organization due to the fact that implementing a bad cost estimation can result on economic losses or, what is even worse, a lack of control in relation to the financial sources.

Moreover, what concerns this thesis is the fact that those wrong estimations, when talking about public organizations, can lead not only to the waste of population´s money paid through taxes, but also to a wrong prioritization in the case of having more than one project to implement when there is a scarcity of public funds. Therefore, despite the fact that in Norway the “Anslag” method can be considered as highly sufficient for ascertaining the accuracy of estimates, there is still a lack of a framework for ascertaining confidence intervals for benefit cost analysis results. These confidence intervals present the uncertainties regarding their expected outcomes and can help decision makers when choosing between different projects.

1.3 Objective

The main goal of this thesis is to establish a framework for ascertaining confidence intervals for BCA results that are conducted to aid informed decision makings in the road transport sector in the case of Norway. Such a framework is currently lacking. Thus, the thesis will be a contribution to the literature on uncertainty of BCA estimates with Norway as case study.

The framework that will be developed will be largely built on a literature review. This review will focus, first of all, on how organizations apply different project management tools in order to compare different alternatives and decide upon the projects they are willing to undertake, since nowadays the limitation of resources make it impossible to implement all the projects proposed. Other learning outcome is to get a good understanding, not only about the developing process when implementing a BCA, but also about the cost estimation process followed by the Norwegian Public Road Administration. During this process uncertainties are dealt, and here the need of a framework for ascertaining uncertainty is clearly evident.

Finally the developed framework will be tested on actual data from proposed projects. In particular, data from BCA estimates of those projects will be used to elaborate the magnitudes of uncertainties in those estimates and strengthen the derived proposal.

1.4 Research questions

Since long time ago Norway has been considered as a country where the communication infrastructures have always been difficult to build because of the complex orography. Norway is a country with more than 385000km^2, which creates the need for long roads as part of the communication network. Moreover, due to the existence of many fiords and mountains, the difficulty of building, not only roads, but also other communication infrastructures, seems to be evident. For that reason, alongside with the fact that nowadays the limitations of funds make it impossible to undertake all possible projects, there is a need for establishing some criteria which, together with some project management tools, allows evaluating different alternative projects before starting to implement them. Research question 1: What are the main considerations that the NPRA takes into account before implementing a road project in Norway?

On the other hand, in the construction industry there are several techniques that can be implemented to estimate project costs, which later will be used as part of the data in the benefit cost analysis used for evaluating projects. Thus, estimating project cost can be considered as one of the most important tasks in both the private and the public sectors.

Due to the fact that many variables are to be considered when estimating project costs, many governments have published their own standards or guidelines with the main aim of including all the existing tools and knowledge that are available in order to create good cost estimations. Some examples of good practices in relation to cost estimation around the world are those suggested by The Authority for Total Cost Management (AACE) or the ones in the guide published by the Accountability Office of the Government of the United States. So the second research question arises here: What is the method used by NPRA to make estimations?

It is important to say that from the early phases of a project until the most mature phases there are several estimations that must be done. All of them have a certain amount of uncertainty that should be considered in all those stages. This amount of uncertainty, due to the lack of information, is greater during the early stages, but must be assessed and analysed with the main aim of reducing it as much as possible. Research question 3: How are uncertainties dealt with regards to cost estimation in the case of Norway?

Those estimations and their uncertainties will be later used in the so-called benefit cost analysis. At this stage the uncertainties can again influence the decision makers. Here the fourth research question arises: How can confidence intervals for BCA results can be analysed and evaluated in order to help decision makers when ranking projects?

By answering the previous four research questions the present master thesis will lead to the objectives established before. Thus the following sketch can represent the whole flow of the thesis.

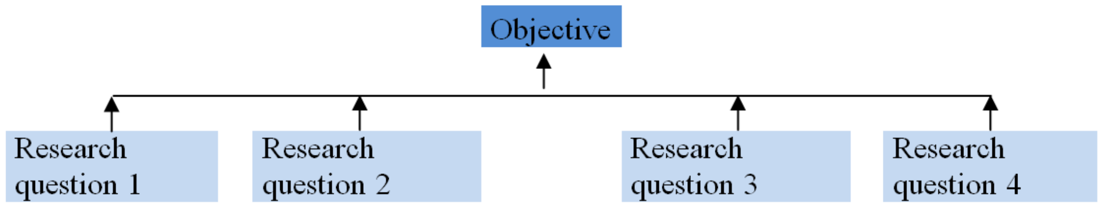


Figure 1.2 - Reaching the objective of the master thesis

1.5 Scope of work

This master thesis focuses on the methodologies that are used by the NPRA to evaluate projects and estimate their costs. Those estimations include uncertainty. Thus, with all the information regarding this topic the author of the thesis wants to create not only an overview of principal practices used in Norway for cost estimation, but also to develop a deep analysis of these practices with the aim of creating a framework for ascertaining uncertainties that can help decision makers when choosing between different projects.

1.6 Content of the chapters

The first chapter of this thesis is an introduction to the topic that is going to be developed later on. In this manner, some background information, together with the objective and the research questions that will lead to that objective are described. Moreover, the scope of work and the outline of the whole thesis are also included.

The second chapter includes the methodology approaches used for writing the present master thesis, with detailed information about the sources used during the literature review and the differentiation of research methods put in use in this case.

The third chapter covers literature related to different project management tools and different methods used to evaluate projects in Norway, where different types of impacts are further considered for that aim.

The fourth chapter is related to the different practices implemented when developing a benefit cost analysis. Thus, different considerations, specifications and limitations of the methods are included.

In the fifth and sixth chapters literature related to cost estimation process, not only in a general way, but also in the specific case of Norway, is covered. It is in this part where the most common techniques for cost estimation are explained, alongside with a deep study of the guidelines that are proposed by NPRA in the handbook 217 in which is related to best practices in cost estimation.

In the seventh chapter literature related to uncertainties and the way of analysing them is included. This chapter will contribute to a better understanding of how uncertainties in different stages of a project can lead to results that cannot be easily interpreted.

The eighth and ninth chapters consist of the development of a framework for ascertaining uncertainties in benefit cost analysis and its further application to a case study where 44 projects are analysed.

Finally, chapter ten and eleven, consist of a discussion and conclusion of the master thesis, respectively.

2. Methodology

In this chapter the methodology used during the present master thesis is going to be further described with the main aim of explaining the different approaches that have been used not only to assess information, but also to analyse thr data. The first step in the elaboration of this thesis was the election of a specific topic, which was initially defined by the author after several considerations in which concerns possible improvements that can be done in relation to different ways of evaluating projects in Norway. Later, in order to contribute to define a more specific topic, a strategy to narrow the scope of the thesis was delineated. At this stage the idea of writing about estimations and uncertainty when considering road projects in Norway came up.

2.1 Literature review

As defined by Cronin et al (2008) a literature review can be considered as the compilation of relevant literature related to a specific topic of research. Thus, the higher the quality of the information collected the more rich the content of the literature review. For that reason, before writing a literature review a research for high quality literature is needed, where the author´s point of view cannot be included.

In the case of this thesis, the purpose of using a literature review is to contribute to a better understanding of the issues that are being addressed, which includes information about different project management tools alongside with details about how evaluations of road projects and cost estimations are done in Norway. This will later allow understanding how the uncertainty of cost estimations can affect decision makers when choosing between several projects. So as it can be seen, this literature review will contribute to the creation of answers for the research questions established before. Thus, the body of the literature review in the present master thesis will consist of a structured and organized text, which will include the necessary information to deliver a clarifying and comprehensive paper about the research topic.

After delimiting the scope of the literature research, there is a need to delimitate the search as much as possible. As it is known, there exist many different sources in relation to academic libraries, institutional websites or other academic online sites, but not all of them can be interesting to use, so a selection of sources must be done with the main objective of choosing just the databases that not only perfectly fit the scope of the literature review, but also contribute with reliable data. One way of selecting and filtrating for relevant search results is to use specific search keywords which, if well chosen, can help to refine the search. In some cases the combination of different keywords can also contribute to improve the search. (Cronin et al., 2008)

Apart from this, it must be also said that during the search all the results must be evaluated according to their relevance with the objective of gathering just the appropriate information. This evaluation can be done by getting the sense of the sources that are being considered. The goal here is to know what the different sources are about by briefly reading the summary, the abstract or simply having a look through the source content. Thus, those sources which can be relevant to develop a further assessment can be determined. (Cronin et al., 2008)

Finally, a selection of the most relevant sources that are going to be used during the literature review must be done through a deeper evaluation, where criteria such as objectivity, accuracy, or reliability have to be considered. In this manner, with the help of a more systematic and critical review of the sources content, the aim is to reduce the amount of sources, without forgetting that they have to contain the necessary amount of information to write the literature review. (Cronin et al., 2008)

2.2 Data collection

Every time a research is to be done there is a need to gather data that will be later analysed or interpreted. The problem here is that such a collection of data is not as simple as it can be considered in the first moment.

In this thesis, due to the fact that an important part of the information that has been used has been already collected by others, the research developed here can be considered as a secondary research based on secondary data where all the data were collected originally by other researchers. (McQueen et al, 2002) Some of the advantages of using this type of data are, for example, the fact that it has been very easy and cheap to find them. On the other hand, some drawbacks with secondary data have also appeared during the implementation of this thesis. The most relevant disadvantage was the huge amount of information that was initially found not only on internet, but also in previous courses. This made the process of focusing in different specific aspect of the topic more complicated because it made the author feel overwhelmed in some cases.

In relation to qualitative data, data that cannot be measured and that deals with descriptions, three different methods for collecting them can be identified:

Documents and materials: On the one hand documents comprise a variety of print sources which in some cases provide historical information about how specific issues were dealt or perceived in the past, while on the other hand materials consist of visual art, instruments, pictures, or other things that can help to tell a story. (Chism et al., 2008)

Interviews: in this case data from certain participants can be collected by the researcher about a specific issue. It means that data are based on the participants´ points of view about the topic that is being addressed. Thus, the researcher can learnt from the experience of those who are being interviewed. However, in this case perceptions and personal views of the different participants have an important role during the interview, so in some cases the results cannot show what the real experience is. (Chism et al., 2008)

Observation: here the observer can be an outsider (direct observation without manipulation of the participants behaviour) or can be a participant-observer, (participant observation) but what is clear is that in this type of method the results are not filtered by the participants, (Chism et al., 2008) which is the main difference in comparison with the interviews.

2.3 Research methods

When conducting a research there are different approaches that must be considered whenever data are collected, analysed or interpreted. Thus, when elaborating a thesis, these methods can help to follow the normal flow of the study that is being developed. These methods can be classified as qualitative, quantitative and mixed methods approach depending on the strategy that is being addressed and the nature of the posed problem. (Creswell, 2014).

On the one hand, as defined by Creswell (2014), **qualitative methods** are research processes that are based 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”. These methods consist in understanding and analysing different interpretations related to a specific problem, with the main aim of understanding non-numerical data in order to create a determined perspective.

On the other hand, **quantitative methods** are based on dealing with numerical data that in some cases can be related to the other researches based on quantitative data. The aim now is to examine different relationships between variables in order to test objective theories. (Creswell, 2014)

Finally, the mixed methods approach can be defined as a mixture of both the previous methods, where both qualitative and quantitative data are combined. In this manner, it is easier to have a better understanding of the research problem than when using only one of the previous methods alone. (Creswell, 2014)

2.4 Research strategy in the present master thesis

This master thesis has as its main subjects of research the methods that are used in Norway to evaluate projects and the cost estimation process that is implemented before undertaking the benefit cost analysis of the various alternatives that can be proposed as solutions for a specific road project.

On the one hand, methodologies that are used for evaluating project have been analysed by using documentation related to several courses that the author attended during a two year master in Project management at NTNU. These courses are Project planning and analysis (TBA 5200), Project planning and control (TPK 5100), Risk management (TPM 5115), Economics of Transport Infrastructures (TBA 4315) and Project Management, advance course (TBA4128). Besides, another part of literature that has been used in this part of the thesis consists of several articles that were found in the net and notes that the author wrote when studying a degree in Civil Engineering in Spain. All this documentation provides a strong theoretical background of all technical information given, together with much information about the studied subject and several details about processes and methodologies used when evaluating projects. Moreover, examples or other documents were also used to contribute to a better understanding of the addressed subject.

On the other hand, everything that is referred to the cost estimation process that is followed by the NPRA, has been described with the help of the guidelines that are included in the Handbook 217, an official document that is available in the NPRA´s website. This document has helped the author of the thesis, after a deep study of the information, to assess the methods and practices used for cost estimation. The goal in this case is to understand the cost estimation method proposed by the NPRA. This goal has been reached not only by using the information in the Handbook 217, but also extra documents in the form of print sources and technical biography, which have been critically examined.

As it can be understood, the majority of the present paper is built on a qualitative approach, where non-numerical data is analysed. These data is based on human experience and interpretations and is to be studied and understood by the author of the thesis. However, after developing a framework for assessing uncertainties during the benefit cost analysis, a case study has been analysed. In this case study numerical data related to 44 different road projects have been used after compiling it with the help of Norwegian consulting companies, so in this last part of the thesis a quantitative approach has been used.

Finally when concluding the thesis, a mixed method approach has been used, due to the fact that part of the conclusions are based in both numerical and non-numerical data.

3. Pre-project development considerations

3. 1 Project management

In this chapter literature related to project management is to be covered with the main aim of understanding how project management tools can be used in the most efficient way to contribute to the achievement of goals in an organization.

As defined by the PMI (2008) a project can be defined as a temporary group of actions that can be undertaken in order to get a unique service or product. In relation to this, it must be highlighted that it is important to take into account the adjectives unique and temporary. The former refers to the definite period of time that every project has and the later refers to the concept of reaching a goal of creating something different from all other products or services that have been created when undertaking other projects. With respect to the temporary character of projects, it must be pointed out that projects, as for instance in case of having a road project, can last for years even after opening the road due to the fact that maintenance and operational activities are also included as part of the whole project. In other cases project can last just some days and it is then when they can be called short-term projects. In all cases, otherwise, there is a common need for the management of those projects. Thus, project management can be defined as the application of all tools, techniques, skills and knowledge that are necessary to accomplish the requirements of the project and its purpose. (PMI, 2008) It can be said that the use of project management tools contribute to a great extent to running the project in time, at the same time it avoids extra costs or a lack of quality in the final result of the project. In other words, it can be said that the use of project management tools has been proved to influence the deliverables in terms of standards. (Rathore, A.,2010)

3.2 Program and portfolio management

Regarding the number of project that a specific enterprise can run at the same time, it must be specified that there are cases where just one single project is run but in other cases several projects can be run at the same time. According to this, the concepts of program management and portfolio management must be defined.

On the one hand, in case of having several parallel projects, more complex governing structures are needed, where program managers are able to manage large-scale efforts comprising parallel projects. In most of the cases this structure is divided in three different levels; the higher the level, the more general the responsibilities. It can be said that in the bottom of that hierarchy are the project managers whose main responsibility is to allocate resources of the various projects that comprises the whole program. In the second level program managers are the ones in charge. Their main responsibility is to ensure the goal, that result from the work efforts, is achieved by following the strategies of the organization. At this point the need of setting and reviewing objectives, coordinating activities across projects, and overseeing the integration and reuse of interim work products and results appears. (Hanford, M., 2004) Besides that, as one of their main tasks, they have to monitor the projects in terms of quality, time, cost and possible risks and problems which can be possibly related to other projects. (APM, 2006) Finally, at the end of this hierarchy are the program sponsors and the program steering committee whose major responsibility is not only to own and oversee the implementation of the program's underlying businesses and strategies, but also to define the program's connection to the organization's overall business plans. (Hanford, M., 2004)

On the other hand, in case of having a set of programmes or independent projects, the concept of portfolio can be introduced. The way these different projects are aligned in the portfolio allows creating an easy way to analyse them and establish ways of collaboration between them. (PMI, 2008) Portfolio management has as its main mission to create an oversight of the different projects that are being developed by the company and steer them in a landscape where all the values of the firm and its commitment are patent. Another important consideration that should be pointed out is the fact that portfolio management has to assign a specific amount of resources for each project or programme within the portfolio. Besides, all projects that belong to the portfolio have to be aligned with the company´s objectives, which normally are referred to the scope, time, cost and quality of each project. It is here where some of the problems could appear, because sometimes it is difficult to choose which of these considerations is the most important. (Eberhardt, H., et al.2011) Therefore, in order to have a successful portfolio management it is not enough to define the main criteria that should be considered when electing a project, but also to prioritize them in order to face possible problems or changes that could appear in the future. (Gutema,E et al, 2014)

Figure 3.1 shows the relation between the three previous concepts. As a differentiation it can be said that while project management insures the success when reaching the objectives and their deliverables within cost, time and scope expectations, program management grant a leadership and vision to the whole project management process which allows delivering value to the stakeholders. Finally, portfolio management can be considered as the main way of aligning projects and programs with the objectives of the organization ensuring that work efforts provide value for the business. (Bucknoff, J., 2009)

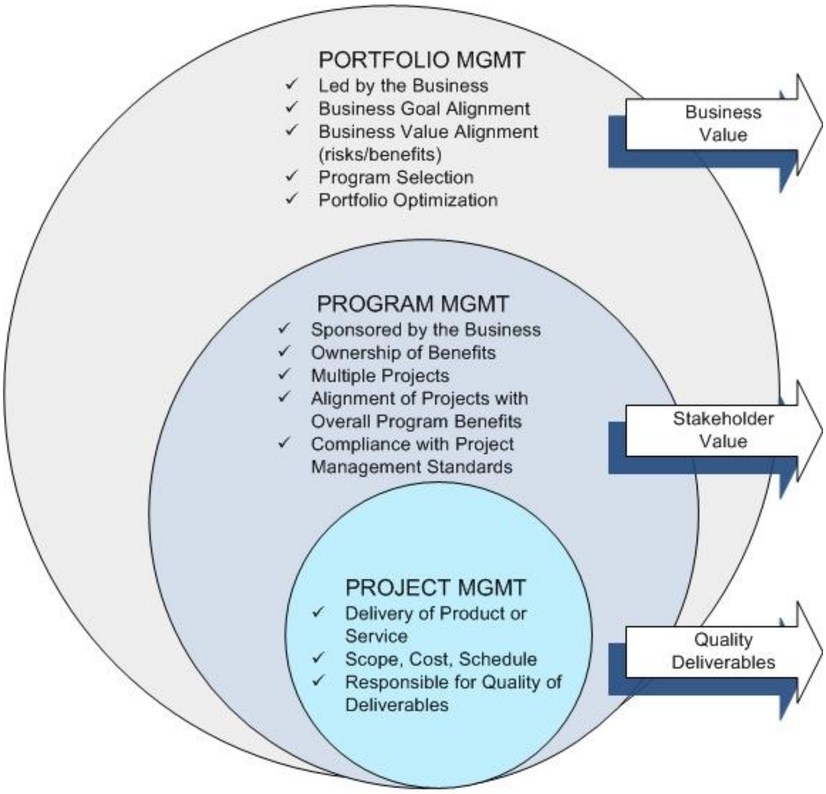


Figure 3.1 - Project, programme and portfolio management (Bucknoff, J., 2009)

3.3 Evaluation of projects

After all the information above, the objective now is to focus on how organizations apply those project management tools in order to compare different alternatives and decide upon the projects they are willing to undertake, since nowadays the limitation of resources makes it impossible to implement as many projects as those organizations would like. (Pinto, 2010) Thus, a deep comparison between different alternatives is necessary alongside with an evaluation of the justifiability of a specific project. (Jones et al., 2014)

As it is known, there are many questions that should be answered when deciding about the implementation of a project. Some of them, which can contribute to create answer to the first research question, are the following ones:

– How can the project, that is being considered, be related to other projects in the same sector?
– How can the project be related to other projects in other sectors?
– What is the best alternative that can be chosen?
– Who is going to be affected in case the project is implemented?

- How will they be affected?
- By how much will they be affected? (Odeck, J., 2013)

In order to solve all these questions it is important to be aware that there is a need for a systematic evaluation of projects and it is here when three different forms of evaluating projects in the transport sector should be distinguished.

- Impact assessment
- Socioeconomic assessment
- Benefit cost analysis (BCA) (Odeck, J., 2013)

Distributional impacts: in this case impacts that are included are those which depend on personal and demographic characteristics (for example income, gender, race, and age) that can be transferred from the area which is under study to another. It is important to highlight the importance of examining these impacts because with them, the possible consequences in case of undertaking the action proposed can be better understood by the decision makers. (NPRA, Handbook 140, 2006)

Monetised impacts: in this group, impacts that are based on changes measured in monetary terms, which need to be identified, valued and quantified are included. Some examples of this type of impacts can be the investment costs, time saved, accidents... (Odeck, J., 2013)

Non-monetised impacts: this term includes all those impacts that cannot be measured in monetary terms, or in other words, impacts that cannot be priced. Despite the fact that these impacts are more difficult to measure and evaluate, they are of particular relevance from the decision makers´ point of view when deciding about which investment alternative should be chosen. In relation to this, special attention should be given to the importance that the society gives to the changes which would be introduced in case the project is implemented. Natural environment and resources, cultural heritage and landscapes are examples of aspects that should be taken into account when considering non-monetised impacts. (NPRA, Handbook 140, 2006)

After the differentiation of impacts, a more clear definition of the three types of evaluation methods that have been described before can be better understood. It must be highlighted that due to the fact of a later deep explanation of the benefit cost analysis procedure is to be detailed later on, a very short explanation of that method is given in this part.

Impact assessment

First of all, it can be said that impact assessment can be considered as a systematic evaluation of all impacts of importance that can accrue to the society if a project is conducted, whether they are negative or positive and regardless of whether they are measurable in monetary terms or not. Moreover, in this type of assessment distributional impacts, which are of political interest, must be also included because they may be of importance for the decision making process.

Due to all above, an impact assessment not only gives a basis for the choice of a specific solution, but also constitutes a way of prioritization when choosing between different projects that are being considered. (NPRA, Handbook 140, 2006)

Socioeconomic assessment

The socioeconomic assessment is a systematic evaluation of monetised and non-monetised impacts which can affect the society in case the project is implemented. In this case, the objective consists of choosing solutions for the project where the disadvantages are outweighed by the advantages. In relation to the way of developing this type of assessment it is important to mark that it is not possible to consider impacts which are caused by circumstances related to other projects; just the ones caused by the project under consideration should be regarded.

Another important consideration related to the socioeconomic assessment is the fact that it allows considering possible impacts that can appear over time but always by considering each impact only under one theme. This can be seen in the following table, where a differentiation between the four main groups of stakeholders which are affected is done. (NPRA, Handbook 140, 2006)

Benefactors	Main them	Sub-theme	Category
Transport users	Benefit to transport users	Travel time	Monetized
		Health of walk/cycling	
		Vehicle operating costs	
Operators	Operator benefit	Increased income/costs	
The government	Budget effects	Investment and maintenance costs	
Third parties	Traffic accidents	Personal injury and material damage	
	Noise and air pollution	Indoor noise. Local, regional and global air pollution	
	Residual value of capital	Benefit of initiative beyond the appraisal period	
	Cost of government funds	Loss of efficiency due to tax financing	
	Landscape		Non-monetized
	Community life and outdoor life		
	Natural environment		
	Cultural heritage		
	Natural resources		

Table 3.1: Main themes covered by the socioeconomic assessment considering the four main groups of stakeholders: transport users, operators, government and third parties. (NPRA 2006)

Benefit cost analysis

This form of evaluating projects will be deeply described in one of the following chapters but as brief definition it can be said that it constitutes a systematic evaluation of impacts which are measurable in monetary terms which would accrue to the society in case of implementing a project.

The differentiation between the three forms of assessment can be understood as follows: The concept of impact assessment is similar to the concept of socioeconomic assessment with the difference that the former account for the distributional impacts, while the later does not. On the other hand, benefit cost analysis can be considered as similar to the socioeconomic assessment with the exception that BCA does not include non monetised terms. That means that if everything is possible to be valued in monetary terms, socioeconomic assessment would be identical to benefit cost analysis because advantages can be termed as benefits, if they have positive effects for the society and disadvantages can be termed as costs, if they have detrimental effects on society. (Odeck, J., 2013)

Thus, the classification of these ways of assessment in relation to which impact are included in them can be broadly represented by the following sketch, where the author of this thesis try to compile both the concepts explained by the Norwegian Public Road Administration and the lessons learned in Odeck´s lectures.

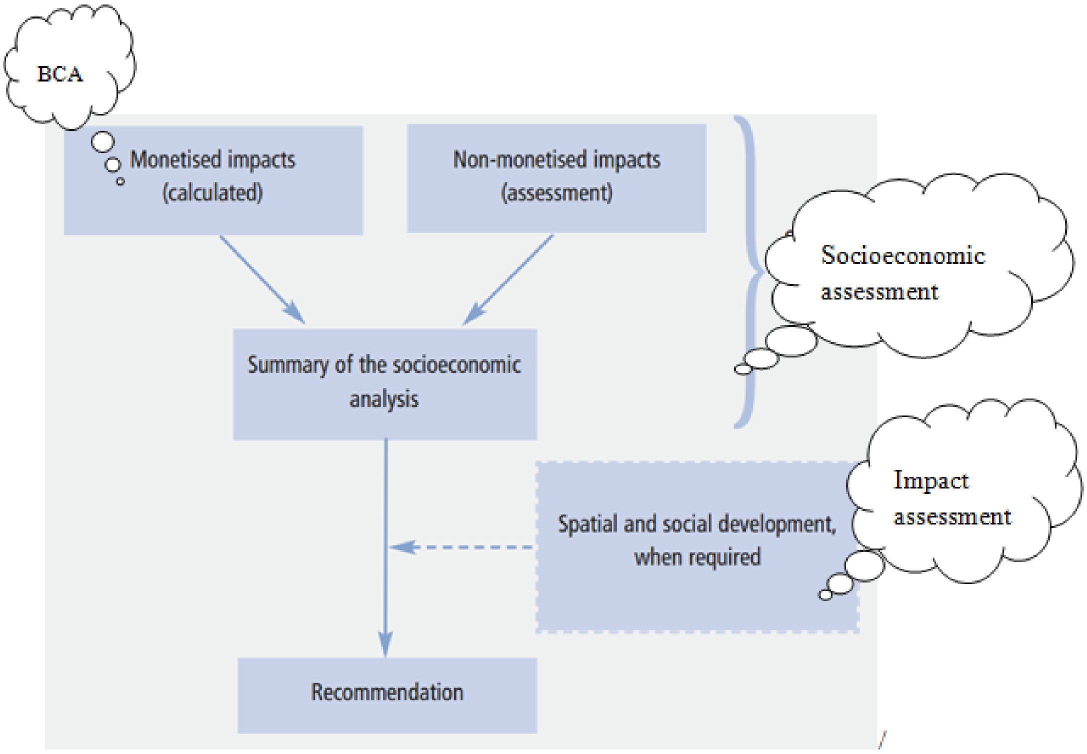


Figure 3.2 - Relationship between impact assessment, socioeconomic assessment and benefit cost analysis. Based on Odeck (2013) and NRPA (2006)

Thus, the differentiation between these ways of assessment in relation to which impact are included in them can be broadly represented by the following sketch, where one can understand that the bigger the narrow, the more impacts included in the evaluation.

