CHALMERS

Risk management in design-construct infrastructure projects

A study of three Swedish Transport Administration projects

Master of Science Thesis in the Master's Programme Design and Construction Project Management

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ABSTRACT

The infrastructure sector in Sweden is considered to have lower productivity growth than other industries. In order to encourage development and innovation in the sector, the Swedish Transport Administration (STA) has decided to increase the volume of projects procured as design-construct (DC). As a result of more DC projects within STA, the risk management process will change. The literature review indicates that a significant factor in choosing DC is the greater possibility of transferring risks to the contractor.

The purpose of this report is to examine how STA staff view risk management in civil engineering projects procured as DC, based on their experiences and opinions. The aim is to provide knowledge that will improve the risk management process in DC projects within STA. Furthermore, an evaluation of the risk management software used in the studied projects is performed.

The literature review provides an understanding of risk management in infrastructure projects, and especially in DC projects. In addition, internal documents and policies within STA have been investigated. In order to examine and evaluate how STA practise risk management, three projects procured as DC have been studied in a qualitative approach. The study includes observations and seven interviews of key persons for the projects.

Findings indicate three categories of risks in DC projects to be of particular importance: geotechnical risks, esthetical risks and environmental risks. Furthermore, results show that the respondents are inexperienced in managing risks in DC projects; as a consequence, some parts of the projects are managed as traditional contracts. Results further show that the risk management software is appropriate for use with DC projects; however, the calculation of the risk reserve needs to be improved.

Key words: risk management, design-construct, design-build, infrastructure, construction

Riskhantering för totalentreprenader inom infrastrukturprojekt
En studie av tre projekt inom Trafikverket
Examensarbete inom Design and Construction Project Management

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SAMMANFATTNING

Anläggningsbranschen i Sverige anses ha en lägre produktivitetsutveckling jämfört med andra branscher. För att främja möjligheterna för en bättre utveckling inom anläggningsbranschen har Trafikverket beslutat att öka andelen projekt upphandlade som totalentreprenader. Enligt Trafikverket kan fler totalentreprenader leda till fler innovativa lösningar. En konsekvens av detta beslut är att riskhanteringen inom Trafikverket kommer att förändras. Enligt litteraturstudien är möjligheterna att föra över risker till entreprenören en viktig faktor vid valet av totalentreprenad som entreprenadform.

Syftet med denna studie är att undersöka hur Trafikverkets anställda betraktar riskhantering för infrastrukturprojekt upphandlade som totalentreprenader, baserat på deras erfarenheter och synpunkter. Målet är att bidra med kunskap om riskhantering för att möjliggöra en förbättring av riskhanteringen inom totalentreprenader. Utöver detta ska även en programvara, speciellt utvecklad som ett stöd för riskhanteringen, utredas för att föreslå förbättringar.

För att uppnå förståelse av infrastrukturprojekt, och främst av totalentreprenader, har en litteraturundersökning gjorts inom dessa områden. Utöver detta har även interna dokument på Trafikverket studerats. För att undersöka och utvärdera hur Trafikverkets riskhantering utövas har tre projekt upphandlade som totalentreprenader studerats med en kvalitativ undersökningsmetod. Denna undersökning inkluderar observationer samt sju intervjuer med nyckelpersoner för de aktuella projekten.

Enligt studien finns det tre huvudsakliga riskkategorier som är särskilt viktiga i en totalentreprenad. Dessa områden är geotekniska risker, estetiska risker samt miljörisker. Studien visar även att respondenterna är osäkra i fråga om hur de ska hantera risker i totalentreprenader. Som en konsekvens av denna osäkerhet hanteras vissa delar i de studerade projekten på samma sätt som i utförandeentreprenader. Studien visar även att den undersökta riskhanteringsprogramvaran är lämplig att använda i en totalentreprenad. Däremot behöver problem med felaktig beräkning av riskreserv lösas.

Nyckelord: riskhantering, totalentreprenad, infrastrukturprojekt, byggindustri

Contents

Preface

This thesis was performed during the spring of 2013 at the Swedish Transport Administration (Trafikverket) in Göteborg.

The research was supervised by Jan Bröchner at Chalmers University of Technology whose reflections and recommendations were much appreciated. A special thanks to Henrik Jansson, Christer Claesson, and Susanne Skoglund at the Swedish Transport Administration for their kindness and support during our study. We would also like to thank Nancy Lea Eik-Nes for the help with language and formatting in this thesis.

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Göteborg, June 2013

Fredrik Ljungmark & Jonas Sjöholm

1 Introduction

The importance of risk management in infrastructure projects has never been greater. One of the reasons is that infrastructure projects of today often are associated with an increased complexity and therefore a higher-risk exposure (Baker et al., 1998). According to Smith et al. (2006) the choice of contract type for an infrastructure project has a significant impact on how risks are shared between the contractor and the client.