Figure 3.3: Differentiation between impact assessment, socioeconomic assessment and benefit cost analysed depending on the impacts considered. (Fernández A., 2014)

As a conclusion one can say that in order to develop a good evaluation of the different alternatives proposed for a specific project one of the main considerations that should be taken into account is the fact that there is a need of implementing a measure and an evaluation of all impacts. That is why a deep explanation of how the Norwegian Public Road Administration classifies and values those impacts is going to be given in the following pages with the main aim of helping answer the first research question of this thesis: "What are the main considerations that must be taken into account before implementing a road project in Norway?"

3.4 Monetised impacts

As it has been explained before, monetised impacts are those impacts whose influence in the society can be measured in monetary terms. In table 3.1 a classification of the most important monetised impacts was done. This classification was developed after taking into account the main groups of stakeholders those impacts are affecting.

Stakeholders affected in a transport project

Referring to this, it is important to mention that nowadays deep studies in relation to stakeholders are carried out with the main objective of not only identifying the main groups of stakeholders, but also sorting them according to the impact that the different actions will have on them. It is here where the differentiation between the traditional shareholder approach and the emergent stakeholder approach can be better understood.

While the traditional shareholder value model focus on short term results, financial measures, vertical control, and efficiency (doing the same things better), the emergent stakeholder value model focus on creating value for the different stakeholders. Moreover, it pays special attention to the sustainable results, organizational measures, empowerment and creativity, and effectiveness (doing different things to create more value). (Thiry, M.. 2006) Thus, if the second approach is used, it is easier to understand the way governance supports value creation, by connecting what is valuable to stakeholders and the organization with effective project actions. (Crawford, L., et al 2008).

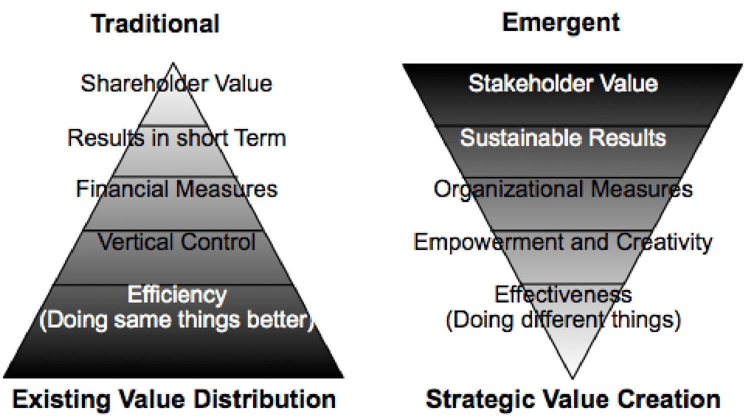


Figure 3.4: Shareholder and stakeholder value approaches to value creation. (Thiry, M., 2006)

As a way of concluding with the explanation of why the stakeholder value approach may be preferable, it must be said that by understanding the requirements and needs of the different stakeholders that are participating in the project a better evaluation can be done when comparing different alternatives. Furthermore, the expectations of the stakeholders can constitute some of the requirements that are needed for the further development of the option chosen or when deciding about the design of the final solution. Finally, by using the requirements imposed by the stakeholders, the direction to go can be better determined and it can constitute a way of creating value for the project by maximizing stakeholder satisfaction. (Charreaux, G. and Desbrières, P., 2001)

In Norway this way of creating value for the project is greatly taken into account and that is why the Norwegian Public Road Administration establishes a differentiation of 4 big groups of stakeholders in case of a transport projects:

- **Transport users:** those who travel or buy freight transportation services. In relation to this, Statens Vegvesen distinguish between five travel groups and three different travel purposes which make a total of 15 groups that must be considered when evaluating monetised impacts.

    - Travel groups:
        - Drivers
        - Passengers
        - Public transport users
        - Cyclists
        - Pedestrians

    - Travel purposes:
        - Business travel
        - Commuting travel
        - Leisure travel (NPRA, Handbook 140, 2006)

- **Operators**: those who can be included in the group of companies that can either provide transportation services or manage transport infrastructure. In this case, 4 groups can be identified:
    - public transport companies
    - parking companies
    - toll-road companies
    - other private stakeholders (NPRA, Handbook 140, 2006)
- **Government:** In this case special attention must be given to the government budget effect, which can be defined as the sum of disbursements and payments over all public authority budgets. Here all state appropriations, which are needed during the project and the tax income the project generate, must be included.

In case of having a single project, only the investment costs and the changes in management and maintenance costs are to be considered alongside with the changes in revenue from transport fees. However, in case of bigger transport systems the budget effect also contains not only the infrastructure owner's budget, but also the state and the county purchase of the transport services. (NPRA, Handbook 140, 2006)

- **Third parties:** in this group all those who are financially responsible for inconvenience and environmental costs are included. For instance, in case of a project where the pollution or the noises are going to be reduced, the neighbours would be directly benefited in case of undertaking the project. (NPRA, Handbook 140, 2006)

  Some of the main costs that are included when analysing the third parties are the following ones:

  ✓ **Cost of accidents**

  In this case, not only the direct costs derived from material damages, medical treatments, loss of work or administrative cost are included, but also the costs derived from the loss in quality of life for the people who were injured and the close family and friends which are also affected. (Horvli, I., 2014)

  ✓ **Cost of noise and air pollution**

  As it is know, both noise and pollution are considered as impacts that can be measured in monetary terms.

  Nowadays both problems constitute one of the main concerns when undertaking transport projects due to the fact that they affect directly the health of people who are living in the area where the project is going to be developed or in areas close to it.

  It is important to stress that pollution has adverse effects on both people and nature. On the one hand, NO_2 and small particles of dust caused by traffic in roads constitute a big problem in urban areas. In relation to this, several studies have shown that air pollution decreases the well-being of people and increases the morbidity problems and the mortality. On the other hand, despite the fact that sulphur emissions, whose impacts is almost negligible, are not considered when evaluating the impacts in the nature, the emission of nitric oxides and carbon dioxides contribute in a big extent to the deterioration of the nature and they are deeply examined when considering monetised impacts. (NPRA, Handbook 140, 2006)

- ✓ **Residual value**

  In case of having a transport project the normal lifetime, period of time during which the infrastructure will be in operation, is 40 years. However, in most of the cases during the last 15 years the benefits are not accounted for due to the fact that only 25 years are considered as the appraisal period. Consequently a correction for this must be done. It is here when the concept of residual value has to be accounted for. It could be said that the residual value can be considered as a positive value when calculating the net benefit of the project which correct that difference between the lifetime and the appraisal period. (Horvli, I., 2014)

- ✓ **Cost of government funds**

  The fact of financing projects through government budget means funding through taxes, which implies a cost to the society that should be considered when developing a socioeconomic assessment. Besides, levying taxes cause inefficiency (efficiency loss) owing to the distortion in use of resources which must be taken

  into account when a benefit cost analysis is used. In Norway, the Ministry of Finance has calculated that every krone financed by taxes cost 0,2 kroner. This is the cost of government fund which must be added to the investment and maintenance costs when calculating the net present value of the project. Thus all cost funded by taxes must be multiplied by a factor of 1,2. (Odeck, J., 2013)

3.5 Non-monetised impacts

Without losing sight of the purposes of this part of the thesis, whose main aim is to map the current practices in the analysis and valuation of impacts that appear as a consequence of implementing a road project in Norway, those impacts that cannot be measured in monetary terms but that are nevertheless crucial for the decision maker's choice of investment alternative are to be further detailed in the following paragraphs.

Firstly, it is important to point out that despite the fact that stakeholders and their influences were explained as a part of the monetised impacts, it does not mean that they are not concern about the non-monetised impacts, what is more, in the majority of the cases they are concerned with both the impacts that can be measured in monetary terms and the ones which cannot be measured in those terms. Moreover, the group that was previously named as third parties constitute a group of stakeholders who are very worried about everything which is related to the non-monetised impacts.

Classification of non-monetised impacts

In this case, the Norwegian Public Road Administration has also a classification of these impacts, which consists in 5 groups that represent the different aspects of the environment:

- **Landscape**

  Any area where there exits an interaction between the human activities and the nature can be defined as a landscape. In relation to this, it can be said that all the visual surroundings of the area where the project has influence can be considered as a part of the landscape which, after the changes introduced by the project, can be highly affected. In relation to this, two different questions should be answered in order to have an idea of the influence the project has on the landscape:

  - How the project is adapted into the landscape as seen from its surroundings?
  - How the landscape is seen when travelling along the new infrastructure? (NPRA, Handbook 140, 2006)

- **Community life and outdoor recreation**

  In this case both terms, which are dealt together, are referred to the staying outdoors and physical activity that usually take place in outdoor recreational areas, parks, residential area, etc.

  When evaluating impacts related to this group the goal is to identify and sort out the impacts on people who live in these areas or users of them that can be affected in case the project is undertaken. The idea is to evaluate how different alternatives suggested for the project can weaken or strengthen the normal development of the activities which are usually part of the normal routine in the outdoor areas. As it can be easily understood, the affection to these activities will have a direct impact in people´s health. (NPRA 2006)

- **Natural environment**

  Here different changes in the ecosystems, the nature, the habitat and the species in the area of study which can affect not only the live of animals, but also the life of plants should be taken into account. Consequently this term includes the biological diversity related to all terrestrial, limnological and marine bodies. (NPRA 2006)

- **Cultural heritage**

  In this case all the areas where monuments, archaeological findings or places related to historical events, tradition or faith are included. In this case the objective is to protect all those sites with the main idea of trying to avoid their destruction which will have a negative impact in terms of culture.

  In Norway cultural heritage places are protected by the law which establishes that archaeological and cultural heritage sites from before 1537 and structures originating prior to 1650 should be carefully considered in case of implementing a project. (NPRA 2006)

- **Natural resources**

  In this group, resources that are related to forestry and other rural areas, agricultural, fish stocks, water resources, wild animals, minerals and rocks can be included. Thus all the impacts that can affect the agriculture, use of water, fishing, use of marine resources, rock, reindeer, gravel, sand and clay are assessed when developing an analysis of the non-monetised impacts.

  In relation to this, the term resource base has to be explained because it is referred to the resources that constitute the basis for employment not only in the primary activities that are developed in the industry field, but also in the secondary processing activities. The evaluation of the resource base includes both quantity and quality problems that can appear in case the project under consideration is carried out, but it does not include all the utilization problems that can appear due to commercial operations.

  A relevant differentiation should be done when talking about natural resources:

  - Renewable resources which include water and biological resources.
  - Non renewable resources which include topsoils and geological resources (rock, gravel, sand and clay). (NPRA, Handbook 140, 2006)

Evaluation of non-monetised impacts

An important difference between the non-monetised and the monetised impacts must be underlined before starting explaining the way of evaluating or analysing non-monetised impacts in a project. While in case of having monetised impacts, a benefit cost analysis can be developed taking into account the fact that money in the future has a lower value than the same amount of money in the present moment, when considering non-monetised impacts this methodology cannot be applied due to the fact that there is a lot of uncertainty in relation to values that some of the impacts will have in the long term.

That means that another approach should be considered in case of the impacts that are not measured in monetary terms must be evaluated and analysed.

First of all, a differentiation between three terms that will shed some light on the methodology that has to be used must be explained.

- **Value:** in this case it is referred to the extent the area where the project will be implemented can be considered as valuable from an environmental point of view.
- **Magnitude:** this term deals with the magnitude of the changes that the project will introduce in the environment after being implemented.
- **Significance:** it is a direct relation between both the previous terms, where the main point is to establish the pros and cons that the option of undertaking the project will have if it is compared to the option of doing anything. . (NPRA, Handbook 140, 2006)

The question that must be addressed after these definitions are explained is related to the fact of how the values and magnitudes of the different impacts can be determined. For this purpose NPRA (2006) propose a method that can be better understood as follows:

On the one hand, a scale with a low, medium and a high value can be used when determining the values of the different impacts. In relation to this, it must be pointed out that in case of evaluating several themes, a relation of values must be established in order to have a way of comparing and relating them.

On the other hand, when assessing the magnitudes of the impacts a scale with 5 different divisions is established (large negative, medium negative, medium positive, large positive and a middle division where the differentiation between small positive and small negative can be included). In case of having a transport project, the assessment is done by evaluating the physical aspects, as for instance the alignment of a road, and the influence the project will have in aspects such as the landscape, community life, natural resources, the ground, the pollution, the noise, barrier effect, land uses...

Another consideration that should be taken into account is the fact that every time that one of the effects can be quantified, the quantification must be done. (NPRA, Handbook 140, 2006)

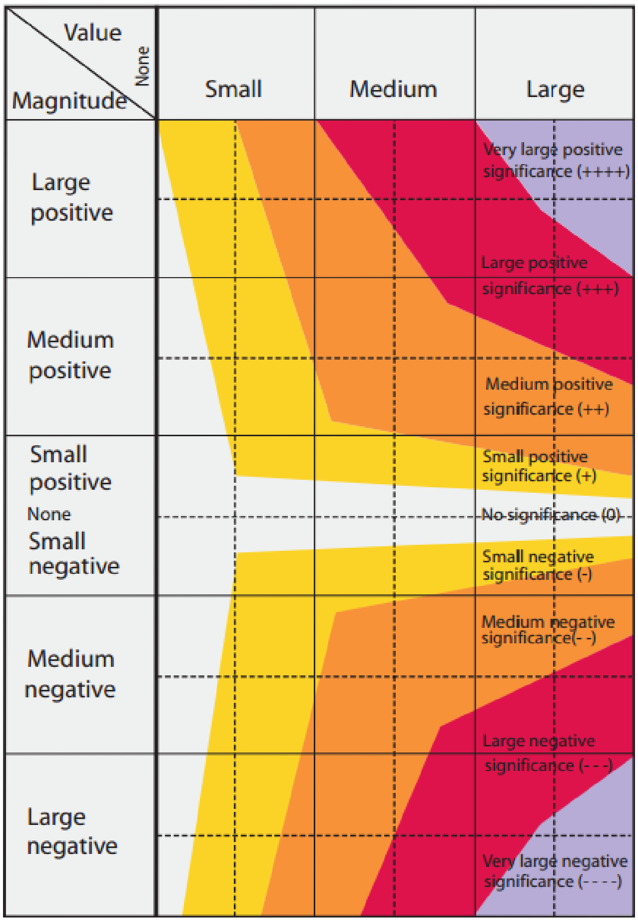


Table 3.2: Significance of non-monetised impacts (NPRA 2006)

Finally, after having established the values and magnitudes of the different impacts in a project, the significance can be obtained by using the table above, where a combination of the values and magnitudes can be found. As it can be seen in that table, impacts that are being considered can be presented in the figure in a scale which is dived in nine segments which vary from a very large positive to a very large negative significance. In this way it can be said that projects can be considered as negative, from the point of view of the non-monetised impacts, when after summing up the significances of the various impacts the result is negative. (NPRA, Handbook 140, 2006)

3.6 Valuation of impacts

As a way of finishing answering the first research question "What are the main considerations that must be taken into account before implementing a road project in Norway?" one can say that it is necessary to take into account all the impacts that will affect the society in case of developing a project, but it cannot be forgotten that it is also necessary to valuate those impacts in order to be able to compare them when having a group of projects. It is here where the concept of opportunity cost principle must be explained.

The opportunity cost principle

The opportunity cost principal can be defined as the principal underlying the monetary evaluation of impacts. Under this principal impacts should be valued at the price they would gain in the best alternative. In relation to this it must be said that the opportunity cost incorporates the notion of scarcity. As it is known resources are limited and they can be used in different ways so a trade-off is needed. It is here when the concept of opportunity cost principle can be understood as way of measure this trade-off. (O'Sullivan and Sheffrin, 2006)

In order to have a better understanding of this principle two different examples when applying this principle are explained in the following paragraphs.

First of all, one of the situations when this principle can be used is when a decision has to be made after considering several alternatives. In this case, an example with the time that can be saved when using a new infrastructure can be further explained. Here the value of time will depend on whether that time is saved during business travels or leisure trips. Times saved during business travels could be used to work; therefore the value of time in this case should be what the employers are willing to pay the employee to work rather than travel. For time saved during trips to/from work and leisure trips one should value them at what trip makers are willing to pay in order to save time. It is here when studies where trip makers are asked about the amount of money that they are willing to pay to save travel time are used. (Odeck, J., 2013)

On the other hand the principle of opportunity cost can also be used when decisions about how to spend money from a fixed budget have to be done. For example, a construction company with a fixed salary budget can increase the number of civil engineers only to the detriment of quantity surveyors. If a civil engineer costs two times as much as a quantity surveyor, the opportunity cost of having one civil engineering is 2 quantity surveyors. (O'Sullivan and Sheffrin, 2006)

In relation to this, it must be highlighted that the way of deriving values based on opportunity cost principle can be different depending on whether the impacts that are being considered can be tradable in the market or not. While values for impacts that can be traded in the market can be derived directly from market prices after considering the necessary adjustment for taxes, values for impacts which are not tradable in the market need previous investigations in order to know how much money people are willing to pay for them. (Odeck, J., 2013) A more detailed explanation of this differentiation is done in the following paragraphs.

Valuing tradable impacts in a market

First of all, a differentiation of the main impacts that can be tradable in the market has to be done.

- **Investment and maintenance costs.**

- **Vehicle operating costs**. For instance gasoline consumption, repair and maintenance of the vehicles.

- **Value of time**. In this case it is necessary to divide the value of time in two different cases:
  - Time saved during business travels can be used to do other activities or work in another thing so the opportunity cost is the salary plus the general costs that the employer is willing to pay.
  - Time saved during leisure trips or when travelling to or from work is not tradable so a different approach, which will be explained later, has to be used

- **Accident costs**

In all these cases the impact of these costs are tradable in the market, where the most desirable situation is to have competitive situation where the prices that consumers are willing to pay equal the prices that the producers are willing to accept. In this way the opportunity cost principle is fulfilled and it can be said that if an impact is tradable, then its value is equal to the market price. (Odeck, J., 2013)

Valuing non- tradable impacts in a market

As it has been pointed out before, when impacts cannot be tradable in the market is necessary to use a different approach to know exactly how much people are willing to pay for those impacts. In order to do this, two different techniques are typically used:

- **Stated preference studies**

  This approach is used for example to calculate the value of time in leisure and trips to/from work, pollution, health etc. It consists in asking people about how much they are willing to pay for a specific level of impact at a given price. In this way, it is possible to create various hypothetical markets that after being summing up can be considered as the total market where the price of the impact can be easily obtained.

- **Revealed preference studies**

  In this case the idea is to observe people´s behavior with respect to complimentary goods to reveal or inform on the value of the goods itself. (Odeck, J., 2013)

A good example of this technique might consist in establishing the price people are willing to pay in order to have less noise. This example can be a residential area where houses with same quality can be built in two different areas, one very close to one of the main roads of the city where the houses are, and the other one far away from that road. The differences in the prices that people would be willing to pay for those two houses in different areas, would be the price that can be established for the noise. (Odeck, J., 2013)

In order to conclude it can be said that the main considerations that are taken into account before implementing a road project in Norway are all the impacts that can affect the society. Thus, when evaluating different alternatives, a clear classification and definition of the main impacts that will appear alongside with a valuation of all of them are necessary.

4. Common practices when considering a road project

In most of countries of the world it is a common practice when considering a road project for investment that the economic benefits over the "do-nothing" scenario is considered. That process is the so-called Benefit-Cost Analysis (BCA).

4.1 Benefit Cost Analysis

Now, after defining the two different types of impacts and explaining how to evaluate the ones that are not measured in monetary terms, a more detailed explanation of the benefit cost analysis, which is the method that is commonly used to evaluate the monetised impacts, is going to be developed.

Firstly, apart from the definition which was given at the beginning of this report, it must be said that a benefit cost analysis can be also considered as method to help decisions makers, because it constitutes a way of understanding some of the economic consequences that the project will have in the future in case of being realized. Due to the fact that this analysis consists in an evaluation of whether the project is profitable from a socioeconomic point of view, it can be used for prioritizing competing projects. This means that this method can be considered as a powerful tool to gather information about the relative magnitude that benefits and costs that accrue, not only in a short term but also in a long term, to society as a result of the necessary actions that must be implemented to undertake the project. Besides, it cannot be forgotten that the main aim of this methodology is to ensure an efficient way of using the society´s resources that are part of the inputs in a project. (Odeck, J., 2013)

4.1.1 Basic steps in a benefit cost analysis

The description of the basic steps in a benefit-cost analysis in the case of a road project is to be given in the following points. This description enables to have a better understanding of the whole procedure.

1. **Identify and define the different alternatives** that will be considered as possible solutions when implementing the project. That definition must allow a fair comparison between all the alternatives.

2. Develop basic **user cost factors**. For instance: values of time, vehicle unit operating costs, accident rate and cost parameters, vehicle emission rate and cost parameters…

3. Decide about which are the **economic factors** that are going to be used. Examples of economic factors could be the discount rate, the analysis period, the evaluation date, the inflation rates, etc.

4. Get **traffic performance data**.

5. Measure **costs** that can affect the main benefactors of the project (road users, the operators, Public authorities or the government and the third parties).

6. Calculate **benefits** the main benefactors can obtain.

7. **Adjust the occurrence of costs and benefits**, which normally occurs at different times.

8. Determine the **net present value** by summing up benefits and costs. (The Puget Sound Regional Council, 2009)

As it has been said before, this is a very general way of defining the usual steps that are normally followed when using a benefit cost analysis. However, more detailed specifications will we given in the following pages in order to strengthen the whole systematic methodology.

4.1.2 Measurement of benefits and costs

In order to understand how benefits and costs can affect the different groups of stakeholders, there is an obvious need of applying the economy theory that will be very helpful when understanding some basic concepts which can be considered as the foundations in a construction project.

It is important to highlight that before starting with the understanding of these economic terms, a list with all the parties affected must be included in order to understand how their welfare can be affected and to what extent it will be affected by the project.

So firstly it is necessary to value the effect of the actions required by the project as they would be valued in monetary terms.

After doing that, three different concepts that are directly linked to the way of measuring benefits and costs, must be understood.

I. Willingness to pay

This term is referred to the amount of money users are willing to pay for the service the project will offered them after being finished. For example in case of having a new road that links directly two cities that were not linked before, the willingness to pay is the amount of money people are willing to pay for using that new road. Here considerations related to safety, time saved or prices of tolls are taken into account by the users when establishing the prices they are willing to pay.

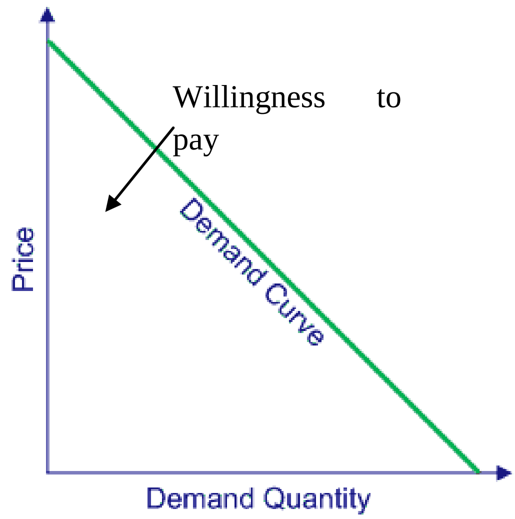


Figure 4.1 – Willingness to pay. Based on Odeck (2013)

In relation to the curves that are usually used in economy the willingness to pay can also be considered as the area under the demand curve. (Odeck, J., 2013)

II. Generalized costs

The generalized costs can be defined as the sum of all the cost components that are considered when making a decision to travel. For instance in the example used before, some of those costs can be the vehicle operating costs, the tolls, or the time costs. In other words, generalized costs are those costs incurred by those travelling by using the new road. (Odeck, J., 2013)

III. <u>Consumer surplus</u>

This term is a measure of the difference between the amount of money the users are willing to pay for the service offered and the amount of money they actually pay.

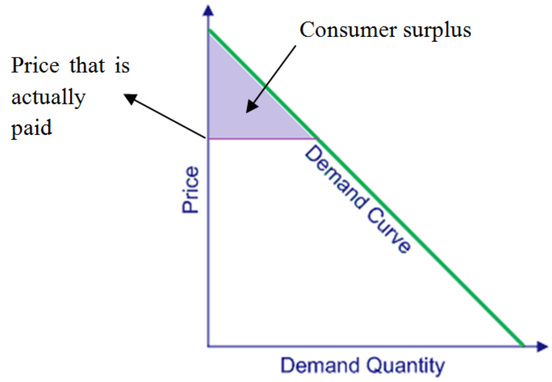


Figure 4.2 – Consumer surplus. Based on Odeck (2013)

Another important idea in relation to this is the **change in consumer surplus** that can be caused by the implementation of a project. For example in case of having a new road with cheaper tolls the direct consequence is the reduction in the price paid by users, which will cause an increase in the demand. This means that a change in generalized costs can indicate an increase or decrease in consumer surplus.

In the following sketch an example where the generalized costs are reduced after implementing the project is shown. It can be seen that such a decrease in costs originates an increase in consumer surplus. Where the green triangle represent the increase in consumer surplus for those that were out of the market before the reduction in the generalized costs occurred and the green rectangle represent the increase in consumer surplus for those buyers that were willing to pay the previous market price. (Odeck, J., 2013)

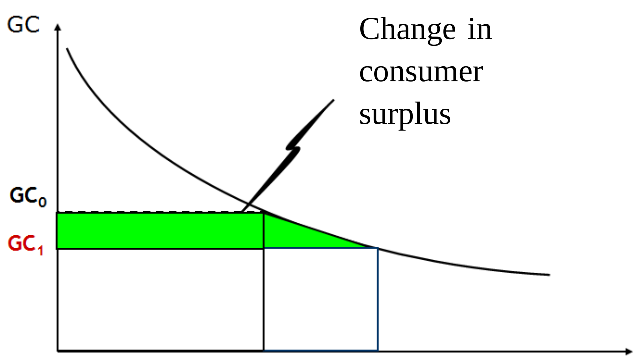


Figure 4.3 - Change in consumer surplus. Based on Odeck (2013)

4.1.3 Handle benefits and costs that occur at different time periods

As it is known infrastructure projects have a long lifetime, which means that it will generate benefits and costs further in the future so there is a need to evaluate the impacts of the alternatives that are being considered by using a long term perspective.

Typically, the appraisal period that is considered in most of the cases when analyzing a transportation project use to be 25 years. (Odeck, J., 2013) However, some smaller investments could have a shorter life time, so in those cases the appraisal that has to be used would be shorter. For that reason, there is a need of a method that allows comparing benefits and costs that occur in different times in the future.

One method that has been commonly used to do this is the Present Value Principle which consists on bringing all the benefits and costs to the present day. In other words this approach is used to calculate future benefits and costs to the value they have today. In order to do this it is necessary to explain the discounting method, which needs two previous concepts to be defined as a basis for a better understanding. (Langston, C., 1994)

- **Rate of discount (r)**
  This rate is defined as the interest rate that the banks use.
  It is know that if money is placed in a bank it is possible to earn interest on it and therefore, in a years' time, the amount of money that can be received will be bigger than the amount of money placed at the beginning.

  Thus, the question is how much an amount of money (X) in year n is worth to us in year 1. This can be easily explained as follows.

  If the amount X_0 is place in a bank, after n years the amount of money that will be available will be:

$$X_n = X_0 \cdot (1+r)^n$$

  So if the inverse way of thinking is used, it can be said that the amount of money that X_n is worth to us nowadays is:

$$\mathbf{X_0 = X_n / (1+r)^n}$$

  The same can be applied to the benefits: $\boxed{\mathbf{B_0^i = B^i / (1+r)^i}}$

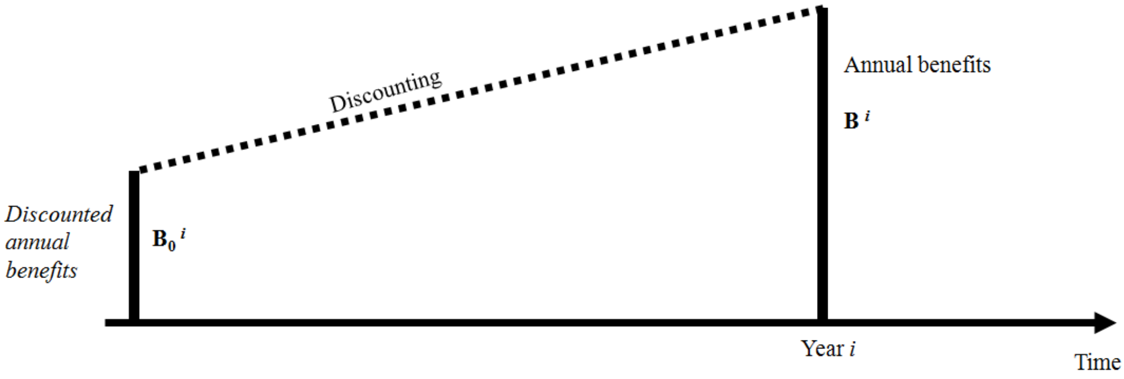


Figure 4.4 – Discounting annual benefits. Based on Odeck (2013)

In relation to the discounting rate, it can be noticed the following two important things:

- This rate puts less weight on future benefits and costs.
- The size of the discount rate determines the size of benefits. The higher it is the lower the benefits. (Odeck, J., 2013)

- **Increase in annual benefits (a)**
  To understand the meaning of this rate, the example of a road project is going to be used.
  Let´s assume that the benefits in a road grow in proportion with the traffic growth. In that case the rate a can be called the traffic growth rate, which has to be also considered when calculating the discounted benefits and costs. (U.S. Environmental Protection Agency)

Thus, after considering these two different rates the **accumulated discount factor** can be calculated as follows:

$$\frac{(\mathbf{1} + \mathbf{a})^{\mathbf{i}}}{(\mathbf{1} + \mathbf{r})^{\mathbf{i}}}$$

However, instead of using this formula it is better to use tables where the rate of discount is given and the lifetime period and the increase in annual benefit have to be chosen in order to find the accumulated discount factor.

Finally, if we know the annual benefit, the discount rate (r), the increase in annual benefit (a) and the lifetime period of the project (i), the total discounted benefits can be calculated by using the following formula. (Odeck, J., 2013)

$$\mathbf{B_0^i = B^i \cdot \frac{(1+a)^i}{(1+r)^i}}$$

The same can be applied to the costs:

$$\textbf{Discounted costs} = \textbf{Annual costs} \cdot \frac{(1+a)^i}{(1+r)^i}$$

4.2 Profitable criteria

When evaluating different alternatives that can be considered as possible solutions in a project, an important criterion that is always taken into account is the profitability of each of the alternatives.

For that reason in this chapter some of the measures for socioeconomic profitability are going to be explained.

Below, the three most important measures of profitability that are used as part of the benefit cost analysis are explained.

- **Net present value (NPV)**

  This is the absolute measure for economic profitability. It can be defined as the difference between the present value of a project's benefit components, minus the present value of all investment and operating costs. (Carpintero, S., 2011) There are several formulas that are used to define the net present value of a project, but the one which represents better the idea behind the definition of this measure is the following one:

$$NPV = \sum_{t=1}^{n} \frac{b_t - k_t}{(1+r)^t} - I_0$$

Where:

b_t = annual benefits
k_t = annual costs
r = discount rate
n= appraisal period
I_0 = costs during the construction period discounted to the year of comparison

Note: In this formula the increase in annual benefits has not been considered.

Another important consideration that has to be taken into account is the fact that it is necessary to consider the cost of government funds. As it was explained before, when calculating NPV, all cost funded by taxes must be multiplied by a factor of 1.2 (Odeck, J., 2013)

It must be also highlighted the fact that this measure can be also considered as the representation of the net contribution of the project to the society. (NPRA 2006)

In this case two different situations can be differentiated:

- If NPV > 0 it means the discounted benefits are higher than the discounted costs, which means that the alternative is profitable from an economic point of view.

- If NPV < 0 it means that the discounted benefits are lower than the discounted costs, which means that the alternative is not profitable,

In case the NPV < 0, no more calculations or measures have to be applied. However in case the NPV is positive, other two measurements, that are explained in the following page, can be calculated to have a more detailed explanation of the profitability of the solution that it is being considered. (Carpintero, S., 2011)

- **Benefit-Cost ratio** (B-C ratio)

This measure is used when not all projects that can be considered as profitable (positive NPV) can be undertaken due to a limitation of the government´s budget.

The formula that is used for this ratio, which is a relative measure for socio-economic profitability, is the following one:

$$\text{B-C ratio} = \frac{NPV}{C_{goverment \quad budget}}$$

In this case the number that has to be included in the denominator is referred to the costs financed through government budget. Thus, this measure can be understood not only as a way of calculating the contribution to the society per each Norwegian krone financed through government budget, but also a way of ranking different projects.

As a way of interpreting the result of this ratio it can be said that always the result is greater than zero, it could be considered as beneficial. For example, let´s say that the value of the B-C ratio is 0.0745; that would mean that for every krone invested in this project, there is a return of 0.0745 kroner; which means a return of over 7 %. Therefore, this project should be ranked higher than any other project with lower benefit-cost ratio. (Odeck, J., 2013)

- **Internal rate of return (IRR)**

  A simple way of defining this concept is that it is considered as the discount rate at which NPV is zero. In other words, it is the rate that makes the NPV be zero. Thus two different cases can appear:

  - If NPV < 0 → the IRR < r (discount rate)
  - If NPV > 0 → the IRR > r (discount rate)

- **First Years Rate of Return (FYRR)**
  In this case, it can be said that this rate is used to know if the project is profitable from the first year or not. Thus, as a timing criterion, it can be used to know when it is better to start with the project. The formula to calculate this rate is the following one.

$$\text{FYRR} = \frac{\textit{Benefits in year } 1}{\textit{Investment costs}}$$

  However, it is important to underlined that this rate cannot be used during the decision making process because it only considers the amount of return that is generated during the first year, and it does not account for what is going to happen during the rest of the years. (Aron, J., 2005)

4.3 Limitations of the BCA

Despite the fact of being one of the most common methods that are usually used to analyse the profitability of projects, the benefit cost analysis has also some limitations that must be considered in order to avoid future problems during the development of the project. Some of those limitations, which are established by The Puget Sound Regional Council, are explained below.

- This method does not include interpersonal comparison. In other words it can be said that BCA cannot be used to find a good balance between what the community losses or wins. The benefit cost analysis assumes that the losses that some parts of the community will have will be compensated by the gains of the other part of the community. This means that this method assumes that there is a perfect balance between "winners" and losers" (Pareto criteria), which in reality does not occur.

- Something that cannot be forgotten is the fact that this method does not take into account the non-monetised impacts and the distributional impacts originated by the project, whose impact on the society is also very relevant.

- The use of BCA is limited by the type of data that this method usually uses. For instance, in a road project, the traffic models or the modeling assumptions can be considered as data which do not represent the reality in all cases.

- The use of a discount rate, which implies that the benefits nowadays are more valuable in the present moment than in the future, can cause some deficiencies when analyzing the profitability of a project because in some cases some of the costs or some of the benefits may not be more valuable in the present than in the long term.

- Apart from the results obtained after developing the BCA, considerations related to the budget or political limitations, alongside with organizational constrains should be taken into account.

- In case of the long term costs, there is a lack of knowledge. For example in case of considering the emissions of CO_2, there is a notable uncertainty in the way those emissions will increase or decrease in the following years, so it is complicated to create a correct assumption.

- In general all the estimations that are used when implementing a BCA include a relevant amount of uncertainty, especially in the front-end phases of the project because it is in this moment when, due to the lack of information, the uncertainty is bigger. (The Puget Sound Regional Council, 2009)

5. Cost estimation process.

In relation to the last BCA limitation that was explained in the previous page, this thesis wants to focus on how the amount of uncertainty in those estimations can affect the BCA results. For that reason this chapter´s main aim is to explain the general aspects of how cost estimation are done. Thus, it will be easier to understand how this estimation process is implemented in the case of Norway, which is the question posed in the second research question.

5.1 General aspects in cost estimation

First of all, as defined by PMI (2008) cost estimation is "the process of developing an approximation of the monetary resources needed to complete project activities". In other words it can be considered as the process of creating an estimated value at a specific point of the project. The cost estimation is then a dynamic process and is usually closer to the real project value when the project matures. Thus, as stated by Nicholas and Steyn (2008), when developing a cost estimate it is necessary to consider a long process that evolves through different phases of maturation, as the same way the project evolves through the different life cycle phases. Besides, it is important to point out that during the development of a project it is necessary to estimate not only the cost of all the activities that need to be implemented to complete the project and create a project budget, but also to control costs and update possible changes with the main objective of avoid cost overruns. In this manner the process of estimating can occur several times during more demanding projects, while in the case of less demanding projects can occur just one time. (PMI, 2008)

Secondly the term estimate must be defined. This time Nicholas and Steyn (2008) consider it as "a realistic assessment based upon known facts about the work, required resources, constraints, and the environmental, derived from estimating methods". Furthermore, these estimates are characterized by the fact that their accuracy depends on the project stage and for that reason they have to be constantly updated during the course of the project with the aim of reflecting recent information. Another important aspect is that they should include, alongside with costs related to materials, resources, services, equipment and so on, other obligations such as financing, inflation or contingency costs. (PMI, 2008)

5.2 Methods for cost estimation

As explained before, during the life cycle of a project several estimations are done, and usually depending on the stage in which the estimation is created, different methods are used. Those methods must be chosen by the project management team taking into account which ones will better fit the estimation purpose. Thus, PMI (2008) differentiate between the following techniques to estimate costs:

Three-Point Estimates

This technique consists in estimating three values: a pessimistic value (higher value), a optimistic vale (lower value) and a most likely value. All together represent the range of uncertainty the activity that is being considered can have. In some cases, a PERT analysis is implemented to calculate expected costs that results from a weighted average of the three estimated costs, which in most of the cases gives more accurate results. (PMI, 2008)

Analogous Estimating

This method is based on using costs of previous projects that have similarities with the one that is being considered for creating a base for estimating costs in the current project. Thus, the more similar the projects are, the more precise the analogous estimate will be.

This technique is usually used during the first stages of the project, when the amount of information is barely detailed. It is considered as a method that, despite the fact of being less accurate than others, is not very expensive and not very time consuming.

It is important to say that this method can be also used to estimate duration of activities or on a narrower scope when there is a need to estimate costs of a specific parameter or a specific element in a project. (PMI, 2008)

Project Management Estimating Software

One of the most common tools that are used nowadays to create estimates is the cost estimation software. In this group, tools as simulations, spreadsheets, statistical programmes apart from others can be included. These tools have been constituted as a way of making the estimation process easier than before, due to the fact that they can fast the process and reduce the human errors by reducing the amount of repetitive tasks. (PMI, 2008)

Bottom-up Estimating

This technique is used to estimate components of work or individual schedule activities. The procedure consists in getting estimates for a complete task by adding the estimates for a particular component of work that were calculated previously. It is important to point out that the estimations for those smaller components are done in a more refined and detailed way, so the accuracy of the final estimates will be directly linked with the accuracy of the estimates for those smaller components. At the same time, the accuracy of those estimates, done at the lower level packages, will be influenced by their complexity and size. (PMI, 2008)

Vendor Bid Analysis

This method consists in creating an estimate by analysing and compiling prices of individual deliverables that are given by vendors of sub-contractors. Then, after getting the costs for all the deliverables, the final project cost can be estimated. Another option that sometimes is used when implementing this method is to base the prices of those individual deliverables on responsive bids. (PMI, 2008)

Expert Judgments

When there is a lack of statistical data or those data are not available, the alternative is to use information from trained and experienced experts. (Vatn, J., 2013)
These experts have historical information in relation to similar projects that were undertaken before, so they can contribute in a great extent to the achievement of meaningful estimates. In this manner, ESA (1991) defines expert judgment data as follows: “Expert Judgment data are estimates of unknown values about a system made by specialists who have system-related knowledge.” Moreover, these experts can also help when deciding about the methods and techniques that can give a better estimate during the estimation process. (PMI, 2008)

6. NPRA´s estimation process

In this chapter a review of the Handbook 217, which was created by NPRA as a guideline to perform cost estimates is done. The main aspects of the method are here briefly described with the objective of assessing the NPRA's practices and create a background that enables to answer not only the second research question which is referred to the way of how estimations in road projects are done in Norway, but also the third one which refers to how uncertainties are dealt with regards to cost estimation.

6.1 Successive calculation method

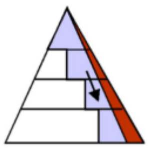
Nowadays all cost estimations that are implemented under the control of the Public Roads Administration in Norway apply the Estimation Method which is contained in the handbook 217. The Estimation Method can be considered as a powerful tool that can be used during all the stages of a project in order to give high quality estimations of cost that can help decision makers not only to choose between different financing alternatives, but also to improve the uncertainty management in the project. (NPRA, Handbook 217, 2011a)

It is important to highlight the fact that this method is based on the successive estimation developed by Steen Lichtenberg in the 1970s.

On the one hand, it can be said that the successive calculation can be considered as a method that can be used in different cases:

- When calculating cost estimates or income estimates, whether as a part of an economical analysis or for tendering or quotation.
- When analyzing uncertainty, which includes the identification and the quantification of the uncertainty itself.
- To assure the quality of the estimates that we previously calculated.
- To create goals or objectives for management and contingency funds.
- In order to take advantage of the value of the process. (Torp, O., 2014)

On the other hand, three different elements can be distinguished when talking about the successive calculation:

- **The successive principle.**
  Lichtenberg in one of his books explains that the successive principle is based on:
  
  - Starting by breaking down the problem from a rough overview and adding details as required (top-down work).
  - Estimations of uncertain quantities by using subjective assessments and triple estimates.

- A combination of different statistical calculation rules alongside with a simple systematic approach which is necessary to allow the procedure to handle the uncertainty (Bayesian statistics).
  (Lichtenberg, S., 2000).

- **The successive Process**
  This is a systematic process that explains the manner that the data and the knowledge flow must be processed in order to develop a project.

- **The theory and calculus of probability**

Thus, it can be seen that the successive calculation method has as one of its main goals to find realistic cost estimations in the project, which needs a complex workflow that will be explained later.

6.2 Requirements

The handbook 217 establishes, among others, which projects are the ones that require an estimate and the accuracy requirements of the different estimated costs. Thus, all investment projects above 5 million Norwegian kroner taken by the NPRA, have to develop a cost estimate process following the estimation method in the handbook 217.

Moreover, it also fixes that 3 different estimations are necessary during the planning phases, where the level of accuracy will increase.

- During the <u>initial study level</u>, very small details about the projects are know, that is why the accuracy is limited and only rough estimations can be done.
- During the <u>municipal (sector) planning level</u> not only the project definition is larger, but also the level of details increase, so it is here when a standard estimation can be implemented. Thus, the accuracy and the resource consumption requirements are higher than before.
- During the <u>area development planning level</u> the most detailed estimates are required. In this case the estimates will be considered as a basis for approval before starting the project, management of the project, and non-compliance reporting. It is in this level where more resources and time are consumed and therefore, in some cases, a supplementary tool called “Anslag 4.0” is used. This tool helps to manage resources and prioritize them among different regions. This tool reflects, by the use of a template, the complexity of the cost estimate, which is being elaborated. (NPRA, Handbook 217, 2011a)

In relation to the documentation required, an estimation report must be included. This document cannot be available to public due to the fact that it has been created just as an internal working document. The content of this document can be summarizes as follows:

- Prerequisites
- Participants/experience
- Reference projects
- Calculation results by item
- Results and interpretations
- Storage of data files
- Storage of an approved cost estimate (NPRA, Handbook 217, 2011a)

6.3 Workflow in the estimation process

First of all, it is important to mention that the successive calculation method is based on a resource group, which works under the supervision of a process facilitator to find cost estimates which should be as realistic as possible. Some of the main characteristics this expert group should have are listed below.

- The number of member in the group varies between 5 and 10.
- All of them must cover requested knowledge and experience.
- They must be motivated.
- They should have cooperation and communication skills.
- They should find a balance between optimism and pessimism. (Torp, O., 2014)

Besides, the expert group follows an estimation process where three different phases can be distinguished:

Preparation	• Composition of the resource group • Preparation and distribution of materials to the participants • Participants' preparations • Practical organisation
Estimation meeting	• Execution of the group process • Calculation and execution
Follow-up work	• Documentation of the process • Basis for a decision-making process

Table 6.1: General workflow in an Estimation Process (Handbook 217, 2011)

In order to understand the workflow for execution of the group process the following figure is used and a deep explanation of each of the steps is given in the following page.

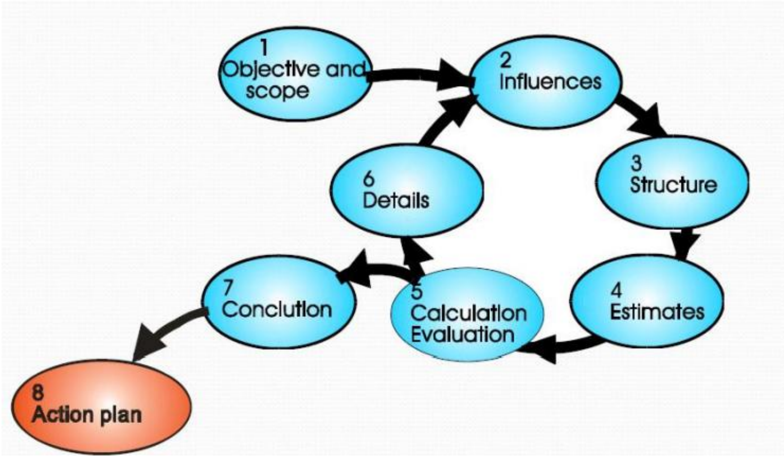


Figure 6.1: Workflow for execution of the group process in the successive calculation method (Hanbook 217, 2011)

In the following paragraphs, the main steps in the workflow are explained in detail.

1. <u>Objective and scope</u>

In this first step a clear definition of the scope of the project must be given, alongside with a distinction of the problems, their limitations and the establishment of the costs estimates. Moreover a good explanation of the goals that are supposed to be reached in the long term should be also included.

2. <u>Influences</u>

Internal and external influencing factors that affect the project must be identified in order to ensure good estimations which include all aspects that can be considered as relevant. It is important to highlight that in most of the cases these internal and external factors significantly contribute to the uncertainty of the project.

3. <u>Structure</u>

In order to reduce the volume of work during the calculation method a cost estimate breakdown is needed. With this division of work, smaller units with not so many details in relation to the information that has to be process are used. Thus the objective here is to create an overview of the whole project. Moreover, a good recommendation when subdividing the work is to start in a high level with general considerations and continue by narrowing the level of details.

4. <u>Estimation</u>

When applying this method a triple estimate of all the processes considered alongside with the external and internal influences is used. This triple estimate, as previously explained, consists in giving three different values for the costs of each item: firstly a low vale (L), followed by a high value (H) and finally the most likely value (M). In this case it is important to carry out a carefully assessment of all the processes in order to give realistic assumptions. Besides, sometimes if needed, data from previous projects with similar conditions can be used in combination with the expert judgments to generate those estimates.

5. Calculation and evaluation

After the results are calculated, in most of the cases by using a computer program, the whole group must agree on the fact that all considerations and assumptions have been developed without forgetting any relevant information or knowledge. In this way all the results must be accepted by all members before final conclusion can be defined.

6. Details

In case of not agreeing with the results the cost estimate must be processed again. In this case tow different circumstances can appear:

- If the information available is enough, the session can continue and progress and only some more adjustments are needed.
- If the information available is not enough, some more details related to some of the items should be given. In this case, items with higher uncertainty should be given special attention. For these purpose a priority list, which includes all the items ordered according to the uncertainty they have, is used. Thus, it becomes easier to know exactly for which items more information or changes in assumptions are needed.

7. Conclusion

After knowing the result of the estimations and having the acceptance of all the members of the group a conclusion can be formulated. In this conclusion all the assumptions and special considerations that had been taken into account must be included alongside with the level of uncertainty the project has, detailing which items are more uncertain.

8. Action plan

The fact of knowing the level of uncertainty is not enough. Something must be done to reduce it. For this reason in this step not only measures to prevent risks, but also to reduce uncertainty should be defined. (NPRA, Handbook 217, 2011a)

6.4 Base for preparing good estimates

In order to have a better understanding of how to prepare good estimates during the successive estimation method, some knowledge in relation to statistics and probability theory is needed. For that reason this part of the chapter is going to explain the most important ideas in relation to those subjects in deep detail.

Firstly it must be said that cost estimates, which are based on uncertainty, are considered as stochastic variables. Stochastic variables can be defined as quantities whose values cannot be predicted exactly. In other words, they can be considered as variables based on the law of randomness. (Vatn, J., 2013)

A stochastic variable X, is characterized by two functions:

- Cumulative distribution function. $F_X(x) = Pr(X \leq x)$

  From the expression above it can be said that $F_X(x)$ states the probability that the random quantity X is less or equal than x, which is one of the values that X can take.

  The fact that the distribution function is strictly increasing can be observed in the figure below, which represents a typical distribution function. Furthermore, it can be stated that $0 \leq F_X(x) \leq 1$. (Torp, O., 2014)

  On the other hand, from $F_X(x)$ we can obtain the probability that X will be within a specified interval, $(a,b]$ can be obtained: $\Pr(a < X \leq b) = F_X(b) - F_X(a)$

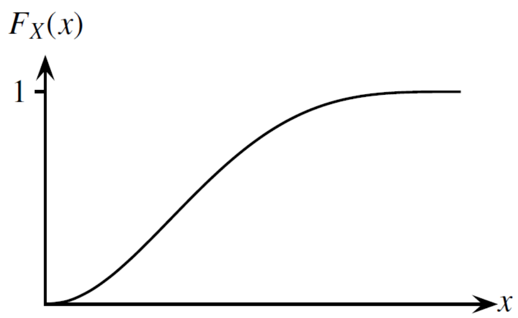


Figure 6.2 - Cumulative distribution function. Based on Torp (2014)

- Probability density function. $f_X(x) = \frac{d}{dx} F_X(x)$

  The function represents how likely the various x-values are. Note that for continuous random variables (variables can take any value among the real numbers) the probability that X will take a specific value vanishes. However, the probability that X will be in a small interval around a specific value is positive.

For each x-value, $f_X(x)$ could be interpreted as the probability that X will fall within a small interval around x divided by the length of this interval. (Vatn, J., 2013)

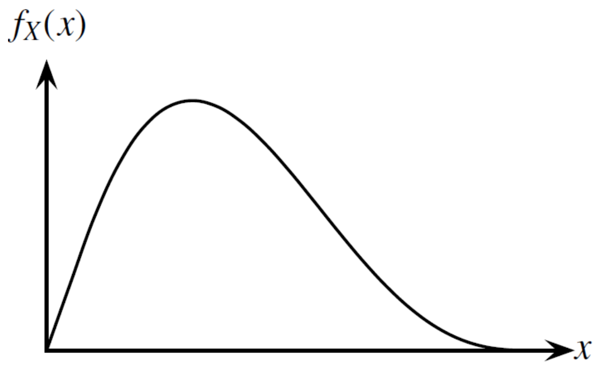
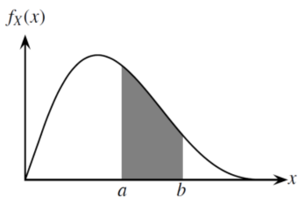


Figure 6.3 - Probability density function. Based on Torp (2014)

The same concept can be expressed in other way, by using integration:

$F_X(x) = \int_{-\infty}^{x} f_X(u)\,du$

$\Pr(a < X \leq b) = \int_{a}^{b} f_X(x)\,dx$ →



Other terms that must be defined in relation to stochastic variables are:

- Expectation E(X): it can be interpreted as the long time run average of X, in case of having an infinite amount of observations

- Median (m_o): this value has to met the following conditions:
  - $\Pr(X \leq m_0) \geq 1/2$
  - $\Pr(X \geq m_0) \geq 1/2$.

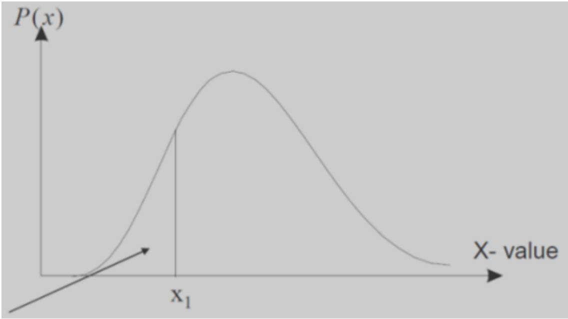
- Most likely value (M): the probability density function at M is higher or equal than for any other value of the stochastic variable.