1.1 Background

The construction industry in Sweden is considered to have a lower productivity growth compared to other industries (Trafikverket, 2012). The governmental report of the Productivity Committee (SOU 2012:39) highlights the lack in productivity growth, the low level of competition and lack of innovation within the infrastructure sector as a problem that needs to be addressed. When the Swedish Transport Administration (STA) was established in 2010, the increase of efficiency within civil engineering projects was a cornerstone for the organisation (Trafikverket, 2012). In addition, the Swedish government has taken a decision in order to encourage development and innovations in the construction industry. According to STA, which is the largest client in Sweden, one way to implement this is to increase the volume of projects procured with a design-construct (DC) contract. When using design-construct, the contractor is responsible for both design and construction. In addition to the change towards more projects procured as design-construct, STA strives to obtain a clearer client perspective. In the Trafikverket (2012) report, these ambitions are stated:

- to create conditions for the market to encourage increased innovation and productivity
- develop STA's role as active clients with the purpose of providing a greater commitment and responsibility to the suppliers
- provide conditions for an increasingly competitive industry

This implies that STA needs to transfer more control over projects and their end results to the contractor. This also requires that STA needs to consider how they shall manage risks in design-construct projects, hence the risk management process needs to be reviewed.

Risk management is in general a growing area of interest in civil engineering projects and the increase in the development, preservation and maintenance of infrastructure is likely to demand an even greater focus on risk management (Faber and Stewart, 2003). Elkington and Smallman (2002) state that projects with a less predictable nature in an organisation are exposed to greater risk compared to their day-to-day activities. Thus, risk management is integrated with project management and most large companies invest substantial recourses into risk management. Furthermore, a study by Elkington and Smallman (2002) found that there is a strong link between the amount of risk management and the project's success level, but also in what stage risk management was introduced.

The fact that risk management is so significant for a project's success, and consequently for government clients, makes the handling of risks essential to investigate. This study will investigate how STA practises risk management in design-construct projects. It will also examine one type of risk management software used by STA for the risk management process.

1.2 Purpose

The purpose of this thesis is to examine how STA staff views risk management in civil engineering projects procured as design-construct, based on their experiences and opinions. The aim is to provide knowledge that will improve the risk management process in design-construct projects within STA. Furthermore, an evaluation of risk management software used in the studied projects will be performed.

1.3 Limitations

The study will focus on risk management in the planning and execution phase from the client's perspective. Subjects closely related to the field of risk management in the construction industry will be discussed. Moreover, only risk areas that are essential according to the studied literature will be investigated. The study will focus only on infrastructure projects procured as design-construct in Sweden. Another criterion is that all projects for this study shall work with risk management according to current guidelines of STA. Therefore, the projects for this study must be rather newly started due to changes in guidelines from April 2010. In order to assemble a sufficient amount of information for this study, the scope of the projects expressed in contract sum need to be in the interval 100 to 300 MSEK.

1.4 Thesis outline

The report consists of eight chapters and references. The report starts with an introduction, which presents the background of the performed study, followed by a presentation of the thesis purpose and limitations. Chapter 2 covers how the study was executed and the methods that were chosen. The main methods involved literature studies, interviews, examining internal documents, plus observation. Chapter 3 contains a literature review regarding: risk definitions, risk management process, risk management standard and risk perception. Chapter 4 presents a theoretical view on two commonly used procurement routes in infrastructure projects: design-bid-build (DBB) and design-construct (DC). Furthermore, a theoretical view on performance specification will be presented in this chapter. In Chapter 5, the internal documents regarding risk definition, risk management process and the risk management software used at the studied company are presented. In addition, general observations from STA main office in Göteborg regarding risk management and observations from one risk meeting are presented. Results from interviews and general observations from STA are presented in Chapter 6. This section is divided in three different risk areas of interest, as well as additional risk areas, the interviewees' attitudes and their view on the risk management software. In Chapter 7, an analysis and a discussion are presented of the most essential results from chapters five and six. The results are connected to the theoretical view of the subject presented in Chapter 3 and 4. The last chapter presents conclusions regarding the study and gives a proposal for further research.

2 Methodology

In order to examine and evaluate how STA practise risk management in infrastructure projects procured as design-construct, a method is required to explain the approach for this study, as well as the main tools used. This study has used the term design-construct (DC) instead of the more commonly used design-build (DB) for the reason that the term DC is more frequently used in infrastructure projects, while the term DB is traditionally used for building projects. Due to the complex subject, one client was studied and a qualitative approach was used in order to investigate risk management in projects procured as DC. The study is divided in two parts. Initially, a literature review was performed. After the literature review was performed, three DC projects were investigated including internal data collecting and seven interviews were performed during the time period February to April 2013. In addition, general observations from STA and observations from one risk meeting were conducted. Finally, the literature review, internal documents and findings regarding the DC project were discussed and concluding remarks were made.