- Variance (Var) This number expresses the variation that the value X will take in the long run. It can be also be defined as the expected squared deviation from the expected value.

- Standard deviation (σ): $\sigma = +\sqrt{Var}$
  This number is the most common measure of uncertainty. (Torp, O., 2014)

Method to estimate the expected value and the variance

Despite the fact that there are several methods to estimate these values the most common method is the three-point estimation, which depends on the quantiles that are being used.
A quantile can be defined as the value with n % probability of not to be exceeded.



n % probability

Figure 6.4 – Identifying probabilities in the probability density function. Based on Torp (2014)

In the figure above the x_1 is the n% quantile which means that $P(X < x_1) = n$ %.

According to this, two different approaches should be distinguished:

- **Three-point estimate using P1 and P99**
  In this case the formulas that have to be used to calculate the expected value and the standard deviation are:

Theoretical formulas

$$E= \frac{L+2{,}9 \cdot M+H}{4{,}9}$$

$$\sigma = \frac{H-L}{4{,}6}$$

Practical formulas

$$E = \frac{L+3 \cdot M+H}{5}$$

$$\sigma = \frac{H-L}{5}$$

- **Three-point estimate using P10 and P90**
  In this other case, the formulas vary slightly, but the results obtained later are quite similar

Theoretical formulas

$$E = \frac{L+0{,}41 \cdot M+H}{2{,}41}$$

$$\sigma = \frac{H-L}{2{,}55}$$

Practical formulas

$$E = \frac{L+0{,}4 \cdot M+H}{2{,}4}$$

$$\sigma = \frac{H-L}{2{,}5}$$

After calculating these values, some other considerations must be taken into account when operating with them: (Torp, O., 2014)

Distribution of the sum:

$E(X_1 + X_2 + . . . + Xn) = E(\sum_{i=1}^{n} Xi) = \sum_{i=1}^{n}(E(Xi))$

$Var(X_1 + X_2 + . . . + Xn) = Var(\sum_{i=1}^{n} Xi) = \sum_{i=1}^{n}(Var(Xi))$

Distribution of the product:

$E(X_1 \cdot X_2 \cdot . . . \cdot Xn) = E(\prod_{i=1}^{n} Xi) = \prod_{i=1}^{n}(E(Xi))$

$Var(X_1 \cdot X_2) = Var(X_1)Var(X_2) + Var(X_1)[E(X_2)]^2 + Var(X_2)[E(X_1)]^2$

6.6. A cost estimate in accordance with the Estimation Method

After understanding the basis of how to use the values obtained by the use of the three point estimation, the method used by NPRA when estimating, now it is necessary to understand how the structure of the cost estimate in accordance with the estimation method is.

First of all, it must be said that the Estimation Method proposes and structure for overarching the cost estimate breakdown. This structure together with the level of detail of the cost estimate will be influenced by the stage and project the estimates are going to be done for. All calculations must be done by identifying the most suitable structure, but the proposed structure has to be considered in all cases when breaking down the estimate. Thus, the following principal breakdown at the overarching level shall be observed by all the cost estimates:

- Open roads
- Bridges and quays
- Rock tunnels
- Technical installations
- Other measures
- Project owner costs
- Land acquisition
- Factors of uncertainty
- Incidents (NPRA, Handbook 217, 2011a)

After this consideration, all the cost elements and their uncertainty are calculated to estimate the total project cost. Thus, the project cost estimate can be built as follows:

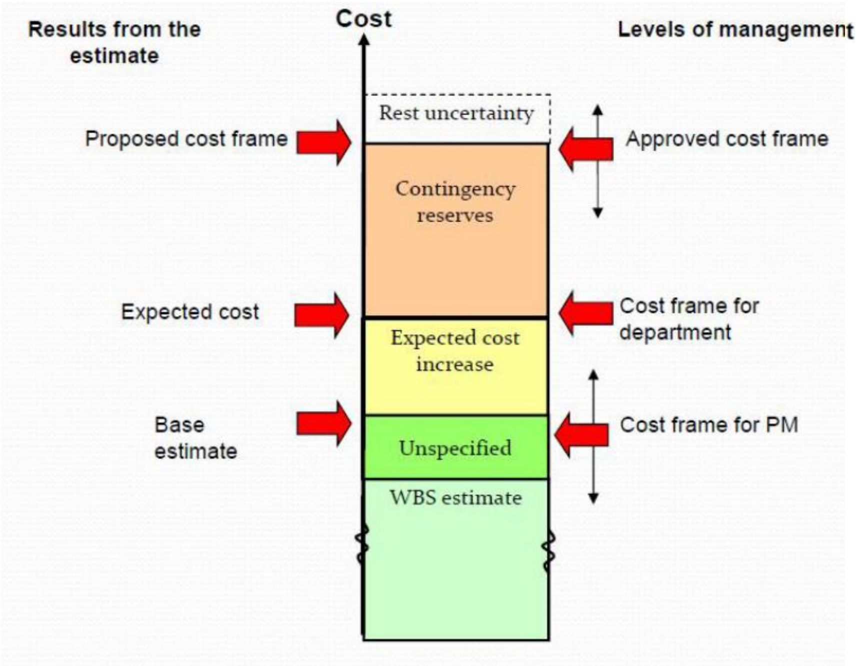


Figure 6.5 - Structure of a cost estimate in accordance with the Estimation Method (NPRA 2011, Handbook 217)

As it can be seen in the figure above there are several elements whose sum defines the cost estimate. These elements are the following ones:

The base estimate, which is calculated by taking into account the sum of all individual expected cost that were defined after choosing the breakdown structure for the calculations. The calculation of this estimate is done by using the three point estimation method explained before, where the P50 value will be in most cases quite identical to the expected value.

The expected supplements, two additional costs that must be considered to achieve the expected cost.

- The first ones are the elements "unspecified" which include all those costs that are expected but whose estimation cannot be done at the time of calculations. This supplement must be given as a percentage markup, which will depend on the planning level the cost estimate is being done. (NPRA, Handbook 217, 2011a)The following guidelines can be used:

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

- The second one is the so-called expected supplement from internal and external influences and incident uncertainty. This supplement is referred to those factors that despite the fact of resulting on uncertainty cannot be allocated to individual items. These uncertainty factors are called “U-factors” and they are determined during the estimation meeting by using a brainstorming session. Thus, these factors alongside with the uncertainty from the triple estimation used when calculating the base estimate, determine the project cost variability. (NPRA, Handbook 217, 2011a)

Apart from this, NPRA establishes, depending on the project phase and the level of detail of the estimate, three different accuracy limits where all the cost estimates must have at least 70% probability of lying within them. Those accuracy requirements are the following ones:

- Initial study: +/- 40 %
- Municipal (sector) plan: +/- 25 %
- Area development plan: +/- 10 %

7. Uncertainty analysis

The aim of this chapter is to continue answering the third research question by improving the understanding in what refers to uncertainty elements or factors that will be later used to estimate the total amount of uncertainty in a project.

First of all, it is important to notice that uncertainty reflects the lack of information required to reach a decision that ensures that the anticipated output is realized, so if the information base is poor, uncertainty is great. In relation to this, it must be said that uncertainty is greatest at the starting point and thereafter diminishes with time as a consequence of gradual acquisition of more information. The potential to reduce uncertainty and risk is larger during the front-end phase and decreases substantially when the project is implemented. However, there are limits on how much an increase in information in the front-end phase may reduce project uncertainty. Clearly, uncertainty cannot be eliminated merely by acquiring more information. Projects are dynamic processes that are implemented in societal context, in which the natural dynamics of the process and the influences of the surroundings dictate that much of what happens cannot be foreseen. (Samset, K., 2013)

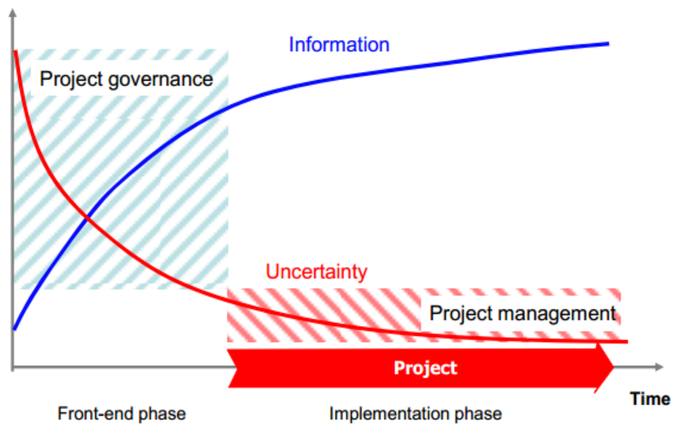


Figure 7.1 - Uncertainty analysis conceptual graph (Samset, K., 2013)

7.1 Estimation of the uncertainty

As it has been explained before, one way of measuring the amount of uncertainty that one specific parameter has consist in estimating the expected value (E) and the standard deviation (σ) of that parameter. This last parameter shows how much variation or dispersion from the average (expected value) exists. The standard deviation reflects the local uncertainty of all the parameters that are being taken into account. A low standard deviation indicates that the data points tend to be very close to the mean; a high standard deviation indicates that the data points are spread out over a large range of values.

Then these values (E and σ) can be represented in a S-curve where the difference between contingency allowance and contingency reserve can be easily understood.

- Contingency allowance is used for unspecified costs (cost that can be expected to incur but cannot be identified at the time of estimation). These costs cover changes in design that do not affect project scope, term changes within the frame of the main schedule, changes in work execution within the determined construction and contract philosophy, price changes within the framework conditions that are used and estimation errors.
- Contingency reserve is used for costs than cannot be expected to incur and that are covered by an uncertainty provision. For instance we could have significant changes in design, significant changes in main schedule, significant changes of the construction and contract philosophy, significant changes in market conditions or unwanted events. (Lichtenberg, S., 2000)

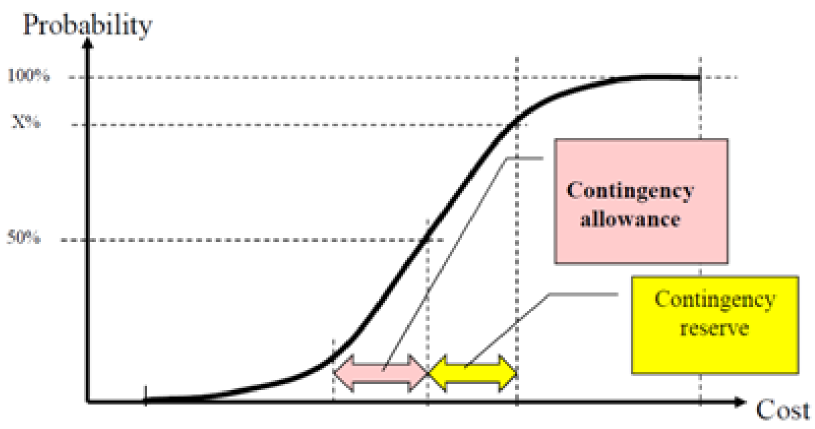


Figure 7.2 - Difference between contingency allowance and contingency reserve. (Samset, K., 2013)

In relation to this, there are some considerations that have to be taken into account in order to reduce the uncertainty in cost estimation. For instance, it would be very relevant to focus on the elements with the highest uncertainty and if possible to collect more exact information about them. Sometimes it can be also necessary to check all preconditions one more time, to make sure that the inputs that are being consider are realistic. In case of having an element with a very high level of uncertainty a good recommendation would be to split its costs in different parts.

7.2 Sensitivity analysis

Another way of showing the magnitudes of uncertainties is to conduct a sensitivity analysis. This analysis consist in vary some of the variables that have been used in the benefit cost analysis by a certain percentage and see how sensitive the new result are with respect to those changes.

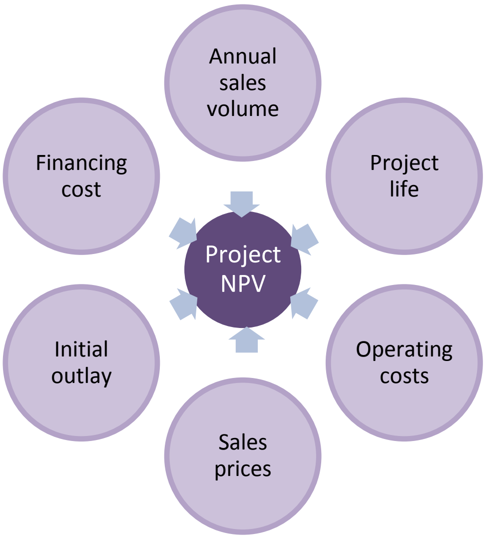


Figure 7.3 – Variables affecting the BCA. Based on Fernández (2014)

Some of the factors that can affect the sensitivity of, for example, NPV calculations are the ones in the figure above.

Assuming that the NPV is positive, it is necessary to examine each input value to see how far the estimation can change before the project becomes unviable for that specific reason. (Fernández A., et al 2014)

7.3 Uncertainty within a portfolio.

In Norway, government departments and ministries are responsible for managing uncertainty within portfolios, where very large projects are involved. The most common practice is to assign a budget to the portfolio that can be considered as a provision for uncertainty. It is important to notice that the uncertainty within a portfolio can turn out either as losses or savings, but it is in case of extra costs when this budget can be used to avoid possible cost overruns. (Berntsen, S., and Sunde, T., 2006)

An important observation in relation to portfolio is that in case of having independent projects the uncertainty provision can offset each other, but this normally does not occur due to the fact that projects within a portfolio are neither equal nor independent of each other. For this reason, it is necessary to assess how much financial preparedness (provision) is necessary for the portfolio overall.

It is here where the consideration of both unsystematic uncertainty and systematic uncertainty (affecting several projects simultaneously) arises.

Unsystematic uncertainty can be defined as those uncertainty factors influencing projects individually. Examples of this type of uncertainty can be ground conditions, quality plan basis, management ability, contract strategy, local weather conditions, productivity or technological development on special equipment.

Systematic uncertainty involves all those uncertainty factors affecting several projects simultaneously. Some examples could be the currency, construction market, market planning, changes in laws and regulations, price on fuel, tax changes, appropriation line, the builder's culture and access to project management, changes in the defence structure, national conditions, development international economics, global demand for war materials etc. As it can be understand all these factors will affect several projects at the same time so their effect cannot be diversified and it is at this point where the need to manage systematic uncertainties at portfolio level appears. (Berntsen, S., and Sunde, T., 2006)

As explained by Vennemo, et al (2014) unsystematic uncertainties are specific to each project and for that reason they can be ignored in BCA due to the fact that they disappear in the large portfolio. However, systematic uncertainties in a project should be taken into account when implementing a BCA. Thus, despite the fact that unsystematic uncertainty must be assessed when implementing individual projects, the main concern within a portfolio is to reduce the systematic uncertainty as much as possible.

In relation to this, Berntsen, S., and Sunde, T., (2006) proposed a simple and practical method to control both systematic and unsystematic uncertainties within a portfolio

For this purpose Berntsen, S., and Sunde, T., (2006) established the following systematic uncertainties as the one that affect portfolio most:

- Currency uncertainty: the dominant systematic uncertainty factor in the majority of defence project.

- Market uncertainty in the construction filed: the dominant systematic uncertainty factor for most road projects.

- Appropriation uncertainty: can be considered as an uncertainty element but that many projects points out as a problem, but in most of the cases can be solved using sensitivity analyses.

- The client's culture and access to project competence. The implementation capacity of an organization is a factor that must be considered when the composition of project portfolio is decided. For this reason it must be included as an ordinary systematic uncertainty element.

- Programme changes and tax changes: In Norway program changes are assumed to be covered through separate appropriations in Parliament, and tax changes handled in the ordinary budget process. Therefore, uncertainties related to these matters must be included.

Finally what is proposed in the method suggested by Berntsen, S., and Sunde, T., (2006) is to deeply examined all these factors alongside with the unsystematic uncertainty factors, in order to estimate different percentages of deviations that both systematic and unsystematic uncertainty factors can suffer during the life time of a projects in order to calculate how large the provision for uncertainty has to be when projects in a portfolio are seen as a whole.

It is important to highlight that this method is seen nowadays as a very useful tool to use when dealing with uncertainties related to cost estimation, but it has not been officially established as a part of the cost estimation process developed by NPRA.

8. A framework for assessing uncertainties

As previously explained, one is aware of the fact that it is during the cost estimation process developed by the NPRA when the uncertainties show up. It is important to notice that those estimation are later used when implementing the benefit cost analysis and the further profitability study where the NPV establishes if the projects is profitable from an economical point of view or not. Besides, if there are many competing projects for limited government funds, the selection criteria is the NPV per budget krone funded through the government budget, which is the so-called benefit-cost ratio (BC-ratio) Projects should then be ranked according to this ratio until the budget is depleted i.e. used up.

While the Norwegian framework for BCA has been found to be succinct and is of an international standard, it has a drawback that needs due consideration. That drawback is that the NPVs and the BC-ratio are presented as one figure without due consideration of the uncertainties regarding their expected outcomes. Notwithstanding, presenting uncertainties is a valuable information that may impact the decision makers decisions. To illustrate this, two projects A and B with a BC-ratio of 0.2 and 0.25 respectively are assumed. From this information, the decision maker will choose project B over A. However, if it turned out that the confidence intervals for the BC-ratio were respectively [0.15; 0.25] and [0.15; 0.30] for projects A and B, the decision maker would probably go for project A. The reason is twofold. First the two BC-ratios are not statistically different since they overlap and hence, the decision maker should be indifferent regarding their choices. Second, project A has a smaller expected variation and hence is more secure as compared to project B, making it a more preferred.

This example leads the fourth research question arises: How can confidence intervals for BCA results can be analysed and evaluated in order to help decision makers when ranking projects?

In order to answer this question the present master thesis is proposing a framework for ascertaining confidence intervals for BCA results, which will consist in various steps that will allow not only to calculate the confidence intervals, but also to rank the different projects within a portfolio. The main objective of this is to help informed decision makers in the road transport sector in Norway to choose in which projects the limited funds should be invested.

8.1 Steps in the framework for assessing uncertainties

Thereupon, all the steps in this framework are described.

1. A distinction between the alternative that is being considered (Alternative 1) and the “do-nothing” scenario (Alternative 0) has to be done.

2. In this step a division of benefits and cost is done depending on the stakeholders they are affecting. Thus, a differentiation between motorists, operators, public administration and society can be established.

Stakeholders	Components
Motorists	Vehicle costs
	Direct costs
	Time costs
Operators	Costs
	Incomes
	Transfers
Public administration (Goverment)	Investments
	Operation and maintenance
	Transfers
	Tax revenues
Society	Accidents
	Air pollution and noise
	Taxes

Table 8.1 - Cost and incomes affecting different stakeholders in a road project.

3. After collecting data from consultant companies in relation to cost and benefits estimations for both of the alternatives, it is necessary to handle benefits and costs that occur at different time periods. It is here when discounted cost and discounted benefits have to be calculated by taking into account not only the discount rate and the lifetime period of the project, but also a possible increase in annual benefit.

4. All the cost and incomes in each group of stakeholders must be added, without forgetting to use the negative sign for cost and the positive sign for incomes, revenues and transfers.

5. The NPV of each of the alternatives is calculated by adding all cost in all groups of stakeholders.

6. In this step a subtraction of the NPV of both alternatives is done in order to see which one is more profitable. In this case different circumstances can appear depending on the values obtained in each alternative:
   - If both NPV are positive, the subtraction can give the following results:
     i. Positive value, which means that alternative 1 is preferred
     ii. Negative value, which means that alternative 0 is preferred
   - If both NPV are negative, which means that both of the alternatives are not profitable, the subtraction can give the following results:
     i. Positive value, which means that alternative 1 is preferred, because alternative 0 has a more negative NPV

ii. Negative value, which means that alternative 0 is preferred, it has a less negative NPV

- If alternative 1 has a positive NPV and alternative 0 has a negative NPV, it is clear that in this case alternative 1 is preferred, but the result of the subtraction will be positive.
- If alternative 1 has a negative NPV and alternative 0 has a positive NPV, it is clear that in this case alternative 0 is preferred, but the result of the subtraction can be different depending on the absolute value of the NPV in both cases.

7. In this case the total budget used by the public administration is obtained by subtracting the total values that belong to the group of stakeholders named as Public administration (Government) of both the alternatives. This number will be considered in the following as the total costs of the road project financed through government budget.

8. Now with both the values obtained by subtracting the NPVs of both the alternative and the total costs of the road project financed through government budget, the BC- ratio can be calculated. That will be the most likely value (M) for the BC-ratio. It is important to notice that this ratio would measure the contribution to the society per each Norwegian krone financed through government budget when comparing both alternatives.

9. In order to measure the amount of uncertainty of all the estimations collecting at the beginning of the process, the variance (Var) and the standard deviation (σ) are calculated.

10. Finally the proposed framework suggests a 95% confidence interval for the BC-ratio which can be calculated as follows:

- For the lower point the following formula is used:

$$L = \left(E - 1.96 \cdot \frac{\sigma}{\sqrt{n}}\right) / \text{Cost of government budget}$$

- For the upper point the following formula is used:

$$H = \left(E + 1.96 \cdot \frac{\sigma}{\sqrt{n}}\right) / \text{Cost of government budget}$$

Where E is the expected NPV after subtracting both alternatives and n is the number of estimations. (Winter, J., 2006).

As a way of delimiting the size of the interval, and having an idea of the amount of uncertainty the author of the thesis recommends to calculate the difference between the upper and the lower points of the confidence interval. The higher this number, the greater the amount of uncertainty.

11. After calculating these confidence intervals, a ranking with the different projects can be done. It is important to remember that this ranking would be necessary in case of having many competing projects for limited government funds and there is a need to choose just some of them to be implemented.

Finally, with all the steps clearly defined a sketch of the whole process is done.

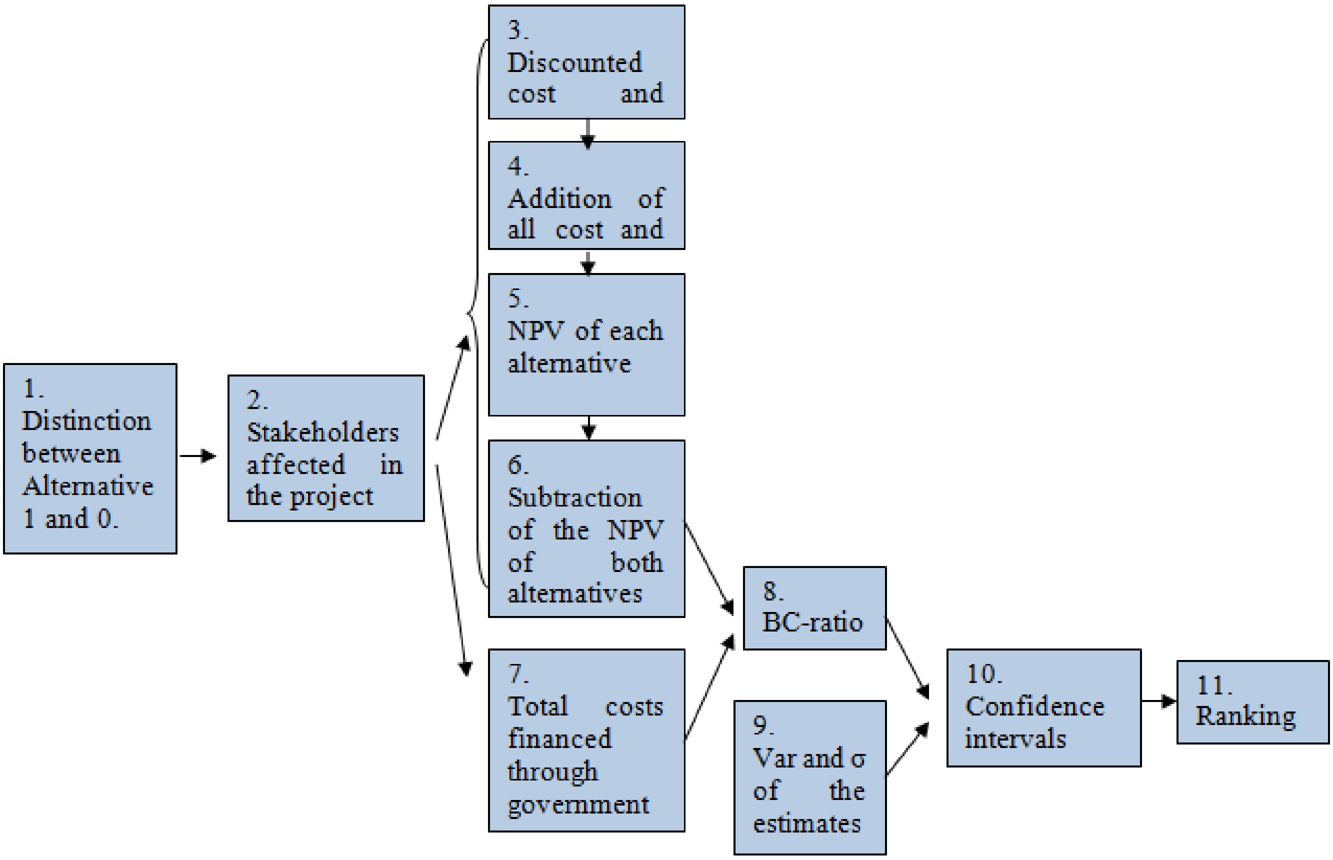


Figure 8.1 – A framework for ascertaining confidence intervals for BCA results

On the one hand, an observation of the previous sketch must be done. It can be said that the step number 9 could be located in the position it is already in the framework, but also at the beginning of the process. The reason is that the inputs for the calculations of the variance and standard deviation are the cost and benefit estimates collected before starting the process, so it would not be necessary to wait until step number 9 to calculate these statistical parameters. However, in the proposed framework the author has decided to put it in the ninth place to make it easy to understand that those parameters are required to calculate the confidence intervals.

On the other hand, due to the fact that the proposed framework can be difficult to understand from a practical point of view, a case study where the proposed framework is going to be tested will be deeply detailed in the following chapter.

9. Case of Study

The present case study is to be considered as a practical application of the framework proposed before. The main objective is not only to test the framework, but also to propose a methodology for ranking different projects, which constitutes the last step in the proposed framework.

9.1 Data in the Case Study.

This case study is based on data of 44 different road projects that have been collected with the help of consulting companies directly linked with the supervisor of the present master thesis.

In all the cases the data contain estimations made by those companies for a period of time from 2022 until 2061 referred to both the Alternative 1 (a new construction project) and Alternative 0 ("do-nothing" scenario). In the following table the names of all projects analysed are included.

E6 Dombås - Sør Trøndelag
E6 Gardermoen Lillehamme
E6 Lillehammer Otta
E6 Otta – Dombås
E16 Fagernes S- Bjørgo
E16 Kneppe - Gardermoen
E16 Olum-Roa
E16 Øye – Hande
E16 Piperud - Kneppe
E16 Vingersnoret Xrv2- Riksgrensen
E136 Dombås – Bjorli
Rv 2 Helset - Elverum
Rv 2 Jømna - Helset
Rv 2 Magnor-Rasta
Rv 2 Rasta – Sundhjørnet
Rv 2 Roverud – Jømna
Rv 2 Vingersnoret – Roverud
Rv 4 Akershus grense _ Roa
Rv 4 Rotnes - Oppland grense
Rv 21 Halden sentrum - X E6 Svingenskogen
Rv 25 Elverum – Hernes
Rv 25 Finstad – Nybergsund

Rv 25 Hernes – Finstad
Rv 25 Nybergsund – Støa
Rv 110 Karlshus - Ørebekk
Rv 110 Ørebekk – Østsiden
Rv 111 Dondern – Kampenes
Rv 111 Gatedalen – Dondern
Rv 111 Moum - Gatedalen
Rv 111 Øra – Moum
Rv3 Alvdal – Motrøa
Rv3 Grundset - Gita bru
Rv3 Kolomoen – Ommangsvollen
Rv3 Motrøa – Ulsberg
Rv3 Nordstumoen - Alvdal
Rv3 Rena – Nordstumoen
Rv3 Skjærodden – Rena
Rv15 Dale – Dønfoss
Rv15 Otta – Dale
Rv15 Strynfjellet (Dønfoss - S-o-F gr)
Rv19 xE6 - rv19-xfv118
Rv19-xfv118- Ferjekaia Moss
Rv25 Åker gård – Tønset
Rv25 Ringgata - Åker gård

Table 9.1 – Projects analysed during the case study.

The estimations of these projects are referred to:

- Vehicle costs
- Direct costs
- Time costs
- Operator Costs
- Operator Income
- Operator Transfers
- Investments
- Operation and maintenance costs
- Transfers costs
- Tax revenues
- Accident costs
- Air pollution and noise costs
- Taxes

In appendix 1 the data obtained from the consulting companies of just one of the projects are presented as an example.

9.2 Testing the proposed framework in the present case study

After analysing the data of all the projects, where the first step of the proposed framework "Distinction between Alternative 1 and 0" was already done, the following steps had to be implemented.

The author of the present master thesis decided to implement all the steps from the second until the seventh one by creating a spreadsheet, where not only a clear distinction of the alternatives and the stakeholders was done, but also all the additions and subtractions were included.

In the table in the following page the results obtained for the project of E6 Dombås - Sør Trøndelag are shown. It is important to point out that the same has been done with the rest of the projects, but it has been considered that in order to understand the procedure it is enough with the table of one of them.

Cost analysis during the period 2022-2061				
Stakeholders	**Components**	**Alternative 1**	**Alternative 0**	**Difference**
Motorist	Vehicle costs	-2774187	-2716983	-57203
	Direct costs	-76346	-76843	497
	Time costs	-5583124	-5942720	359596
-	TOTAL	-8433657	-8736546	**302890**
Operator	Costs	-117818	-118585	767
	Income	70691	71151	-460
	Transfers	47127	47434	-307
	TOTAL	0	0	**0**
Public administration	Investments	-1462912	0	-1462912
	Operation and maintenance	-151468	-146074	-5395
	Transfers	-47127	-47434	307
	Tax revenues	750695	723810	26886
	TOTAL	-910812	530302	**-1441114**
Society	Accidents	-537760	-707443	169682
	Air pollution and noise	-346128	-328359	-17769
	Taxes	-182162	106060	-288223
	TOTAL	-1066050	-929741	**-136309**
TOTAL		-10410519	-9135986	**-1274534**

NPV (E)	Cost of government budget (B)
-1274534	-1441114

Table 9.2 – Implementation of steps 2-7 of the framework in the case of E6 Dombås - Sør Trøndelag project.

Now with the values obtained by subtracting the NPVs of both the alternative (-1274534) and the total costs of the road project financed through government budget without its negative sign (1441114), the eighth step, where the BC- ratio is calculated, can be developed. In this case spreadsheets are used again with the main aim of accelerating the process when calculating this ratio for all the 44 projects.

The formula used for this ratio is the following one:

$$\text{B-C ratio} = \frac{NPV}{C_{goverment \quad budget}} = \frac{E}{B}$$

The result in the case E6 Dombås - Sør Trøndelag project is then:

$$\text{BC-ratio} = \frac{-274534}{1441114} = -\ 0{,}884408588$$

It is important to notice that the value of the BC-ratio is negative due to the fact that that the NPV is negative. In cases like this the first consideration that has to be taken into account is that the project is not profitable, so in a normal case there would not be a need to calculate the BC-ratio. The reason for this is, as it has been explained before, that this ratio is just used when choosing between different profitable projects which cannot be undertaken due to a limitation of the government´s budget. However, due to the fact that all spreadsheets are programmed to calculate this ratio, the author decided to calculate it even if the project is not profitable, which as will be later seen occurs in most of the projects analysed.

The following step in the proposed framework is to calculate the variance of the estimations which has been done by applying the "_xlfn.VAR.S( )" function in Excel. In this case the estimates analysed by this function are the ones after subtracting both alternatives, which in the fifth table given by the consulting companies for each of the projects.

For the example that is been further described, E6 Dombås - Sør Trøndelag project, the values of the variance and the standard deviation are:

$$\text{Variance (Var)} = 4290493469$$
$$\sigma = +\sqrt{\text{Var}} = 65501{,}85852$$

Finally, in order to calculate the 95% confidence interval for the BC-ratio, the formulas previously detailed for the lower and upper points are programmed in Excel. Thus, the results for this specific project are obtained:

- Lower point:

$$L = \left(E - 1.96 \cdot \frac{\sigma}{\sqrt{n}}\right) / \text{Cost of government budget}$$
$$L = \left(-1274534 - 1.96 \cdot \frac{65501{,}85852}{\sqrt{40}}\right) / 1441114 = -0{,}870322793$$

- Upper point:

$$H = \left(E + 1.96 \cdot \frac{\sigma}{\sqrt{n}}\right) / \text{Cost of government budget}$$
$$H = \left(-1274534 + 1.96 \cdot \frac{65501{,}85852}{\sqrt{40}}\right) / 1441114 = -0{,}898494384$$

So the 95% confidence interval for the BC-ratio in the case E6 Dombås - Sør Trøndelag project is: (-0,870322793, -0,898494384) and the difference between the limits is 0,028171591.

The same procedure is implemented for all projects and then the following table is created to have an overview. It is important to mention that E, L and H are referred to the expected value, low value and high value of both the NPVs and the BC-ratios. On the other hand, the term “Budget (B)” is referred to the cost of the government budget, and the variation (H-L) is the difference between both the limits of the confidence interval for BC-ratio, that is the amplitude of the interval.

In order to know easily which projects are profitable and which ones are not, green and red colours, respectively, have been used to highlight the results. As it can be seen in the table, only 8 of the 44 projects are profitable, something that commonly occur in Norway due to two main important reasons: the difficulties to build in the Norwegian orography which makes the costs increase in a great extent and the low traffic levels, which makes the benefits for the population not to be so high. As a consequence, when calculating the NPV (discounted benefits - discounted costs) the values obtained are negative.

Confidence interval: 95%		Net Present Value (NPV)				Benefit- Cost Ratio (BCratio) = NPV/B			
	Budget (B)	E	σ	L	H	E	L	H	Variation (H-L)
E6 Dombås - Sør trøndelag	-1441114	-1274534	65501,85852	-1294833,236	-1254234,76	-0,884408867	-0,89849466	-0,870323072	0,02817159
E6 Gardermoen Lillehammer	-21076149	-2634216	862632,7517	-2901548,659	-2366883,34	-0,124985641	-0,13766977	-0,112301509	0,025368264
E6 Lillehammer Otta	-6910594	-2749460	288515,2408	-2838871,799	-2660048,2	-0,397861602	-0,41079997	-0,384923235	0,025876733
E6 Otta – Dombås	-2405369	-1733792	110590,9421	-1768064,488	-1699519,51	-0,720800842	-0,73504917	-0,706552513	0,028496657
E16 Fagernes S- Bjørgo	-1022421	-2015157	50543,6249	-2030820,632	-1999493,37	-1,970965972	-1,98628611	-1,955645833	0,030640278
E16 Kneppe - Gardermoen	-250938	832113	13765,96533	827846,8831	836379,117	3,316010329	3,299009648	3,33301101	0,034001362
E16 Olum-Roa	-548111	-440752	24661,1416	-448394,567	-433109,433	-0,804129091	-0,81807256	-0,790185625	0,027886932
E16 Øye – Hande	-2482872	-2570154	111567,8986	-2604729,25	-2535578,75	-1,035153645	-1,04907915	-1,021228138	0,027851013
E16 Piperud - Kneppe	-120305	-85176	5359,346734	-86836,87876	-83515,1212	-0,708000499	-0,72180607	-0,694194932	0,027611134
E16 Vingersnoret Xrv2- Riksgrensen	-2264926	-2570646	101432,3032	-2602080,196	-2539211,8	-1,134980127	-1,14885881	-1,121101442	0,027757372
E136 Dombås – Bjorli	-2608645	-2372253	119247,4798	-2409208,177	-2335297,82	-0,909381307	-0,92354773	-0,895214881	0,028332852
Rv 2 Helset - Elverum	-291593	-227888	12894,26501	-231883,9741	-223892,026	-0,781527677	-0,79523162	-0,767823733	0,027407888
Rv 2 Jømna - Helset	-821377	-308685	38178,26356	-320516,5665	-296853,434	-0,375814029	-0,39021858	-0,361409479	0,028809101
Rv 2 Magnor-Rasta	-1798430	-547890	80287,52721	-572771,3625	-523008,638	-0,304649055	-0,3184841	-0,290814009	0,027670093
Rv 2 Rasta – Sundhjørnet	-126047	142431	5939,827893	140590,2283	144271,772	1,12998326	1,115379408	1,144587112	0,029207704
Rv 2 Roverud – Jømna	-4798666	-4261290	217309,7713	-4328634,996	-4193945	-0,888015544	-0,90204965	-0,873981437	0,028068216
Rv 2 Vingersnoret – Roverud	-759385	-614103	34376,53698	-624756,3992	-603449,601	-0,808684659	-0,82271364	-0,794655676	0,028057966
Rv 4 Akershus grense _ Roa	-1582355	-954095	71594,34322	-976282,3168	-931907,683	-0,602958881	-0,61698059	-0,588937175	0,028043412
Rv 4 Rotnes - Oppland grense	-2195632	1261408	107689,1272	1228034,794	1294781,21	0,574507932	0,559308114	0,58970775	0,030399636
Rv 21 Halden sentrum - X E6 Svingenskogen	-1669572	1440338	68957,48122	1418967,855	1461708,14	0,862698943	0,849899169	0,875498718	0,025599549
Rv 25 Elverum – Hernes	-45244	-31832	2031,088181	-32461,44075	-31202,5593	-0,703562903	-0,71747504	-0,689650766	0,027824275
Rv 25 Finstad – Nybergsund	-2243083	-2469713	100975,5442	-2501005,645	-2438420,35	-1,101035049	-1,11498578	-1,087084319	0,02790146
Rv 25 Hernes – Finstad	-446868	-254007	20328,64458	-260306,9122	-247707,088	-0,568416177	-0,5825141	-0,55431825	0,028195853
Rv 25 Nybergsund – Støa	-1054955	-1217897	47238,63108	-1232536,403	-1203257,6	-1,154453981	-1,16833079	-1,140577178	0,027753607
Rv 110 Karlshus – Ørebekk	-3327472	-1384293	152005,006	-1431399,839	-1337186,16	-0,416019429	-0,43017637	-0,401862483	0,028313891
Rv 110 Ørebekk – Østsiden	-2211733	140691	97688,32603	110417,0741	170964,926	0,063611204	0,049923329	0,07729908	0,027375751
Rv 111 Dondern – Kampenes	-535899	583916	26504,70916	575702,1055	592129,894	1,089600839	1,074273521	1,104928157	0,030654636
Rv 111 Gatedalen – Dondern	-1089139	294416	48861,07298	279273,7966	309558,203	0,27031995	0,256417038	0,284222862	0,027805823
Rv 111 Moum - Gatedalen	-1034750	-106723	48591,77707	-121781,7477	-91664,2523	-0,103138922	-0,11769195	-0,088585893	0,02910606
Rv 111 Øra – Moum	-1839936	-1016659	80698,36896	-1041667,684	-991650,316	-0,552551284	-0,56614343	-0,538959136	0,027184297
Rv3 Alvdal – Motrøa	-1090417	-794731	49674,67904	-810125,3425	-779336,657	-0,728832181	-0,74295003	-0,714714332	0,028235698
Rv3 Grundset - Gita bru	-966730	-269626	46034,46697	-283892,2291	-255359,771	-0,278905175	-0,29366238	-0,264147974	0,029514402
Rv3 Kolomoen – Ommangsvollen	-1004250	-590964	46656,31159	-605422,9408	-576505,059	-0,588463032	-0,60286078	-0,574065282	0,028795501
Rv3 Motrøa – Ulsberg	-3675354	-4036955	165480,6992	-4088238	-3985672	-1,098385353	-1,11233857	-1,084432139	0,027906428
Rv3 Nordstumoen – Alvdal	-3628998	-3261993	164940,1937	-3313108,496	-3210877,5	-0,898868779	-0,91295407	-0,884783487	0,028170584
Rv3 Rena – Nordstumoen	-2509728	-2312211	113051,2881	-2347245,957	-2277176,04	-0,92129944	-0,9352591	-0,907339777	0,027919326
Rv3 Skjærodden – Rena	-61555	-20482	2857,698478	-21367,60993	-19596,3901	-0,332743075	-0,34713037	-0,31835578	0,02877459
Rv15 Dale – Dønfoss	-3223121	-2695932	147094,5202	-2741517,064	-2650346,94	-0,836435244	-0,85057839	-0,8222921	0,028286288
Rv15 Otta – Dale	-138904	20091	6959,364896	17934,27047	22247,7295	0,144639463	0,1291127	0,160166227	0,031053527
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-3114396	-3499918	139527,5202	-3543158,026	-3456677,97	-1,123787084	-1,137671	-1,109903164	0,027767841
Rv19 xE6 - rv19-xfv118	-605977	-406092	27931,82858	-414748,1634	-397435,837	-0,670144246	-0,68442889	-0,655859606	0,02856928
Rv19-xfv118- Ferjekaia Moss	-1293670	-633511	57735,84327	-651403,5232	-615618,477	-0,489700619	-0,50353144	-0,475869794	0,02766165
Rv25 Åker gård – Tønset	-3770856	-2868161	171157,9649	-2921203,403	-2815118,6	-0,76061271	-0,77467912	-0,746546301	0,028132818
Rv25 Ringgata - Åker gård	-865599	-547365	38760,87629	-559377,12	-535352,88	-0,632354011	-0,64623125	-0,618476777	0,027754468

Table 9.3 – Costs of government budget, NPVs and BC-ratios of the projects analysed.

Now, before discussing the results, the objective is to order the projects depending on some of the results obtained. Thus, table 9.4 shows the result of the different projects listing them by descending order of the expected NPV, table 9.5 shows the result of the different projects in decreasing order of the variation of BC-ratios and table 9.6 shows the results in order of decreasing expected value of the BC-ratio. It is important to notice that in these three tables, profitable projects appear in the first place.

Project	NPV (E)	BC-ratio (variation)
Rv 21 Halden sentrum - X E6 Sving.	1440338	0,025599549
Rv 4 Rotnes - Oppland grense	1261408	0,030399636
E16 Kneppe - Gardermoen	832113	0,034001362
Rv 111 Dondern – Kampenes	583916	0,030654636
Rv 111 Gatedalen – Dondern	294416	0,027805823
Rv 2 Rasta – Sundhjørnet	142431	0,029207704
Rv 110 Ørebekk – Østsiden	140691	0,027375751
Rv15 Otta – Dale	20091	0,031053527
Rv3 Skjærodden – Rena	-20482	0,02877459
Rv 25 Elverum – Hernes	-31832	0,027824275
E16 Piperud - Kneppe	-85176	0,027611134
Rv 111 Moum - Gatedalen	-106723	0,02910606
Rv 2 Helset - Elverum	-227888	0,027407888
Rv 25 Hernes – Finstad	-254007	0,028195853
Rv3 Grundset - Gita bru	-269626	0,029514402
Rv 2 Jømna - Helset	-308685	0,028809101
Rv19 xE6 - rv19-xfv118	-406092	0,02856928
E16 Olum-Roa	-440752	0,027886932
Rv25 Ringgata - Åker gård	-547365	0,027754468
Rv 2 Magnor-Rasta	-547890	0,027670093
Rv3 Kolomoen – Ommangsvollen	-590964	0,028795501
Rv 2 Vingersnoret – Roverud	-614103	0,028057966
Rv19-xfv118- Ferjekaia Moss	-633511	0,02766165
Rv3 Alvdal – Motrøa	-794731	0,028235698
Rv 4 Akershus grense _ Roa	-954095	0,028043412
Rv 111 Øra – Moum	-1016659	0,027184297
Rv 25 Nybergsund – Støa	-1217897	0,027753607
E6 Dombås - Sør trøndelag	-1274534	0,028171591
Rv 110 Karlshus – Ørebekk	-1384293	0,028313891
E6 Otta – Dombås	-1733792	0,028496657
E16 Fagernes S- Bjørgo	-2015157	0,030640278
Rv3 Rena – Nordstumoen	-2312211	0,027919326
E136 Dombås – Bjorli	-2372253	0,028332852
Rv 25 Finstad – Nybergsund	-2469713	0,02790146
E16 Øye – Hande	-2570154	0,027851013
E16 Vingersnoret Xrv2- Riksgrensen	-2570646	0,027757372
E6 Gardermoen Lillehammer	-2634216	0,025368264
Rv15 Dale – Dønfoss	-2695932	0,028286288
E6 Lillehammer Otta	-2749460	0,025876733
Rv25 Åker gård – Tønset	-2868161	0,028132818
Rv3 Nordstumoen – Alvdal	-3261993	0,028170584
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-3499918	0,027767841
Rv3 Motrøa – Ulsberg	-4036955	0,027906428
Rv 2 Roverud – Jømna	-4261290	0,028068216

Table 9.4 - Result of the different projects listing them by descending order of the expected NPV.

Project	NPV	BC-ratio (variation)
Rv 21 Halden sentrum - X E6 Sving.	1440338	0,025599549
Rv 110 Ørebekk – Østsiden	140691	0,027375751
Rv 111 Gatedalen – Dondern	294416	0,027805823
Rv 2 Rasta – Sundhjørnet	142431	0,029207704
Rv 4 Rotnes - Oppland grense	1261408	0,030399636
Rv 111 Dondern – Kampenes	583916	0,030654636
Rv15 Otta – Dale	20091	0,031053527
E16 Kneppe - Gardermoen	832113	0,034001362
E6 Gardermoen Lillehammer	-2634216	0,025368264
E6 Lillehammer Otta	-2749460	0,025876733
Rv 111 Øra – Moum	-1016659	0,027184297
Rv 2 Helset - Elverum	-227888	0,027407888
E16 Piperud - Kneppe	-85176	0,027611134
Rv19-xfv118- Ferjekaia Moss	-633511	0,02766165
Rv 2 Magnor-Rasta	-547890	0,027670093
Rv 25 Nybergsund – Støa	-1217897	0,027753607
Rv25 Ringgata - Åker gård	-547365	0,027754468
E16 Vingersnoret Xrv2- Riksgrensen	-2570646	0,027757372
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-3499918	0,027767841
Rv 25 Elverum – Hernes	-31832	0,027824275
E16 Øye – Hande	-2570154	0,027851013
E16 Olum-Roa	-440752	0,027886932
Rv 25 Finstad – Nybergsund	-2469713	0,02790146
Rv3 Motrøa – Ulsberg	-4036955	0,027906428
Rv3 Rena – Nordstumoen	-2312211	0,027919326
Rv 4 Akershus grense _ Roa	-954095	0,028043412
Rv 2 Vingersnoret – Roverud	-614103	0,028057966
Rv 2 Roverud – Jømna	-4261290	0,028068216
Rv25 Åker gård – Tønset	-2868161	0,028132818
Rv3 Nordstumoen – Alvdal	-3261993	0,028170584
E6 Dombås - Sør trøndelag	-1274534	0,028171591
Rv 25 Hernes – Finstad	-254007	0,028195853
Rv3 Alvdal – Motrøa	-794731	0,028235698
Rv15 Dale – Dønfoss	-2695932	0,028286288
Rv 110 Karlshus – Ørebekk	-1384293	0,028313891
E136 Dombås – Bjorli	-2372253	0,028332852
E6 Otta – Dombås	-1733792	0,028496657
Rv19 xE6 - rv19-xfv118	-406092	0,02856928
Rv3 Skjærodden – Rena	-20482	0,02877459
Rv3 Kolomoen – Ommangsvollen	-590964	0,028795501
Rv 2 Jømna - Helset	-308685	0,028809101
Rv 111 Moum - Gatedalen	-106723	0,02910606
Rv3 Grundset - Gita bru	-269626	0,029514402
E16 Fagernes S- Bjørgo	-2015157	0,030640278

Table 9.5 - Result of the different projects listing them by descending order of the variation of the BC-ratio.

Projects	NPV	Bcratio (E)
E16 Kneppe - Gardermoen	832113	3,31601033
Rv 2 Rasta – Sundhjørnet	142431	1,12998326
Rv 111 Dondern – Kampenes	583916	1,08960084
Rv 21 Halden sentrum - X E6 Sving.	1440338	0,86269894
Rv 4 Rotnes - Oppland grense	1261408	0,57450793
Rv 111 Gatedalen – Dondern	294416	0,27031995
Rv15 Otta – Dale	20091	0,14463946
Rv 110 Ørebekk – Østsiden	140691	0,0636112
Rv 111 Moum - Gatedalen	-106723	-0,10313892
E6 Gardermoen Lillehammer	-2634216	-0,12498564
Rv3 Grundset - Gita bru	-269626	-0,27890518
Rv 2 Magnor-Rasta	-547890	-0,30464906
Rv3 Skjærodden – Rena	-20482	-0,33274308
Rv 2 Jømna - Helset	-308685	-0,37581403
E6 Lillehammer Otta	-2749460	-0,3978616
Rv 110 Karlshus – Ørebekk	-1384293	-0,41601943
Rv19-xfv118- Ferjekaia Moss	-633511	-0,48970062
Rv 111 Øra – Moum	-1016659	-0,55255128
Rv 25 Hernes – Finstad	-254007	-0,56841618
Rv3 Kolomoen – Ommangsvollen	-590964	-0,58846303
Rv 4 Akershus grense _ Roa	-954095	-0,60295888
Rv25 Ringgata - Åker gård	-547365	-0,63235401
Rv19 xE6 - rv19-xfv118	-406092	-0,67014425
Rv 25 Elverum – Hernes	-31832	-0,7035629
E16 Piperud - Kneppe	-85176	-0,7080005
E6 Otta – Dombås	-1733792	-0,72080084
Rv3 Alvdal – Motrøa	-794731	-0,72883218
Rv25 Åker gård – Tønset	-2868161	-0,76061271
Rv 2 Helset - Elverum	-227888	-0,78152768
E16 Olum-Roa	-440752	-0,80412909
Rv 2 Vingersnoret – Roverud	-614103	-0,80868466
Rv15 Dale – Dønfoss	-2695932	-0,83643524
E6 Dombås - Sør trøndelag	-1274534	-0,88440889
Rv 2 Roverud – Jømna	-4261290	-0,88801554
Rv3 Nordstumoen – Alvdal	-3261993	-0,89886878
E136 Dombås – Bjorli	-2372253	-0,90938131
Rv3 Rena – Nordstumoen	-2312211	-0,92129944
E16 Øye – Hande	-2570154	-1,03515364
Rv3 Motrøa – Ulsberg	-4036955	-1,09838535
Rv 25 Finstad – Nybergsund	-2469713	-1,10103505
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-3499918	-1,12378708
E16 Vingersnoret Xrv2- Riksgrensen	-2570646	-1,13498013
Rv 25 Nybergsund – Støa	-1217897	-1,15445398
E16 Fagernes S- Bjørgo	-2015157	-1,97096597

Table 9.6 - Result of the different projects listing them by descending order of the expected value of the BC-ratio.

As it can be seen, the order of the projects in the three previous tables varies. For this reason the author of the thesis has developed an analysis of the regression lines where the relation between both the expected value for the BC-ratio and the confidence interval (BC-ratio variation) are examined.

First of all, it is important to point out that after implementing a model using a regression line, there are some considerations directly linked with how well the model fits the data that must be taken into account. One way of measuring how close the data are to the plotted regression line is by the use of the R^2. As defined by Frost, J., (2013) R^2 is "the percentage of response variable variation that is explained by a linear model". In other words, it can be defined as the relation between the explained variation and the total variation in a linear model. Thus, R^2 is a value that varies between 0 and 1 and the higher it is, the better the model fits the data, which mean the more variance is accounted by the regression model. Nevertheless, in some cases a low R^2 value can represent a good model or high values of R^2 can represent bad models. That is why R^2 should be always evaluated in conjunction with the residual plots, which can be considered as the estimates of the errors in the linear model. (Frost, J., 2013) By using residual plots the observed deviations can be evaluated in relation to stochastic deviations, that is random and unpredictable deviations, which is what the linear models aims to represent. In this manner, if the residuals show that the model is systematically incorrect, that would mean that the linear model is not good enough. . (Frost, J., 2012)

Now, after having a clear understanding about the regression linear model, this is apply to the case of this thesis, which concerns the confidence intervals in relation to the BC-ratio.

In the following graph, the regression line relating these two parameters has been plotted and the equation of the regression line and the value of the R^2 are obtained.