2.1 Literature review and theoretical framework

The purpose of the literature review is to assemble knowledge of the theoretical framework and to develop an argument around the significance of the research (Bryman and Bell, 2007). The literature review has investigated risk management in construction projects and frequently used procurement routes in infrastructure projects.

The first part introduces definitions for the risk management process, but also a comprehensive view of risk management is presented. Secondly, the literature review will present the use of DC and DBB for infrastructural projects, but also how it is used in other countries to reduce risk from primarily the client's perspective. Additional to these two parts, a risk management software used at STA has been investigated in order to determine if it is an effective instrument to manage risks for DC infrastructure projects.

2.2 Qualitative case studies

A qualitative research approach is often used to answer a complex research question (Mack et al., 2005). When a study has to define *"how"* and *"why"* to a complex issue, a combination with the qualitative approach and the case study technique can be used. This enables the researcher to gain a holistic view on the issue and allows for a round picture on the subject if many sources of evidence are used (Noor, 2008). According to Noor (2008) there should be two or more cases within the same study in order to validate the results as the researcher may try to predict the outcome in advance. The use of multiple cases will also enhance the accuracy and reliability of the result by capturing the holistic essence of the subject. Hence, we have three cases for this study.

Problems with qualitative research, according to Bryman (2008), can be the lack of transparency and problems with generalization, but also that the results can be difficult to replicate. The interviewees and the cases are often chosen by the researcher, which can make it unclear about how the researcher has drawn conclusions. When looking only in depth of a specific problem the breadth is often limited, this is often the other way around in quantitative research. But also the nature of qualitative research is that the findings tend to be oriented to uniqueness for the studied subject. As the scope of the research is restricted and there are a small number of persons interviewed it will be hard to generalize the findings for the study. However, this thesis uses a combination of interviews, observations and extensive literature review from both the internal documents and previous research made in the subject in order to reduce problems regarding generalization (Bryman, 2008).

2.3 Internal documents from STA

Internal documents and policies were investigated to examine how risk management for DC projects is intended to be carried out at STA. The results from the internal documents are compared with theories and how the process is carried out in practice. All internal documents and policies were collected from STA intranet.

In order to compare how STA carried out risk management in the field, three infrastructure DC projects were selected for the study. Studied internal documents for the investigation were: tendering documents for the cases, standards on risk management and reports regarding procurement strategies. In addition, the database for the risk management software was examined in order to get an understanding of the STA risk management practice.

2.4 Observations

To examine how STA practise risk management in projects procured as DC, general observations at STA as well as observations from one specific risk meeting were performed. The purpose of the risk meeting is to identify and analyse risks in a middle size DC project. The purpose of the observations was to obtain certain information that cannot be obtained from other methods (Noor, 2008). According to Noor (2008), observations generated on site during the research provide a better understanding of the complex issue.

The observation technique that was used during the session was unstructured observation, where the observers do not follow a specific schedule when observing the participants (Bryman, 2008). Both the authors performed unstructured general observations as well as observations during the risk meeting without recording. The purpose for this was to gather as much detailed information regarding the participants' attitude towards risk management as possible. Regarding the observations for the risk meeting, it is a weakness that only one risk meeting was observed. Therefore, it is important to be critical towards the findings from this meeting because other meetings can be different.

2.5 Interviews

Interviews are a tool to collect data for the case study (Noor, 2008). Therefore, it is important to design the questions carefully in order to achieve adequate coverage for the research. As the subject for the study is complex concerning value and individual experience it is recommended to choose semi-structured interview rather than structured interviews because it offers flexibility to approach different respondents differently and still cover the same area of data collecting.

The semi-structured interviews use an interview guide, which is a list of questions that needs to be covered during the interview. The interviewer follows the guide, although if there is questions that are of interest for the specific participant the interviewer may stray from the guide, which offers flexibility in the interview (Cohen and Crabtree, 2006). The benefits of using semi-structured interviews are that the questions can be prepared ahead of time, allowing the interviewer to be prepared and appear competent during the interview. It also allows the informant the freedom to express their views in their own way.

Seven semi-structured interviews were conducted with four persons. The selection of interviewees was made due to their key roles for the relevant project. The interviewees' experience with DC projects varied. The interviewees also varied in age and length of employment.

Each interview lasted one to one and a half hours. All the interviews were structured and performed according to the interview guide, which can be found in the appendix. Six interviews were performed in person at STA's local offices and the seventh was a telephone interview.

All the interviews were recorded and supported with notes. Bryman (2008) recommends recording the interviews in order for errors to become less likely when interpreting the response to the open questions; when conducting qualitative research, the manner in which the respondents answer is also of interest.