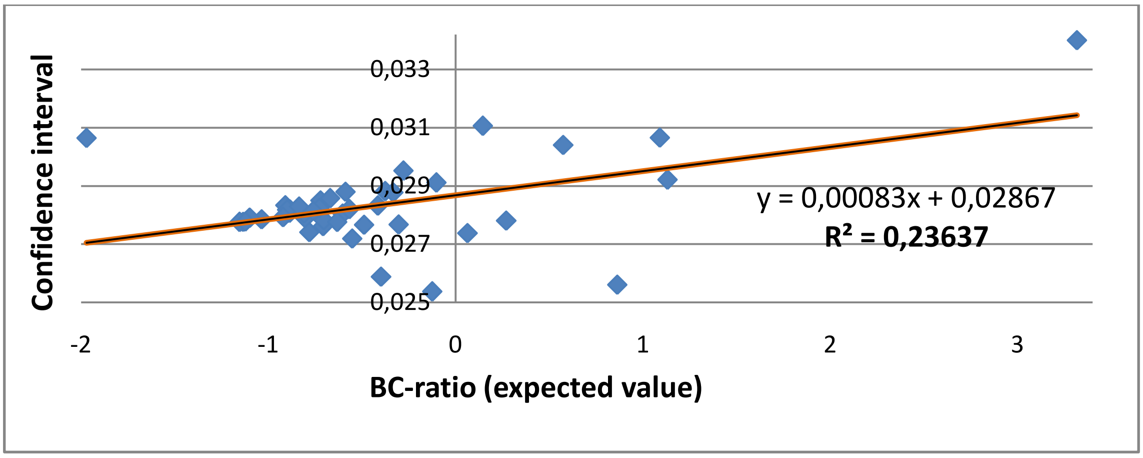


Figure 9.1- Regression line relating confidence interval and BC-ratio (E)

As it can be seen, there are some data that are away from the regression line. This fact together with the low value of the R^2, indicates that there is not a clear linear dependency between both the parameters. However, when plotting the residuals it can be seen that there is a randomness in them, which means that the deviations are not following any pattern. Nevertheless, the author of the thesis considers this linear model not good enough in order to create conclusions about the linear dependency between both the BC-ratio and the confidence intervals.

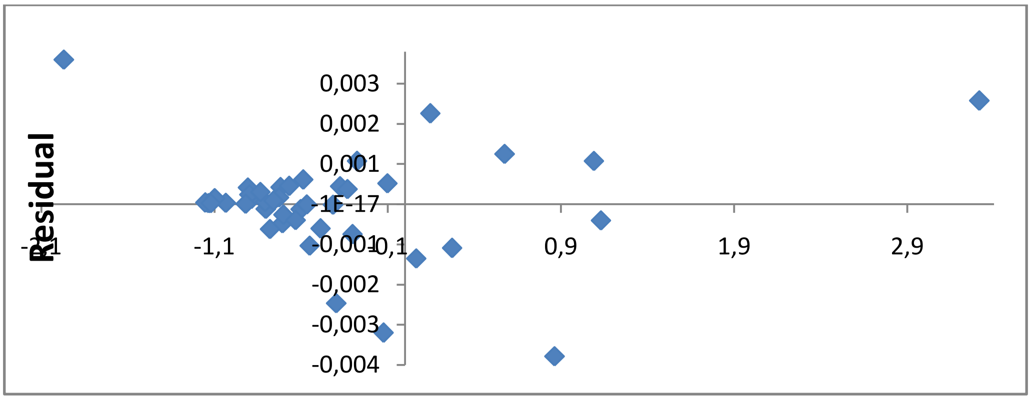


Figure 9.2- Residuals plot of the regression line relating confidence interval and BC-ratio (E)

The main reason that can explain why it is not possible to establish a linear dependency between both the BC-ratio and the confidence interval is the fact that when calculating the confidence intervals the standard deviation of the estimates is taken into account. This statistical variable depends on many different factors that, as has been explained before, are directly linked to the amount of systematic uncertainty of the estimates used when developing a BCA.

In the following table, the projects are ordered in relation to the expected values of the BC-ratio. But in this case, the other parameter that can be seen in the table is the standard deviation of the BC- ratio, which can be calculated as follows:

$$\sigma_{\text{BC-ratio}} = \frac{\sigma_{\text{NPV}}}{Governement \quad budget}$$

The reason for this is that the aim now is to study the possibility of getting a good regression model which relates these two variables.

Projects	BC-ratio (E)	BC- ratio (σ)
E16 Kneppe - Gardermoen	3,316010329	0,054858034
Rv 2 Rasta – Sundhjørnet	1,12998326	0,047123913
Rv 111 Dondern – Kampenes	1,089600839	0,049458404
Rv 21 Halden sentrum - X E6 Sving.	0,862698943	0,04130249
Rv 4 Rotnes - Oppland grense	0,574507932	0,049046984
Rv 111 Gatedalen – Dondern	0,27031995	0,044862109
Rv15 Otta – Dale	0,144639463	0,050101976
Rv 110 Ørebekk – Østsiden	0,063611204	0,044168227
Rv 111 Moum - Gatedalen	-0,103138922	0,04695992
E6 Gardermoen Lillehammer	-0,124985641	0,040929334
Rv3 Grundset - Gita bru	-0,278905175	0,047618743

Rv 2 Magnor-Rasta	-0,304649055	0,044643121
Rv3 Skjærodden – Rena	-0,332743075	0,046425124
Rv 2 Jømna - Helset	-0,375814029	0,046480804
E6 Lillehammer Otta	-0,397861602	0,041749702
Rv 110 Karlshus – Ørebekk	-0,416019429	0,045681829
Rv19-xfv118- Ferjekaia Moss	-0,489700619	0,044629498
Rv 111 Øra – Moum	-0,552551284	0,043859335
Rv 25 Hernes – Finstad	-0,568416177	0,045491386
Rv3 Kolomoen – Ommangsvollen	-0,588463032	0,046458861
Rv 4 Akershus grense _ Roa	-0,602958881	0,045245437
Rv25 Ringgata - Åker gård	-0,632354011	0,044779253
Rv19 xE6 - rv19-xfv118	-0,670144246	0,046093876
Rv 25 Elverum – Hernes	-0,703562903	0,044891879
E16 Piperud - Kneppe	-0,708000499	0,044547997
E6 Otta – Dombås	-0,720800842	0,045976705
Rv3 Alvdal – Motrøa	-0,728832181	0,045555672
Rv25 Åker gård – Tønset	-0,76061271	0,045389685
Rv 2 Helset - Elverum	-0,781527677	0,044220077
E16 Olum-Roa	-0,804129091	0,04499297
Rv 2 Vingersnoret – Roverud	-0,808684659	0,045268918
Rv15 Dale – Dønfoss	-0,836435244	0,045637294
E6 Dombås - Sør Trøndelag	-0,884408888	0,04545224
Rv 2 Roverud – Jømna	-0,888015544	0,045285455
Rv3 Nordstumoen – Alvdal	-0,898868779	0,045450616
E136 Dombås – Bjorli	-0,909381307	0,045712422
Rv3 Rena – Nordstumoen	-0,92129944	0,045045235
E16 Øye – Hande	-1,035153645	0,044935018
Rv3 Motrøa – Ulsberg	-1,098385353	0,045024425
Rv 25 Finstad – Nybergsund	-1,101035049	0,04501641
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-1,123787084	0,044800828
E16 Vingersnoret Xrv2- Riksgrensen	-1,134980127	0,044783937
Rv 25 Nybergsund – Støa	-1,154453981	0,044777864
E16 Fagernes S- Bjørgo	-1,970965972	0,049435237

Table 9.7 - Results of the different projects listing them by descending order of the expected BC-ratio, with their respective values of the standard deviations.

In the following figure the regression line for both this two parameter is plotted.

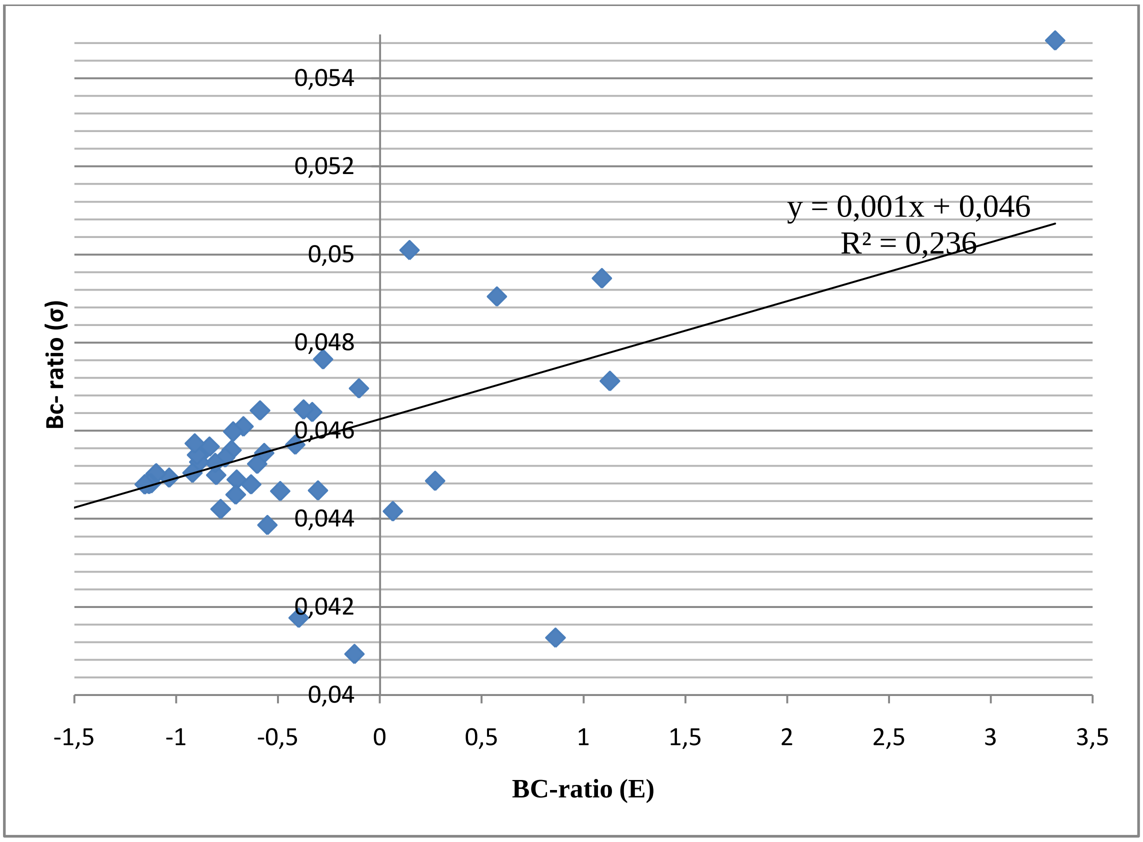


Figure 9.3- Regression line relating standard deviation and BC-ratio (E)

As it can be seen in this case the value of the R^2 is almost the same as in the previous regression line, so this analysis concludes with the fact that there is no possibility of considering the regression models good enough to affirm that a linear dependency can be established between these two parameters.

However, a deeper study of the BC-ratio in relation to its uncertainty is going to be detailed. For this purpose the S-curves of the 8 profitable projects analysed in this case study are to be included.

Projects		BC-ratio (E)	Bc- ratio (σ)
P 1	E16 Kneppe - Gardermoen	3,316010329	0,054858034
P 2	Rv 2 Rasta – Sundhjørnet	1,12998326	0,047123913
P 3	Rv 111 Dondern – Kampenes	1,089600839	0,049458404
P 4	Rv 21 Halden sentrum - X E6 Sving.	0,862698943	0,04130249
P 5	Rv 4 Rotnes - Oppland grense	0,574507932	0,049046984
P 6	Rv 111 Gatedalen – Dondern	0,27031995	0,044862109
P 7	Rv15 Otta – Dale	0,144639463	0,050101976
P 8	Rv 110 Ørebekk – Østsiden	0,063611204	0,044168227

The main aim of using these curves is to graphically understand how much uncertainty is linked to each of the projects. In this way the longer the S-curve the more uncertainty the project has.

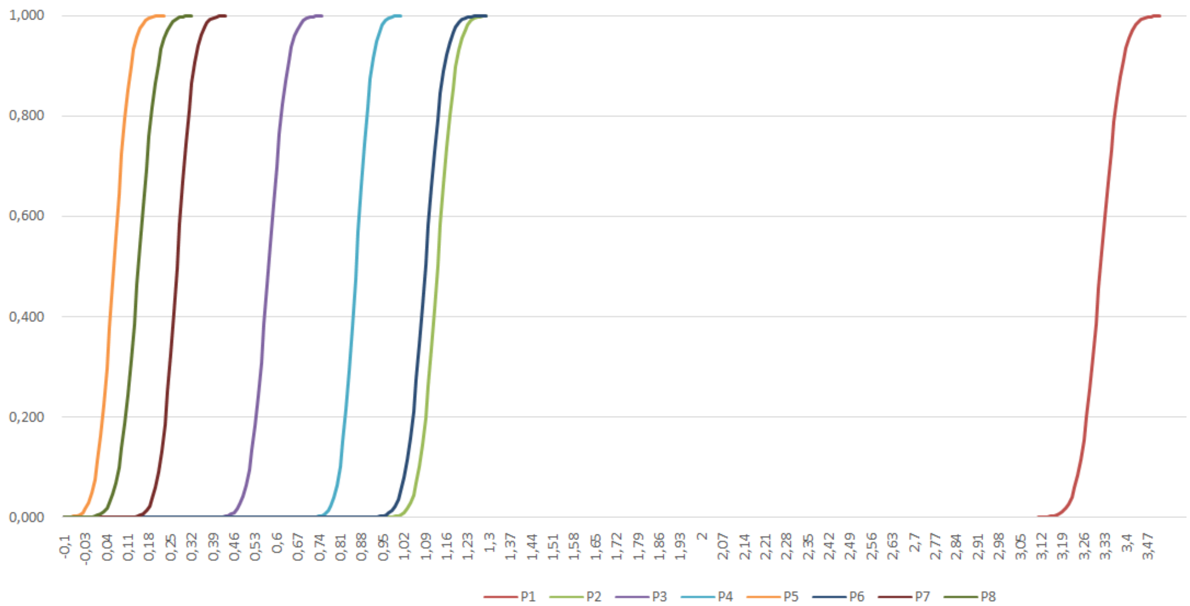


Figure 9.4 – S-curves of the profitable projects.

It can be observed that despite the fact that the expected value of the BC-ratio of each of the projects are quite different, the shapes of all the S-curves are very similar, and they can practically be considered as parallel. The reason for this is that the standard deviations of the projects are very similar, which makes the values which correspond to 100% (E+ 3 σ) and 0% (E- 3 σ) be equally separated in all cases.

Finally, in order to finish analysing the BC-ratio of all these 8 projects, the “pRisk” programme, created by Vatn, J. (2013), has been used to run a Monte Carlo Simulation. It is important to highlight that this technique is used when the situation that is being analysed is too complex to be just analysed by using analytical methods. The idea of Monte Carlo simulation is to generate stochastic variables. This can be done by inserting uniform distributed stochastic variables, that have been previously created for example in Excel, into a deterministic model, for example a MS Excel model, which is the one used in the present master thesis. (Vatn, J. 2013)

In this case, the aim of using this simulation is to create a stochastic variable which can represent the expected value of the BC-ratio that a possible future project could have.

In the following page, a figure with the results obtained after implementing the Monte Carlo Simulation in pRisk can be observed. It can be seen that in this case the stochastic variable created after running the simulation 3000 times is 1.129567 which is supposed to be the expected value of the BC-ratio for a future project. Moreover, other parameters like the standard deviation, the lowest and the highest values of this ratio or the S-curve can be also obtained.

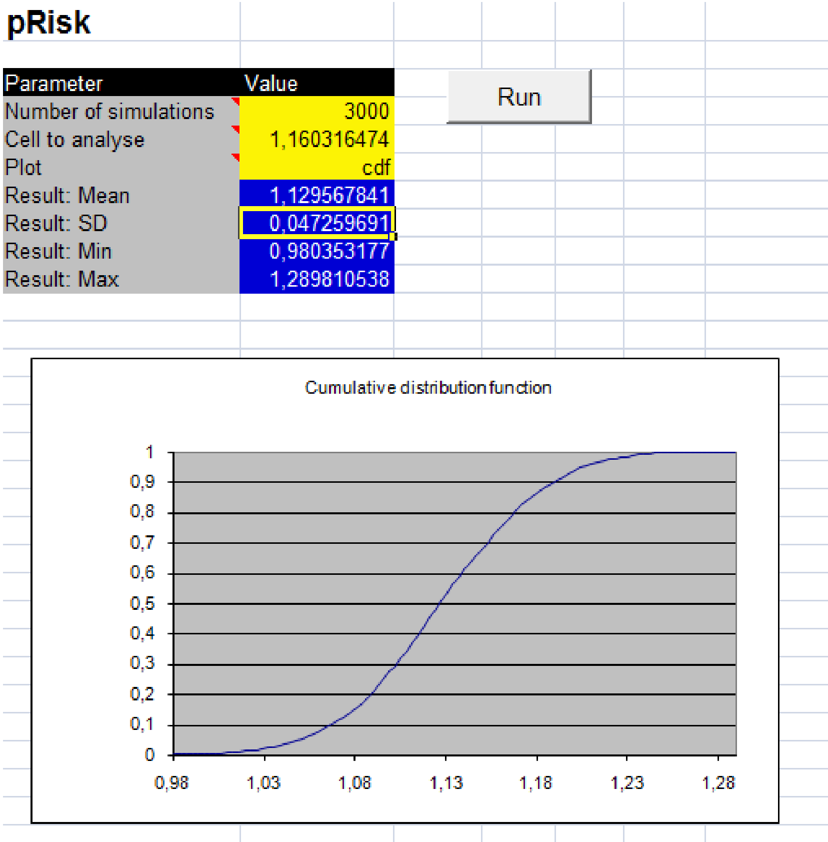


Figure 9.5 – Implementation of the Monte Carlo Simulation.

9.3 Ranking the projects

This third part of the chapter aims to establish a method to rank the 44 projects that are being considered by taking into account the following 4 different parameters:

- The NPV
- The expected value of the BC-ratio (expected value)
- The standard deviation (σ)
- The difference between the limits of the confidence intervals (BC-ratio variation)

Thus, the next considerations are taken into account:

- The higher the NPV, the better.
- The higher the expected value of the BC-ratio, the better.

- The lower the σ, the better.
- The lower the BC-ratio variation, the better.
- The profitable projects are always ranked in the first places even if the values of the variables considered to rank are lower in the profitable projects than the ones in non-profitable projects. This consideration has been taken into account by the author of the present thesis based on the fact that the profitability of the projects is the main aspect to consider when ranking projects.

The ranking can be done in different ways:

Projects	NPV
Rv 21 Halden sentrum - X E6 Svingenskogen	1440338
Rv 4 Rotnes - Oppland grense	1261408
E16 Kneppe - Gardermoen	832113
Rv 111 Dondern – Kampenes	583916
Rv 111 Gatedalen – Dondern	294416
Rv 2 Rasta – Sundhjørnet	142431
Rv 110 Ørebekk – Østsiden	140691
Rv15 Otta – Dale	20091
Rv3 Skjærodden – Rena	-20482
Rv 25 Elverum – Hernes	-31832
E16 Piperud - Kneppe	-85176
Rv 111 Moum - Gatedalen	-106723
Rv 2 Helset - Elverum	-227888
Rv 25 Hernes – Finstad	-254007
Rv3 Grundset - Gita bru	-269626
Rv 2 Jømna - Helset	-308685
Rv19 xE6 - rv19-xfv118	-406092
E16 Olum-Roa	-440752
Rv25 Ringgata - Åker gård	-547365
Rv 2 Magnor-Rasta	-547890
Rv3 Kolomoen – Ommangsvollen	-590964
Rv 2 Vingersnoret – Roverud	-614103
Rv19-xfv118- Ferjekaia Moss	-633511
Rv3 Alvdal – Motrøa	-794731
Rv 4 Akershus grense _ Roa	-954095
Rv 111 Øra – Moum	-1016659
Rv 25 Nybergsund – Støa	-1217897
E6 Dombås - Sør Trøndelag	-1274534
Rv 110 Karlshus – Ørebekk	-1384293
E6 Otta – Dombås	-1733792
E16 Fagernes S- Bjørgo	-2015157
Rv3 Rena – Nordstumoen	-2312211

E136 Dombås – Bjorli	-2372253
Rv 25 Finstad – Nybergsund	-2469713
E16 Øye – Hande	-2570154
E16 Vingersnoret Xrv2- Riksgrensen	-2570646
E6 Gardermoen Lillehammer	-2634216
Rv15 Dale – Dønfoss	-2695932
E6 Lillehammer Otta	-2749460
Rv25 Åker gård – Tønset	-2868161
Rv3 Nordstumoen – Alvdal	-3261993
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-3499918
Rv3 Motrøa – Ulsberg	-4036955
Rv 2 Roverud – Jømna	-4261290

Table 9.8 - Ranking of the projects considering the NPV

Projects	BC-ratio (E)
E16 Kneppe - Gardermoen	3,316010329
Rv 2 Rasta – Sundhjørnet	1,12998326
Rv 111 Dondern – Kampenes	1,089600839
Rv 21 Halden sentrum - X E6 Svingenskogen	0,862698943
Rv 4 Rotnes - Oppland grense	0,574507932
Rv 111 Gatedalen – Dondern	0,27031995
Rv15 Otta – Dale	0,144639463
Rv 110 Ørebekk – Østsiden	0,063611204
Rv 111 Moum - Gatedalen	-0,103138922
E6 Gardermoen Lillehammer	-0,124985641
Rv3 Grundset - Gita bru	-0,278905175
Rv 2 Magnor-Rasta	-0,304649055
Rv3 Skjærodden – Rena	-0,332743075
Rv 2 Jømna - Helset	-0,375814029
E6 Lillehammer Otta	-0,397861602
Rv 110 Karlshus – Ørebekk	-0,416019429
Rv19-xfv118- Ferjekaia Moss	-0,489700619
Rv 111 Øra – Moum	-0,552551284
Rv 25 Hernes – Finstad	-0,568416177
Rv3 Kolomoen – Ommangsvollen	-0,588463032
Rv 4 Akershus grense _ Roa	-0,602958881
Rv25 Ringgata - Åker gård	-0,632354011
Rv19 xE6 - rv19-xfv118	-0,670144246
Rv 25 Elverum – Hernes	-0,703562903
E16 Piperud - Kneppe	-0,708000499
E6 Otta – Dombås	-0,720800842

Rv3 Alvdal – Motrøa	-0,728832181
Rv25 Åker gård – Tønset	-0,76061271
Rv 2 Helset - Elverum	-0,781527677
E16 Olum-Roa	-0,804129091
Rv 2 Vingersnoret – Roverud	-0,808684659
Rv15 Dale – Dønfoss	-0,836435244
E6 Dombås - Sør Trøndelag	-0,884408888
Rv 2 Roverud – Jømna	-0,888015544
Rv3 Nordstumoen – Alvdal	-0,898868779
E136 Dombås – Bjorli	-0,909381307
Rv3 Rena – Nordstumoen	-0,92129944
E16 Øye – Hande	-1,035153645
Rv3 Motrøa – Ulsberg	-1,098385353
Rv 25 Finstad – Nybergsund	-1,101035049
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	-1,123787084
E16 Vingersnoret Xrv2- Riksgrensen	-1,134980127
Rv 25 Nybergsund – Støa	-1,154453981
E16 Fagernes S- Bjørgo	-1,970965972

Table 9.9 - Ranking of the projects considering the expected value of the BC-ratio

Projects	BC-ratio variation
Rv 21 Halden sentrum - X E6 Svingenskogen	0,025599549
Rv 110 Ørebekk – Østsiden	0,027375751
Rv 111 Gatedalen – Dondern	0,027805823
Rv 2 Rasta – Sundhjørnet	0,029207704
Rv 4 Rotnes - Oppland grense	0,030399636
Rv 111 Dondern – Kampenes	0,030654636
Rv15 Otta – Dale	0,031053527
E16 Kneppe - Gardermoen	0,034001362
E6 Gardermoen Lillehammer	0,025368264
E6 Lillehammer Otta	0,025876733
Rv 111 Øra – Moum	0,027184297
Rv 2 Helset - Elverum	0,027407888
E16 Piperud - Kneppe	0,027611134
Rv19-xfv118- Ferjekaia Moss	0,02766165
Rv 2 Magnor-Rasta	0,027670093
Rv 25 Nybergsund – Støa	0,027753607
Rv25 Ringgata - Åker gård	0,027754468
E16 Vingersnoret Xrv2- Riksgrensen	0,027757372
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	0,027767841
Rv 25 Elverum – Hernes	0,027824275
E16 Øye – Hande	0,027851013

E16 Olum-Roa	0,027886932
Rv 25 Finstad – Nybergsund	0,02790146
Rv3 Motrøa – Ulsberg	0,027906428
Rv3 Rena – Nordstumoen	0,027919326
Rv 4 Akershus grense _ Roa	0,028043412
Rv 2 Vingersnoret – Roverud	0,028057966
Rv 2 Roverud – Jømna	0,028068216
Rv25 Åker gård – Tønset	0,028132818
Rv3 Nordstumoen – Alvdal	0,028170584
E6 Dombås - Sør Trøndelag	0,028171591
Rv 25 Hernes – Finstad	0,028195853
Rv3 Alvdal – Motrøa	0,028235698
Rv15 Dale – Dønfoss	0,028286288
Rv 110 Karlshus – Ørebekk	0,028313891
E136 Dombås – Bjorli	0,028332852
E6 Otta – Dombås	0,028496657
Rv19 xE6 - rv19-xfv118	0,02856928
Rv3 Skjærodden – Rena	0,02877459
Rv3 Kolomoen – Ommangsvollen	0,028795501
Rv 2 Jømna - Helset	0,028809101
Rv 111 Moum - Gatedalen	0,02910606
Rv3 Grundset - Gita bru	0,029514402
E16 Fagernes S- Bjørgo	0,030640278

Table 9.10 - Ranking of the projects considering the BC-ratio variation

Projects	σ
Rv 2 Rasta – Sundhjørnet	5939,827893
Rv15 Otta – Dale	6959,364896
E16 Kneppe - Gardermoen	13765,96533
Rv 111 Dondern – Kampenes	26504,70916
Rv 111 Gatedalen – Dondern	48861,07298
Rv 21 Halden sentrum - X E6 Svingenskogen	68957,48122
Rv 110 Ørebekk – Østsiden	97688,32603
Rv 4 Rotnes - Oppland grense	107689,1272
Rv 25 Elverum – Hernes	2031,088181
Rv3 Skjærodden – Rena	2857,698478
E16 Piperud - Kneppe	5359,346734
Rv 2 Helset - Elverum	12894,26501
Rv 25 Hernes – Finstad	20328,64458
E16 Olum-Roa	24661,1416
Rv19 xE6 - rv19-xfv118	27931,82858
Rv 2 Vingersnoret – Roverud	34376,53698

Rv 2 Jømna - Helset	38178,26356
Rv25 Ringgata - Åker gård	38760,87629
Rv3 Grundset - Gita bru	46034,46697
Rv3 Kolomoen – Ommangsvollen	46656,31159
Rv 25 Nybergsund – Støa	47238,63108
Rv 111 Moum - Gatedalen	48591,77707
Rv3 Alvdal – Motrøa	49674,67904
E16 Fagernes S- Bjørgo	50543,6249
Rv19-xfv118- Ferjekaia Moss	57735,84327
E6 Dombås - Sør Trøndelag	65501,85852
Rv 4 Akershus grense _ Roa	71594,34322
Rv 2 Magnor-Rasta	80287,52721
Rv 111 Øra – Moum	80698,36896
Rv 25 Finstad – Nybergsund	100975,5442
E16 Vingersnoret Xrv2- Riksgrensen	101432,3032
E6 Otta – Dombås	110590,9421
E16 Øye – Hande	111567,8986
Rv3 Rena – Nordstumoen	113051,2881
E136 Dombås – Bjorli	119247,4798
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	139527,5202
Rv15 Dale – Dønfoss	147094,5202
Rv 110 Karlshus – Ørebekk	152005,006
Rv3 Nordstumoen – Alvdal	164940,1937
Rv3 Motrøa – Ulsberg	165480,6992
Rv25 Åker gård – Tønset	171157,9649
Rv 2 Roverud – Jømna	217309,7713
E6 Lillehammer Otta	288515,2408
E6 Gardermoen Lillehammer	862632,7517

Table 9.11 - Ranking of the projects considering the standard deviation.

Now, the proposed method for ranking consists in considering the four parameters all together. The present master thesis proposes to do this by giving numbers (punctuations) out of 44 to all the projects, where 1 represents the best value for each of the parameters and 44 represents the worst value for each of the parameter. Thus, for example, the project with the highest NPV will have the number 1 in which concerns the NPV parameter and the project with the highest standard deviation will have the number 44, which means that it is the worst project in relation to what the standard deviation concerns.

In this manner the following table is obtained.

Project	NPV	Bcratio (E)	BCratio (variation)	σ
Rv 21 Halden sentrum - X E6 Svingenskogen	1	4	1	6
Rv 4 Rotnes - Oppland grense	2	5	5	8
E16 Kneppe - Gardermoen	3	1	8	3
Rv 111 Dondern – Kampenes	4	3	6	4
Rv 111 Gatedalen – Dondern	5	6	3	5
Rv 2 Rasta – Sundhjørnet	6	2	4	1
Rv 110 Ørebekk – Østsiden	7	8	2	7
Rv15 Otta – Dale	8	7	7	2
Rv3 Skjærodden – Rena	9	10	39	10
Rv 25 Elverum – Hernes	10	9	20	9
E16 Piperud - Kneppe	11	11	13	11
Rv 111 Moum - Gatedalen	12	22	42	22
Rv 2 Helset - Elverum	13	12	12	12
Rv 25 Hernes – Finstad	14	13	32	13
Rv3 Grundset - Gita bru	15	19	43	19
Rv 2 Jømna - Helset	16	17	41	17
Rv19 xE6 - rv19-xfv118	17	15	38	15
E16 Olum-Roa	18	14	22	14
Rv25 Ringgata - Åker gård	19	18	17	18
Rv 2 Magnor-Rasta	20	28	15	28
Rv3 Kolomoen – Ommangsvollen	21	20	40	20
Rv 2 Vingersnoret – Roverud	22	16	27	16
Rv19-xfv118- Ferjekaia Moss	23	25	14	25
Rv3 Alvdal – Motrøa	24	23	33	23
Rv 4 Akershus grense _ Roa	25	27	26	27
Rv 111 Øra – Moum	26	29	11	29
Rv 25 Nybergsund – Støa	27	21	16	21
E6 Dombås - Sør trøndelag	28	26	31	26
Rv 110 Karlshus – Ørebekk	29	38	35	38
E6 Otta – Dombås	30	32	37	32
E16 Fagernes S- Bjørgo	31	24	44	24
Rv3 Rena – Nordstumoen	32	34	25	34
E136 Dombås – Bjorli	33	35	36	35
Rv 25 Finstad – Nybergsund	34	30	23	30
E16 Øye – Hande	35	33	21	33
E16 Vingersnoret Xrv2- Riksgrensen	36	31	18	31
E6 Gardermoen Lillehammer	37	44	9	44
Rv15 Dale – Dønfoss	38	37	34	37
E6 Lillehammer Otta	39	43	10	43
Rv25 Åker gård – Tønset	40	41	29	41
Rv3 Nordstumoen – Alvdal	41	39	30	39
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	42	36	19	36
Rv3 Motrøa – Ulsberg	43	40	24	40
Rv 2 Roverud – Jømna	44	42	28	42

Table 9.12 – Punctuations of the projects in relation to the different parameters considered

Moreover, this thesis goes further and gives different grades of importance to the different parameter by giving weight to each of them.

As it can be understood the lower the total sum of the punctuations, the better, so the parameters must be weighted in accordance to that. That means that the lower the weight, the more importance is given to a specific parameter in order to consider a project as preferable. In this way the weights proposed to each of the parameter considered to rank the projects in the present master thesis are the following ones:

- The NPV → 0,1
- The expected value of the BC-ratio (expected value) → 0,2
- The amplitude of the confidence intervals (BC-ratio variation) →0,3
- The standard deviation (σ) →0,4

Project	NPV	Bcratio (E)	BCratio (variation)	σ	Total
Rv 21 Halden sentrum - X E6 Svingenskogen	0,1	0,8	0,3	2,4	3,6
Rv 4 Rotnes - Oppland grense	0,2	1	1,5	3,2	5,9
E16 Kneppe - Gardermoen	0,3	0,2	2,4	1,2	4,1
Rv 111 Dondern – Kampenes	0,4	0,6	1,8	1,6	4,4
Rv 111 Gatedalen – Dondern	0,5	1,2	0,9	2	4,6
Rv 2 Rasta – Sundhjørnet	0,6	0,4	1,2	0,4	2,6
Rv 110 Ørebekk – Østsiden	0,7	1,6	0,6	2,8	5,7
Rv15 Otta – Dale	0,8	1,4	2,1	0,8	5,1
Rv3 Skjærodden – Rena	0,9	2	11,7	4	18,6
Rv 25 Elverum – Hernes	1	1,8	6	3,6	12,4
E16 Piperud - Kneppe	1,1	2,2	3,9	4,4	11,6
Rv 111 Moum - Gatedalen	1,2	4,4	12,6	8,8	27
Rv 2 Helset - Elverum	1,3	2,4	3,6	4,8	12,1
Rv 25 Hernes – Finstad	1,4	2,6	9,6	5,2	18,8
Rv3 Grundset - Gita bru	1,5	3,8	12,9	7,6	25,8
Rv 2 Jømna - Helset	1,6	3,4	12,3	6,8	24,1
Rv19 xE6 - rv19-xfv118	1,7	3	11,4	6	22,1
E16 Olum-Roa	1,8	2,8	6,6	5,6	16,8
Rv25 Ringgata - Åker gård	1,9	3,6	5,1	7,2	17,8
Rv 2 Magnor-Rasta	2	5,6	4,5	11,2	23,3
Rv3 Kolomoen – Ommangsvollen	2,1	4	12	8	26,1
Rv 2 Vingersnoret – Roverud	2,2	3,2	8,1	6,4	19,9
Rv19-xfv118- Ferjekaia Moss	2,3	5	4,2	10	21,5
Rv3 Alvdal – Motrøa	2,4	4,6	9,9	9,2	26,1
Rv 4 Akershus grense _ Roa	2,5	5,4	7,8	10,8	26,5
Rv 111 Øra – Moum	2,6	5,8	3,3	11,6	23,3
Rv 25 Nybergsund – Støa	2,7	4,2	4,8	8,4	20,1
E6 Dombås - Sør trøndelag	2,8	5,2	9,3	10,4	27,7
Rv 110 Karlshus – Ørebekk	2,9	7,6	10,5	15,2	36,2
E6 Otta – Dombås	3	6,4	11,1	12,8	33,3
E16 Fagernes S- Bjørgo	3,1	4,8	13,2	9,6	30,7
Rv3 Rena – Nordstumoen	3,2	6,8	7,5	13,6	31,1
E136 Dombås – Bjorli	3,3	7	10,8	14	35,1
Rv 25 Finstad – Nybergsund	3,4	6	6,9	12	28,3
E16 Øye – Hande	3,5	6,6	6,3	13,2	29,6
E16 Vingersnoret Xrv2- Riksgrensen	3,6	6,2	5,4	12,4	27,6
E6 Gardermoen Lillehammer	3,7	8,8	2,7	17,6	32,8
Rv15 Dale – Dønfoss	3,8	7,4	10,2	14,8	36,2
E6 Lillehammer Otta	3,9	8,6	3	17,2	32,7
Rv25 Åker gård – Tønset	4	8,2	8,7	16,4	37,3
Rv3 Nordstumoen – Alvdal	4,1	7,8	9	15,6	36,5
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	4,2	7,2	5,7	14,4	31,5
Rv3 Motrøa – Ulsberg	4,3	8	7,2	16	35,5
Rv 2 Roverud – Jømna	4,4	8,4	8,4	16,8	38

Table 9.13 – Weighted punctuations of the projects in relation to the different parameters considered.

This way of weighting leads to the final ranking result.

Project	Total
Rv 2 Rasta – Sundhjørnet	3
E16 Kneppe - Gardermoen	5,3
Rv15 Otta – Dale	5,9
Rv 111 Dondern – Kampenes	6
Rv 21 Halden sentrum - X E6 Svingenskogen	6
Rv 111 Gatedalen – Dondern	6,6
Rv 110 Ørebekk – Østsiden	8,5
Rv 4 Rotnes - Oppland grense	9,1
Rv 25 Elverum – Hernes	16
E16 Piperud - Kneppe	16
Rv 2 Helset - Elverum	16,9
E16 Olum-Roa	22,4
Rv3 Skjærodden – Rena	22,6
Rv 25 Hernes – Finstad	24
Rv25 Ringgata - Åker gård	25
Rv 2 Vingersnoret – Roverud	26,3
Rv19 xE6 - rv19-xfv118	28,1
Rv 25 Nybergsund – Støa	28,5
Rv 2 Jømna - Helset	30,9
Rv19-xfv118- Ferjekaia Moss	31,5
Rv3 Grundset - Gita bru	33,4
Rv3 Kolomoen – Ommangsvollen	34,1
Rv 2 Magnor-Rasta	34,5
Rv 111 Øra – Moum	34,9
Rv3 Alvdal – Motrøa	35,3
Rv 111 Moum - Gatedalen	35,8
Rv 4 Akershus grense _ Roa	37,3
E6 Dombås - Sør trøndelag	38,1
E16 Vingersnoret Xrv2- Riksgrensen	40
Rv 25 Finstad – Nybergsund	40,3
E16 Fagernes S- Bjørgo	40,3
E16 Øye – Hande	42,8
Rv3 Rena – Nordstumoen	44,7
Rv15 Strynfjellet (Dønfoss - S-o-F gr)	45,9
E6 Otta – Dombås	46,1
E136 Dombås – Bjorli	49,1
E6 Lillehammer Otta	49,9
E6 Gardermoen Lillehammer	50,4
Rv15 Dale – Dønfoss	51
Rv 110 Karlshus – Ørebekk	51,4
Rv3 Motrøa – Ulsberg	51,5
Rv3 Nordstumoen – Alvdal	52,1
Rv25 Åker gård – Tønset	53,7
Rv 2 Roverud – Jømna	54,8

Table 9.14 – Final ranking result

The reasons to choose these specific weights for each of the parameters can be explained as follows.

On the one hand, the author of the thesis has decided that the sum of all the weights is 1, which facilitates the process of comparing the weights between themselves. On the other hand the highest weight (0,4) is given to the standard deviation parameter due to the fact that it is considered to be the parameter which most affects the uncertainty of the project, making a project with higher standard deviation less preferable than others. For the same reason the following weight (0,3) is given to the difference between the limits in the confidence intervals which, as explained before, also expresses uncertainty. Finally the lowest weights, 0,2 and 0,1, are given to the BC-ratio and the NPV respectively. In this case the reason to choose 0,1 as the weight for the NPV was the fact that this parameter is considered as the main indicator to measure the profitability of a project, which should be the most important consideration when ranking projects.

10. Discussion

In Norway the difficult orography and the low traffic levels have led during the last decades to the construction of many projects that in most cases are not profitable. For this reason, alongside with the fact that nowadays the government funds are in some cases limited, there is an increasing need to implement project management tools and techniques that can contribute to the overcoming of such difficulties.

In relation to this, the NPRA, which usually undertakes many different projects within a portfolio at the same time, needs to apply different project management methods in order to compare different alternatives and decide upon the projects they are willing to undertake. Thus, the main considerations that the NPRA takes into account when comparing between different road projects are the different forms of evaluating projects in the transport sector: Impact assessment, socioeconomic assessment and the benefit cost analysis. These different approaches allow developing a systematic evaluation of all impacts (distributional, monetised and non-monetised impacts) that can accrue the society if a project is conducted, taking into account the different stakeholders these impacts are affecting to.

In case of focusing in monetised impacts, the NPRA applies the benefit cost analysis, which is a common practice that enables a quantitative evaluation when considering a road project for investment. During this evaluation all the monetised impacts are considered with regards to their cost for the society. Aspects like the reduction of traffic accidents, the decrease of the travel time, the increase of security or the reduction of noise and pollution are included on such evaluation. It is in relation to the costs that are used when developing a BCA when the need for cost estimation arises. Cost estimation implies the development of an approximation of the monetary resources that are necessary to complete a project. (PMI 2008) This approximation can be done by using different techniques, but in the specific case of Norway it is base in the so-called Estimation Method, which is applied for all investment projects above 5million Norwegian kroner.

The Estimation Method consists of a workflow developed by an expert group, through which three different cost estimates are created during three different levels of the planning phases. Thus, the accuracy of the estimates will increase from the initial planning phase until the so-called area development planning level, due to a reduction of the uncertainty, which at the same time is the result of an increase in the available information during the project process. In other words it can be said that the Estimation Method can be considered as a dynamic process that evolves different phases of maturation, where the accuracy of the estimates will depend on the amount of uncertainty in each of the phases of the project. For these reason, the NPRA defines the final cost estimate that results after the application of the Estimation Method as the sum of a basic estimate calculated by using the three point estimation, and the expected supplements, whose values are given by the guidelines included in the Handbook 217 and are directly linked to the uncertainty that is present during the whole project.

In relation to uncertainty, and how it is dealt in regards to costs estimation it must be also pointed out that, apart from the traditional method which consist of using the standard deviation (σ) as a parameter to show how much variation or dispersion from the average (expected value) exists, there is a method that also shows the magnitudes of the uncertainties. This method is called sensitivity analysis and consists in varying some of the variables that have been used in the benefit cost analysis by a certain percentage and see how sensitive the new result are with respect to those changes. In addition to this, Berntsen, S., and Sunde, T., (2006) have developed during the last years a new method that deeply examined both the systematic and unsystematic uncertainty factors with the aim of estimating different percentages of deviations that both systematic and unsystematic uncertainty factors can suffer during the life time of a projects, in order to calculate how large the provision for uncertainty has to be when projects in a portfolio are seen as a whole.

Going deeper in what uncertainty concerns, it must be highlighted that nowadays there is a lack of a framework for ascertaining confidence intervals for BCA results in the Norwegian road sector. This framework alongside with a systematic method for ranking projects would help decision makers when choosing between many competing projects.

The framework suggested in the master thesis, which have been tested in real projects, reveal that there is a need to consider uncertainty parameters when ranking projects. That means that it is not enough to consider the profitability of the project or the contribution to the society that the project can have per each Norwegian krone finance by the government; there are other parameters directly linked with uncertainties that can make a decision maker change his point of view due to the fact that in some cases the reduction of the uncertainty in a project can be preferable. For this reason, the method proposed in this thesis suggests to use parameters such as the expected NPV, the BC-ratio, the standard deviation and the amplitude of the confidence intervals in order to rank projects. Besides, due to the fact that each parameter can have different grades of importance in which refers to ranking, the author has decided to give weights to these parameters. After this, the proposed method sums all the punctuations obtained by each of the projects in relation to these four parameters and gets the total result for each of the projects. Finally a table with all the projects, where a descending order of total punctuation is uses, establishes the final ranking.

11. Conclusions

Every time a group of projects are being evaluated there are many different characteristics or factors that can make them differ from each other. Nevertheless, some conclusion that the author includes in this chapter of the thesis can be applied to all of them in what is referred to how a good evaluation should be done.

First of all, the main idea that cannot be forgotten is that always different alternatives are being considered as possible solutions in a project, not only impacts that can be measured in monetary terms, which are the easiest to identify and evaluate, should be included, but also the non-monetised impacts which affect the landscape, the natural environment, the natural resources, the cultural heritage, the community life and outdoor recreation must be considered. Moreover, it is not enough with evaluating the impacts themselves; nowadays it is also necessary to take into account the needs and requirements of the different stakeholders which constitute and important part of the project.

Another important conclusion in relation to this thesis is related to the procedures implemented in Norway when developing a BCA. As a rule, not only special attention should be given to the challenge of getting a good understanding of the way of discounting costs and the way of applying the discount rate, but also to the limitations that the methods have. One of these limitations is related to the fact that all the estimations that are used when implementing a BCA include a relevant amount of uncertainty. In relation to this, it can be said that the methodologies that the NPRA follows when implementing a BCA are succinct and of an international standard but they present some drawbacks in relation of the treatment of uncertainties. The NPRA deals with uncertainties every time a cost estimate is created during the so-called Estimation Method, but it is later, when using those estimations in the BCA, where those uncertainties are not properly considered as important factors.

In relation to those relevant uncertainty factors the final conclusion of the present master thesis can be drawn. In most of the cases, when there are many competing projects for limited government funds, a suitable treatment and consideration of the uncertainty when analyzing the results of a BCA can make projects with lower values of profitability but with smaller expected variation during the whole project process life time be preferable in comparison with others. Thus, the addition of uncertainty parameters when ranking projects can be considered as a way of influencing decision makers, who will have now all the relevant information necessary to choose between different project alternatives.

12. Recommendations and future research

The main recommendations that the present thesis can suggest are obviously influence by the author´s perspective and interpretation. However they can be considered as valid and could be applied during the planning and other project phases. In relation to this, it must be highlighted that in some special cases, due to the existence of very specific reasons, as for example when a project of force majeure has to be implemented, some of these recommendations could be difficult to apply due to the lack of time for planning or the necessity of undertaking actions whose costs are higher than normal.

In relation to the way projects can be evaluated, the recommendation is to apply different approaches that allow assessing all impacts that will accrue to the society in case a project is implemented. For this purpose it is recommended to clear distinguish between the three methods explained in this thesis, whose application will lead to a success evaluation. Moreover, the application of the emergent stakeholder value approach, which focuses on creating value by satisfying not only the technical requirements of the project, but also the stakeholders´ requirements, can also contribute the same objective. Regarding to this value model, more investigations and studies should be conducted with the main aim of identifying how it would be possible to link what is valuable for the stakeholders and what is valuable for the company, with the goal of avoiding conflicts of interest between both parts.

Another recommendation that can be drawn concerns the amount of uncertainty all projects have. In this case it could be said that the sooner new information that can help to get more accuracy results can be got, the better due to the fact that, as it is known, the potential to reduce uncertainty by acquiring more information is larger during the front-end phase and decreases substantially when the project is implemented. Also in relation to this uncertainty, the recommendation is to follow the whole project process by controlling how this uncertainty evolves. Thus, by not only identifying the uncertainties but also following them along the whole project process, the possibility of decreasing the uncertainty can increase. Furthermore, these uncertainties can be directly link to possible risks in projects. For that reason, the author suggests, as part of other future researches, to investigate how the implementation of risk management tools, which can be considered as a form of proactive management, can make the project turn to be more predictable with the consequent reduction of uncertainty.

Finally, the last recommendation is referred to the fact that in case of limited funds, when there is a need of choosing between different projects to undertake, uncertainty parameters must be used to rank those projects, with the main aim of allowing decisions makers to choose those projects where the uncertainty can be considered as a minor problem. According to this, apart from the proposal suggest in this master thesis, future investigations can research about other ways of considering economical, uncertainty and risk parameters all together in order to contribute to the improvement of the methods that nowadays are use in Norway in what respect the analysis of the BCA results.

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Appendix 1: Data given by the consulting companies

In this appendix, all data related to E6 Dombås - Sør Trøndelag project given by the consulting companies is included. It can be seen that 5 tables are given in total, 2 with the costs and benefits of Alternative 0 with and without considering negative signs for the costs, 2 with the costs and benefits of Alternative 1 with and without considering negative signs for the costs and the last table which includes a subtraction of both the alternatives after considering costs as negative values.

År	Kjøretøykostnader	Direkteutgifter	Tidskostnader	Operatørkostnader	Operatørinntekter	Operatøroverføringer	Drift_vedlikehold	Offentlige_overføringer	Skatte_avgiftsinntekter	Ulykker	Støy_luft	Skattekostnad	Investeringer
2022	116064,3	2927,71	196749,4	4518,071	2710,843	1807,228	7039,097	-1807,228	31243,1	29682,51	8328,269	4479,356	0
2023	112993,8	2869,688	194142	4428,531	2657,118	1771,412	6771,526	-1771,412	30273,04	28848,77	8866,737	4346,022	0
2024	110006,4	2812,798	191577,7	4340,738	2604,443	1736,295	6514,168	-1736,295	29332,24	28045,21	9364,977	4216,356	0
2025	107099,6	2757,019	189055,7	4254,659	2552,795	1701,864	6266,632	-1701,864	28419,79	27265,11	9824,818	4090,26	0
2026	104147,2	2698,84	186575,3	4164,877	2498,926	1665,951	6028,542	-1665,951	27478,41	26502,72	10215,21	3956,785	0
2027	101273,5	2641,851	184135,8	4076,93	2446,158	1630,772	5799,538	-1630,772	26565,55	25768,45	10567,36	3827,048	0
2028	98476,33	2586,027	181736,4	3990,782	2394,469	1596,313	5579,271	-1596,313	25680,33	25056,37	10883,08	3700,951	0
2029	95753,58	2531,345	179376,6	3906,397	2343,838	1562,559	5367,408	-1562,559	24821,95	24361,13	11164,11	3578,398	0
2030	93103,15	2477,784	177055,6	3823,74	2294,244	1529,496	5171,074	-1529,496	23989,6	23685,38	11412,11	3457,807	0
2031	86367,02	2419,022	174186,2	3733,059	2239,835	1493,224	4974,181	-1493,224	23230,03	22972,87	11090,32	3352,526	0
2032	83760,09	2361,654	171368,4	3644,527	2186,716	1457,811	4784,804	-1457,811	22494,93	22281,64	10778,18	3250,463	0
2033	81233,65	2305,645	168601,1	3558,094	2134,856	1423,238	4602,656	-1423,238	21783,5	21612,56	10475,4	3151,522	0
2034	78785,15	2250,964	165883,6	3473,709	2084,226	1389,484	4427,46	-1389,484	21094,98	20966,31	10181,68	3055,607	0
2035	76412,13	2197,578	163214,8	3391,325	2034,795	1356,53	4258,952	-1356,53	20428,61	20337,64	9896,743	2962,625	0
2036	74237,97	2146,872	160593,7	3313,074	1987,844	1325,23	4096,875	-1325,23	19844,18	19727,3	9654,502	2884,415	0
2037	72127,51	2097,336	158019,6	3236,629	1941,977	1294,652	3940,983	-1294,652	19277,06	19136,13	9418,739	2808,285	0
2038	70078,82	2048,943	155491,4	3161,948	1897,169	1264,779	3791,04	-1264,779	18726,72	18564,79	9189,271	2734,181	0
2039	68090,06	2001,666	153008,5	3088,99	1853,394	1235,596	3646,818	-1235,596	18192,65	18008,66	8965,92	2662,048	0
2040	66159,42	1955,48	150569,8	3017,716	1810,63	1207,087	3508,099	-1207,087	17674,36	17473,41	8748,511	2591,835	0
2041	64245,23	1902,84	148055	2936,481	1761,889	1174,592	3374,629	-1174,592	17166,75	16950,84	8521,698	2523,507	0
2042	62386,64	1851,616	145584,9	2857,432	1714,459	1142,973	3246,25	-1142,973	16673,78	16442,56	8301,003	2456,913	0
2043	60582,04	1801,772	143158,6	2780,512	1668,307	1112,205	3122,768	-1112,205	16195,02	15949,13	8086,254	2392,011	0
2044	58829,85	1753,269	140775,4	2705,662	1623,397	1082,265	3003,993	-1082,265	15730,06	15471,05	7877,289	2328,762	0
2045	57128,55	1706,072	138434,4	2632,827	1579,696	1053,131	2889,748	-1053,131	15278,51	15008,51	7673,948	2267,126	0
2046	55476,65	1660,146	136134,9	2561,953	1537,172	1024,781	2781,419	-1024,781	14839,96	14558,1	7476,076	2206,753	0
2047	53872,71	1615,456	133876	2492,987	1495,792	997,1949	2675,667	-997,1949	14414,05	14124,01	7283,523	2148,238	0
2048	52315,34	1571,969	131657	2425,878	1455,527	970,3512	2573,945	-970,3512	14000,42	13702,78	7096,142	2091,224	0
2049	50803,18	1529,653	129477,1	2360,575	1416,345	944,23	2476,101	-944,23	13598,69	13294,98	6913,79	2035,673	0
2050	49334,89	1488,476	127335,6	2297,03	1378,218	918,8121	2381,986	-918,8121	13208,54	12897,42	6736,329	1981,549	0
2051	47885,9	1446,976	125185,7	2232,988	1339,792	893,195	2291,427	-893,195	12822,64	12511,07	6558,411	1927,603	0
2052	46479,55	1406,633	123074,1	2170,73	1302,438	868,2922	2204,32	-868,2922	12448,03	12133,9	6385,38	1875,084	0
2053	45114,6	1367,415	121000,2	2110,209	1266,125	844,0836	2120,532	-844,0836	12084,38	11769,27	6217,098	1823,954	0
2054	43789,81	1329,291	118963,2	2051,375	1230,825	820,5499	2039,937	-820,5499	11731,38	11417,34	6053,433	1774,18	0
2055	42504,01	1292,229	116962,5	1994,181	1196,509	797,6725	1962,413	-797,6725	11388,71	11075,5	5894,255	1725,726	0
2056	41256,05	1256,202	114997,3	1938,583	1163,15	775,433	1887,843	-775,433	11056,07	10744,19	5739,438	1678,559	0
2057	40044,8	1221,178	113067	1884,534	1130,72	753,8135	1816,114	-753,8135	10733,16	10423,43	5588,859	1632,647	0
2058	38869,18	1187,131	111170,9	1831,992	1099,195	732,7969	1747,117	-732,7969	10419,7	10111,19	5442,4	1587,958	0
2059	37728,16	1154,033	109308,3	1780,915	1068,549	712,3661	1680,749	-712,3661	10115,42	9809,995	5299,946	1544,46	0
2060	36620,7	1121,858	107478,8	1731,263	1038,758	692,5051	1616,909	-692,5051	9820,029	9517,736	5161,383	1502,124	0
2061	35545,81	1090,581	105681,6	1682,995	1009,797	673,1978	1610,637	-673,1978	9533,285	9232,636	5026,604	1449,891	0

Table A1.1 – Estimations for the Alternative 0, without considering negative signs for the costs.

År	Kjøretøykostnader	Direkteutgifter	Tidskostnader	Operatørkostnader	Operatørinntekter	Operatøroverføringer	Drift_vedlikehold	Offentlige_overføringer	Skatte_avgiftsinntekter	Ulykker	Støy_luft	Skattekostnad	Investeringer
2022	118560,4	2913,668	184818,5	4496,402	2697,841	1798,561	7299,209	-1798,561	32374,4	22445,64	8771,277	-287927,2	1462912
2023	115429,9	2855,433	182371,5	4406,533	2643,919	1762,613	7021,634	-1762,613	31371,27	21822,4	9338,609	4517,406	0
2024	112383,8	2798,342	179964,9	4318,429	2591,057	1727,371	6754,657	-1727,371	30398,3	21221,48	9863,709	4383,255	0
2025	109419,7	2742,372	177598	4232,055	2539,233	1692,822	6497,871	-1692,822	29454,57	20637,95	10348,49	4252,777	0
2026	106403,5	2683,8	175270,1	4141,667	2485	1656,667	6250,888	-1656,667	28479,23	20067,63	10759,94	4114,336	0
2027	103467,4	2626,436	172980,5	4053,141	2431,885	1621,256	6013,332	-1621,256	27533,35	19518,1	11131,17	3979,754	0
2028	100609,3	2570,254	170728,7	3966,441	2379,865	1586,577	5784,842	-1586,577	26616,06	18985,04	11464,11	3848,93	0
2029	97827,09	2515,232	168514	3881,53	2328,918	1552,612	5565,072	-1552,612	25726,52	18464,53	11760,55	3721,767	0
2030	95118,54	2461,345	166335,7	3798,372	2279,023	1519,349	5362,665	-1519,349	24863,88	17958,5	12022,27	3596,375	0
2031	88120,69	2402,86	163641,3	3708,118	2224,871	1483,247	5158,402	-1483,247	24078,94	17423,84	11684,52	3487,459	0
2032	85462,85	2345,764	160995,3	3620,006	2172,004	1448,003	4961,94	-1448,003	23319,23	16905,04	11356,88	3381,858	0
2033	82887	2290,024	158396,9	3533,987	2120,392	1413,595	4772,979	-1413,595	22583,92	16402,73	11039,03	3279,47	0
2034	80390,55	2235,607	155845,1	3450,01	2070,006	1380,004	4591,233	-1380,004	21872,23	15917,38	10730,65	3180,199	0
2035	77971,03	2182,482	153339	3368,028	2020,817	1347,211	4416,426	-1347,211	21183,37	15445,17	10431,46	3083,948	0
2036	75756,88	2132,118	150877,8	3290,306	1974,184	1316,122	4248,292	-1316,122	20579,62	14986,62	10176,91	3003,041	0
2037	73607,49	2082,917	148460,7	3214,378	1928,627	1285,751	4086,577	-1285,751	19993,69	14542,36	9929,145	2924,273	0
2038	71520,91	2034,851	146086,7	3140,202	1884,121	1256,081	3931,034	-1256,081	19425,04	14112,85	9687,976	2847,585	0
2039	69495,27	1987,894	143755,1	3067,738	1840,642	1227,095	3781,427	-1227,095	18873,14	13694,72	9453,215	2772,925	0
2040	67528,72	1942,021	141465	2996,945	1798,167	1198,778	3637,531	-1198,778	18337,5	13292,1	9224,681	2700,238	0
2041	65576,82	1889,738	139102,5	2916,262	1749,757	1166,505	3499,083	-1166,505	17811,65	12898,87	8985,747	2629,213	0
2042	63681,57	1838,863	136781,9	2837,751	1702,651	1135,101	3365,917	-1135,101	17300,94	12516,32	8753,252	2559,985	0
2043	61841,32	1789,358	134502,5	2761,354	1656,813	1104,542	3237,832	-1104,542	16804,93	12144,85	8527,017	2492,512	0
2044	60054,47	1741,185	132263,5	2687,014	1612,208	1074,806	3114,632	-1074,806	16323,2	11784,84	8306,871	2426,753	0
2045	58319,46	1694,309	130064,3	2614,675	1568,805	1045,87	2996,132	-1045,87	15855,33	11436,4	8092,646	2362,667	0
2046	56634,79	1648,696	127903,9	2544,283	1526,57	1017,713	2884,012	-1017,713	15400,93	11097,06	7884,179	2299,841	0
2047	54998,97	1604,31	125781,7	2475,787	1485,472	990,3148	2774,314	-990,3148	14959,6	10769,87	7681,311	2238,994	0
2048	53410,61	1561,119	123697	2409,135	1445,481	963,6539	2668,798	-963,6539	14530,96	10452,3	7483,888	2179,702	0
2049	51868,3	1519,091	121649,1	2344,277	1406,566	937,7107	2567,306	-937,7107	14114,65	10144,74	7291,76	2121,928	0
2050	50370,71	1478,195	119637,3	2281,165	1368,699	912,4659	2469,684	-912,4659	13710,32	9844,871	7104,783	2065,635	0
2051	48892,39	1436,978	117617,3	2217,559	1330,535	887,0236	2375,751	-887,0236	13310,22	9553,289	6917,286	2009,49	0
2052	47457,55	1396,911	115633,4	2155,727	1293,436	862,2907	2285,401	-862,2907	12921,82	9268,606	6734,937	1954,825	0
2053	46064,91	1357,961	113684,8	2095,618	1257,371	838,2474	2198,494	-838,2474	12544,77	8993,282	6557,589	1901,606	0
2054	44713,21	1320,097	111771	2037,186	1222,312	814,8745	2114,901	-814,8745	12178,74	8727,446	6385,104	1849,794	0
2055	43401,27	1283,288	109891,2	1980,383	1188,23	792,1533	2034,494	-792,1533	11823,42	8469,172	6217,346	1799,354	0
2056	42127,91	1247,506	108044,8	1925,164	1155,099	770,0656	1957,151	-770,0656	11478,48	8218,78	6054,181	1750,253	0
2057	40891,98	1212,722	106231,1	1871,485	1122,891	748,5939	1882,756	-748,5939	11143,62	7976,279	5895,48	1702,455	0
2058	39692,39	1178,908	104449,6	1819,302	1091,581	727,7208	1811,197	-727,7208	10818,55	7740,173	5741,119	1655,928	0
2059	38528,06	1146,036	102699,7	1768,574	1061,145	707,4297	1742,364	-707,4297	10502,99	7512,321	5590,976	1610,639	0
2060	37397,96	1114,081	100980,8	1719,261	1031,557	687,7045	1676,154	-687,7045	10196,64	7291,17	5444,932	1566,557	0
2061	36301,08	1083,017	99292,2	1671,323	1002,794	668,5292	1675,792	-668,5292	9899,245	7075,399	5302,873	1510,985	0

Table A1.2 – Estimations for the Alternative 1, without considering negative signs for the costs

År	Kjøretøykostnader	Direkteutgifter	Tidskostnader	Operatørkostnader	Operatørinntekter	Operatøroverføringer	Drift_vedlikehold	Offentlige_overføringer	Skatte_avgiftsinntekter	Ulykker	Støy_luft	Skattekostnad	Investeringer	NN
2022	-116064,3	-2928	-196749,4	-4518	2711	1807	-7039	-1807	31243	-29683	-8328	4479	0	-324854,058
2023	-112993,8	-2870	-194142	-4429	2657	1771	-6772	-1771	30273	-28849	-8867	4346	0	-321644,872
2024	-110006,4	-2813	-191577,7	-4341	2604	1736	-6514	-1736	29332	-28045	-9365	4216	0	-316508,952
2025	-107099,6	-2757	-189055,7	-4255	2553	1702	-6267	-1702	28420	-27265	-9825	4090	0	-311460,693
2026	-104147,2	-2699	-186575,3	-4165	2499	1666	-6029	-1666	27478	-26503	-10215	3957	0	-306398,568
2027	-101273,5	-2642	-184135,8	-4077	2446	1631	-5800	-1631	26566	-25768	-10567	3827	0	-301424,673
2028	-98476,33	-2586	-181736,4	-3991	2394	1596	-5579	-1596	25680	-25056	-10883	3701	0	-296532,51
2029	-95753,58	-2531	-179376,6	-3906	2344	1563	-5367	-1563	24822	-24361	-11164	3578	0	-291716,384
2030	-93103,15	-2478	-177055,6	-3824	2294	1529	-5171	-1529	23990	-23685	-11412	3458	0	-286987,187
2031	-86367,02	-2419	-174186,2	-3733	2240	1493	-4974	-1493	23230	-22973	-11090	3353	0	-276920,281
2032	-83760,09	-2362	-171368,4	-3645	2187	1458	-4785	-1458	22495	-22282	-10778	3250	0	-271047,186
2033	-81233,65	-2306	-168601,1	-3558	2135	1423	-4603	-1423	21784	-21613	-10475	3152	0	-265319,227
2034	-78785,15	-2251	-165883,6	-3474	2084	1389	-4427	-1389	21095	-20966	-10182	3056	0	-259734,06
2035	-76412,13	-2198	-163214,8	-3391	2035	1357	-4259	-1357	20429	-20338	-9897	2963	0	-254283,138
2036	-74237,97	-2147	-160593,7	-3313	1988	1325	-4097	-1325	19844	-19727	-9655	2884	0	-249053,854
2037	-72127,51	-2097	-158019,6	-3237	1942	1295	-3941	-1295	19277	-19136	-9419	2808	0	-243949,605
2038	-70078,82	-2049	-155491,4	-3162	1897	1265	-3791	-1265	18727	-18565	-9189	2734	0	-238968,142
2039	-68090,06	-2002	-153008,5	-3089	1853	1236	-3647	-1236	18193	-18009	-8966	2662	0	-234102,522
2040	-66159,42	-1955	-150569,8	-3018	1811	1207	-3508	-1207	17674	-17473	-8749	2592	0	-229355,611
2041	-64245,23	-1903	-148055	-2936	1762	1175	-3375	-1175	17167	-16951	-8522	2524	0	-224534,572
2042	-62386,64	-1852	-145584,9	-2857	1714	1143	-3246	-1143	16674	-16443	-8301	2457	0	-219825,249
2043	-60582,04	-1802	-143158,6	-2781	1668	1112	-3123	-1112	16195	-15949	-8086	2392	0	-215225,738
2044	-58829,85	-1753	-140775,4	-2706	1623	1082	-3004	-1082	15730	-15471	-7877	2329	0	-210734,294
2045	-57128,55	-1706	-138434,4	-2633	1580	1053	-2890	-1053	15279	-15009	-7674	2267	0	-206348,723
2046	-55476,65	-1660	-136134,9	-2562	1537	1025	-2781	-1025	14840	-14558	-7476	2207	0	-202065,359
2047	-53872,71	-1615	-133876	-2493	1496	997	-2676	-997	14414	-14124	-7284	2148	0	-197882,273
2048	-52315,34	-1572	-131657	-2426	1456	970	-2574	-970	14000	-13703	-7096	2091	0	-193795,883
2049	-50803,18	-1530	-129477,1	-2361	1416	944	-2476	-944	13599	-13295	-6914	2036	0	-189804,671
2050	-49334,89	-1488	-127335,6	-2297	1378	919	-2382	-919	13209	-12897	-6736	1982	0	-185903,424
2051	-47885,9	-1447	-125185,7	-2233	1340	893	-2291	-893	12823	-12511	-6558	1928	0	-182022,437
2052	-46479,55	-1407	-123074,1	-2171	1302	868	-2204	-868	12448	-12134	-6385	1875	0	-178229,061
2053	-45114,6	-1367	-121000,2	-2110	1266	844	-2121	-844	12084	-11769	-6217	1824	0	-174524,865
2054	-43789,81	-1329	-118963,2	-2051	1231	821	-2040	-821	11731	-11417	-6053	1774	0	-170908,001
2055	-42504,01	-1292	-116962,5	-1994	1197	798	-1962	-798	11389	-11076	-5894	1726	0	-167374,143
2056	-41256,05	-1256	-114997,3	-1939	1163	775	-1888	-775	11056	-10744	-5739	1679	0	-163921,827
2057	-40044,8	-1221	-113067	-1885	1131	754	-1816	-754	10733	-10423	-5589	1633	0	-160549,388
2058	-38869,18	-1187	-111170,9	-1832	1099	733	-1747	-733	10420	-10111	-5442	1588	0	-157253,057
2059	-37728,16	-1154	-109308,3	-1781	1069	712	-1681	-712	10115	-9810	-5300	1544	0	-154033,669
2060	-36620,7	-1122	-107478,8	-1731	1039	693	-1617	-693	9820	-9518	-5161	1502	0	-150887,738
2061	-35545,81	-1091	-105681,6	-1683	1010	673	-1611	-673	9533	-9233	-5027	1450	0	-147877,89

Table A1.3 – Estimations for the Alternative 0, considering negative signs for the costs.

År	Kjøretøykostnader	Direkteutgifter	Tidskostnader	Operatørkostnader	Operatørinntekter	Operatøroverføringer	Drift_vedlikehold	Offentlige_overføringer	Skatte_avgiftsinntekter	Ulykker	Støy_luft	Skattekostnad	Investeringer	NN
2022	-118560,4	-2914	-184818,5	-4496	2698	1799	-7299	-1799	32374	-22446	-8771	-287927	-1462912	-2063050,06
2023	-115429,9	-2855	-182371,5	-4407	2644	1763	-7022	-1763	31371	-21822	-9339	4517	0	-304713,414
2024	-112383,8	-2798	-179964,9	-4318	2591	1727	-6755	-1727	30398	-21221	-9864	4383	0	-299932,705
2025	-109419,7	-2742	-177598	-4232	2539	1693	-6498	-1693	29455	-20638	-10348	4253	0	-295229,858
2026	-106403,5	-2684	-175270,1	-4142	2485	1657	-6251	-1657	28479	-20068	-10760	4114	0	-290498,959
2027	-103467,4	-2626	-172980,5	-4053	2432	1621	-6013	-1621	27533	-19518	-11131	3980	0	-285845,09
2028	-100609,3	-2570	-170728,7	-3966	2380	1587	-5785	-1587	26616	-18985	-11464	3849	0	-281263,832
2029	-97827,09	-2515	-168514	-3882	2329	1553	-5565	-1553	25727	-18465	-11761	3722	0	-276750,799
2030	-95118,54	-2461	-166335,7	-3798	2279	1519	-5363	-1519	24864	-17959	-12022	3596	0	-272318,114
2031	-88120,69	-2403	-163641,3	-3708	2225	1483	-5158	-1483	24079	-17424	-11685	3487	0	-262348,46
2032	-85462,85	-2346	-160995,3	-3620	2172	1448	-4962	-1448	23319	-16905	-11357	3382	0	-256774,688
2033	-82887	-2290	-158396,9	-3534	2120	1414	-4773	-1414	22584	-16403	-11039	3279	0	-251338,868
2034	-80390,55	-2236	-155845,1	-3450	2070	1380	-4591	-1380	21872	-15917	-10731	3180	0	-246038,095
2035	-77971,03	-2182	-153339	-3368	2021	1347	-4416	-1347	21183	-15445	-10431	3084	0	-240865,461
2036	-75756,88	-2132	-150877,8	-3290	1974	1316	-4248	-1316	20580	-14987	-10177	3003	0	-235912,081
2037	-73607,49	-2083	-148460,7	-3214	1929	1286	-4087	-1286	19994	-14542	-9929	2924	0	-231076,977
2038	-71520,91	-2035	-146086,7	-3140	1884	1256	-3931	-1256	19425	-14113	-9688	2848	0	-226357,777
2039	-69495,27	-1988	-143755,1	-3068	1841	1227	-3781	-1227	18873	-13695	-9453	2773	0	-221748,657
2040	-67528,72	-1942	-141465	-2997	1798	1199	-3638	-1199	18338	-13292	-9225	2700	0	-217251,093
2041	-65576,82	-1890	-139102,5	-2916	1750	1167	-3499	-1167	17812	-12899	-8986	2629	0	-212678,4
2042	-63681,57	-1839	-136781,9	-2838	1703	1135	-3366	-1135	17301	-12516	-8753	2560	0	-208211,997
2043	-61841,32	-1789	-134502,5	-2761	1657	1105	-3238	-1105	16805	-12145	-8527	2493	0	-203849,976
2044	-60054,47	-1741	-132263,5	-2687	1612	1075	-3115	-1075	16323	-11785	-8307	2427	0	-199590,351
2045	-58319,46	-1694	-130064,3	-2615	1569	1046	-2996	-1046	15855	-11436	-8093	2363	0	-195431,12
2046	-56634,79	-1649	-127903,9	-2544	1527	1018	-2884	-1018	15401	-11097	-7884	2300	0	-191369,579
2047	-54998,97	-1604	-125781,7	-2476	1485	990	-2774	-990	14960	-10770	-7681	2239	0	-187402,196
2048	-53410,61	-1561	-123697	-2409	1445	964	-2669	-964	14531	-10452	-7484	2180	0	-183526,707
2049	-51868,3	-1519	-121649,1	-2344	1407	938	-2567	-938	14115	-10145	-7292	2122	0	-179741,43
2050	-50370,71	-1478	-119637,3	-2281	1369	912	-2470	-912	13710	-9845	-7105	2066	0	-176042,054
2051	-48892,39	-1437	-117617,3	-2218	1331	887	-2376	-887	13310	-9553	-6917	2009	0	-172360,308
2052	-47457,55	-1397	-115633,4	-2156	1293	862	-2285	-862	12922	-9269	-6735	1955	0	-168762,451
2053	-46064,91	-1358	-113684,8	-2096	1257	838	-2198	-838	12545	-8993	-6558	1902	0	-165248,907
2054	-44713,21	-1320	-111771	-2037	1222	815	-2115	-815	12179	-8727	-6385	1850	0	-161818,098
2055	-43401,27	-1283	-109891,2	-1980	1188	792	-2034	-792	11823	-8469	-6217	1799	0	-158466,149
2056	-42127,91	-1248	-108044,8	-1925	1155	770	-1957	-770	11478	-8219	-6054	1750	0	-155191,66
2057	-40891,98	-1213	-106231,1	-1871	1123	749	-1883	-749	11144	-7976	-5895	1702	0	-151992,836
2058	-39692,39	-1179	-104449,6	-1819	1092	728	-1811	-728	10819	-7740	-5741	1656	0	-148866,63
2059	-38528,06	-1146	-102699,7	-1769	1061	707	-1742	-707	10503	-7512	-5591	1611	0	-145813,257
2060	-37397,96	-1114	-100980,8	-1719	1032	688	-1676	-688	10197	-7291	-5445	1567	0	-142829,604
2061	-36301,08	-1083	-99292,2	-1671	1003	669	-1676	-669	9899	-7075	-5303	1511	0	-139988,66

Table A1.4 – Estimations for the Alternative 1, considering negative signs for the costs.

År	Kjøretøykostnader	Direkteutgifter	Tidskostnader	Operatørkostnader	Operatørinntekter	Operatøroverføringer	Drift_vedlikehold	Offentlige_overføringer	Skatte_avgiftsinntekter	Ulykker	Støy_luft	Skattekostnad	Investeringer	NN
2022	2496,1	-14,042	-11930,9	-21,669	13,002	8,667	260,112	-8,667	-1131,3	-7236,87	443,008	292406,556	1462912	1738195,997
2023	2436,1	-14,255	-11770,5	-21,998	13,199	8,799	250,108	-8,799	-1098,23	-7026,37	471,872	-171,384	0	-16931,458
2024	2377,4	-14,456	-11612,8	-22,309	13,386	8,924	240,489	-8,924	-1066,06	-6823,73	498,732	-166,899	0	-16576,247
2025	2320,1	-14,647	-11457,7	-22,604	13,562	9,042	231,239	-9,042	-1034,78	-6627,16	523,672	-162,517	0	-16230,835
2026	2256,3	-15,04	-11305,2	-23,21	13,926	9,284	222,346	-9,284	-1000,82	-6435,09	544,73	-157,551	0	-15899,609
2027	2193,9	-15,415	-11155,3	-23,789	14,273	9,516	213,794	-9,516	-967,8	-6250,35	563,81	-152,706	0	-15579,583
2028	2132,97	-15,773	-11007,7	-24,341	14,604	9,736	205,571	-9,736	-935,73	-6071,33	581,03	-147,979	0	-15268,678
2029	2073,51	-16,113	-10862,6	-24,867	14,92	9,947	197,664	-9,947	-904,57	-5896,6	596,44	-143,369	0	-14965,585
2030	2015,39	-16,439	-10719,9	-25,368	15,221	10,147	191,591	-10,147	-874,28	-5726,88	610,16	-138,568	0	-14669,073
2031	1753,67	-16,162	-10544,9	-24,941	14,964	9,977	184,221	-9,977	-848,91	-5549,03	594,2	-134,933	0	-14571,821
2032	1702,76	-15,89	-10373,1	-24,521	14,712	9,808	177,136	-9,808	-824,3	-5376,6	578,7	-131,395	0	-14272,498
2033	1653,35	-15,621	-10204,2	-24,107	14,464	9,643	170,323	-9,643	-800,42	-5209,83	563,63	-127,948	0	-13980,359
2034	1605,4	-15,357	-10038,5	-23,699	14,22	9,48	163,773	-9,48	-777,25	-5048,93	548,97	-124,592	0	-13695,965
2035	1558,9	-15,096	-9875,8	-23,297	13,978	9,319	157,474	-9,319	-754,76	-4892,47	534,717	-121,323	0	-13417,677
2036	1518,91	-14,754	-9715,9	-22,768	13,66	9,108	151,417	-9,108	-735,44	-4740,68	522,408	-118,626	0	-13141,773
2037	1479,98	-14,419	-9558,9	-22,251	13,35	8,901	145,594	-8,901	-716,63	-4593,77	510,406	-115,988	0	-12872,628
2038	1442,09	-14,092	-9404,7	-21,746	13,048	8,698	139,994	-8,698	-698,32	-4451,94	498,705	-113,404	0	-12610,365
2039	1405,21	-13,772	-9253,4	-21,252	12,752	8,501	134,609	-8,501	-680,49	-4313,94	487,295	-110,877	0	-12353,865
2040	1369,3	-13,459	-9104,8	-20,771	12,463	8,309	129,432	-8,309	-663,14	-4181,31	476,17	-108,403	0	-12104,518
2041	1331,59	-13,102	-8952,5	-20,219	12,132	8,087	124,454	-8,087	-644,9	-4051,97	464,049	-105,706	0	-11856,172
2042	1294,93	-12,753	-8803	-19,681	11,808	7,872	119,667	-7,872	-627,16	-3926,24	452,249	-103,072	0	-11613,252
2043	1259,28	-12,414	-8656,1	-19,158	11,494	7,663	115,064	-7,663	-609,91	-3804,28	440,763	-100,501	0	-11375,762
2044	1224,62	-12,084	-8511,9	-18,648	11,189	7,459	110,639	-7,459	-593,14	-3686,21	429,582	-97,991	0	-11143,943
2045	1190,91	-11,763	-8370,1	-18,152	10,891	7,261	106,384	-7,261	-576,82	-3572,11	418,698	-95,541	0	-10917,603
2046	1158,14	-11,45	-8231	-17,67	10,602	7,068	102,593	-7,068	-560,97	-3461,04	408,103	-93,088	0	-10695,78
2047	1126,26	-11,146	-8094,3	-17,2	10,32	6,8801	98,647	-6,8801	-545,55	-3354,14	397,788	-90,756	0	-10480,077
2048	1095,27	-10,85	-7960	-16,743	10,046	6,6973	94,853	-6,6973	-530,54	-3250,48	387,746	-88,478	0	-10269,176
2049	1065,12	-10,562	-7828	-16,298	9,779	6,5193	91,205	-6,5193	-515,96	-3150,24	377,97	-86,255	0	-10063,241
2050	1035,82	-10,281	-7698,3	-15,865	9,519	6,3462	87,698	-6,3462	-501,78	-3052,549	368,454	-84,086	0	-9861,37
2051	1006,49	-9,998	-7568,4	-15,429	9,257	6,1714	84,324	-6,1714	-487,58	-2957,781	358,875	-81,887	0	-9662,129
2052	978	-9,722	-7440,7	-15,003	9,002	6,0015	81,081	-6,0015	-473,79	-2865,294	349,557	-79,741	0	-9466,61
2053	950,31	-9,454	-7315,4	-14,591	8,754	5,8362	77,962	-5,8362	-460,39	-2775,988	340,491	-77,652	0	-9275,958
2054	923,4	-9,194	-7192,2	-14,189	8,513	5,6754	74,964	-5,6754	-447,36	-2689,894	331,671	-75,614	0	-9089,903
2055	897,26	-8,941	-7071,3	-13,798	8,279	5,5192	72,081	-5,5192	-434,71	-2606,328	323,091	-73,628	0	-8907,994
2056	871,86	-8,696	-6952,5	-13,419	8,051	5,3674	69,308	-5,3674	-422,41	-2525,41	314,743	-71,694	0	-8730,167
2057	847,18	-8,456	-6835,9	-13,049	7,829	5,2196	66,642	-5,2196	-410,46	-2447,151	306,621	-69,808	0	-8556,552
2058	823,21	-8,223	-6721,3	-12,69	7,614	5,0761	64,08	-5,0761	-398,85	-2371,017	298,719	-67,97	0	-8386,427
2059	799,9	-7,997	-6608,6	-12,341	7,404	4,9364	61,615	-4,9364	-387,57	-2297,674	291,03	-66,179	0	-8220,412
2060	777,26	-7,777	-6498	-12,002	7,201	4,8006	59,245	-4,8006	-376,611	-2226,566	283,549	-64,433	0	-8058,134
2061	755,27	-7,564	-6389,4	-11,672	7,003	4,6686	65,155	-4,6686	-365,96	-2157,237	276,269	-61,094	0	-7889,23

Table A1.5 - Subtraction of both the alternatives after considering costs as negative values.