3 Risk management

Risk management in general is a very broad subject and definitions of risk can therefore differ depending on the industry and the organisation. This chapter will present a comprehensive view of the risk management process in the project context, based on established theories. Moreover, this chapter mainly focuses on the construction industry. In order to have a clear understanding of this thesis, one definition of project risk will be chosen. Initially, some commonly used definitions of risk will be presented followed by an explanation of the human aspect of risk management, i.e. why some people rate a specific risk different compared to others. This chapter will also illustrate the established risk management standard ISO 31000. Finally, the risk management process within the construction industry will be presented.

3.1 Definitions of project risk

A number of different definitions on project risk can be found in the research literature. A commonly used risk definition in the project context is from the international Project Management Institute (PMI), "A Guide to the Project Management Body of Knowledge". They define project risk as:

> *an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope or quality.* (PMI, 2004, p. 238)

This definition of risk is very broad and open for interpretation. However, in contrast to some other definitions, this views risk as something that can be both positive and negative for the project (Osipova, 2008). Furthermore, several studies have shown that project managers generally use the term risk only for the negative consequences of an event, particularly time or budget overrun (Winch, 2010). For this reason, Winch (2010) argues against the use of risk as a term for both negative and positive outcomes and instead argues for the implementation of a framework that refers to threat and opportunity as terms to communicate potential downside and upside risk events. The main advantage of this approach is that organisations can give more focus to opportunities, which often are missed out when trying to avoid threats. However, the generally prevailing definition still describes risk as both positive and negative (Winch, 2010). The established international risk management standard ISO 31000:2009 defines risk as:

> *"effect of uncertainty on objectives"*, with the clarification *"An effect is a deviation from the expected - positive and/or negative."*

This definition, which also views risk as either positive or negative, is becoming more and more frequently used as this international standard on risk is becoming more established, especially in larger organisations (Purdy, 2010).

There is a distinction between risks and uncertainties in the literature. However, Samson et al. (2008) argue that a general worldwide accepted definition of either risk or uncertainty does not exist. However, uncertainty is defined by Winch as

> *the lack of all the information required to take a decision at a given time.* (Winch, 2010, p. 7)

This definition is explained as when there are enough data available for a probability assessment, then, it is a risk rather than an uncertainty. Further, Winch defines risk as

> *the condition where information is still missing, but a probability distribution can be assigned to the occurrence of the event about which a decision needs to be taken.* (Winch, 2010, p. 347)

This definition is also supported by the analogous description by Smith et al. (2006). This can be illustrated by the following example: In the beginning of a construction project, the uncertainty is usually very high. During the project life cycle, the uncertainty is reduced as more information is collected and building tasks are performed. During this process, according to the definitions, some uncertainties become risks.

In this report we will use the risk definition by ISO 31000:2009, "effect of uncertainty on objectives".

3.2 Risk perception

Risk perception, according to Sjöberg et al. (2004), is the subjective assessment of the probability for a particular type of risks and how concerned we are with the consequences. Smith et al. (2006) define two major categories of groups regarding risk, i.e. risk takers and risk avoiders. Risk takers generally accept a higher exposure to risks and try to receive higher payoff, while risk avoiders generally strive to receive a lower risk exposure and security. There is a difference in how risks are perceived by risk takers and risk avoiders. Risk takers tend to underestimate risk while risk avoiders regard all risks as obstacles and tend to overestimate risk.

Grimvall et al. (2003) state that in most cases it is the perceived size of the actual risk that is decisive for the individual risk perception. Individuals are for the most part good at interpreting the perceived size of a risk, but there is still a tendency towards underestimating large risks and overestimate small risks. The perceived size could be explained by three aspects: number of victims, new risk and fear. Number of victims may include the financial cost if the risk would bear out. Secondly, the new risk includes if the type of risk is new to the person, organisation or the world and, finally, fear includes how much the person or organisation fears the outcome of the risk if it falls out. If these aspects are high, the person will perceive the risk as high (Grimvall et al., 2003).

The level of education, age and the group composition are also factors that influence our risk perception. Research has shown that people with high levels of education rate the same risk lower than people with less education. In the same way, age has been shown to influence the risk perception. Seniors tend to be more audacious and assess risk as less significant than their younger colleagues (Grimvall et al., 2003). According to Smith et al. (2006) groups are less risk aware than individuals and large complex organisations are more likely to take risks than smaller organisations.

3.3 The risk management standard

ISO 31000 is an international standard for risk management, published in 2009 by the International Organization for Standardization (ISO). Although ISO 31000 is not the first ISO standard for risk management, this version is the first that claims to be a standard for managing risks in all sectors and fields (Leitch, 2010). To create this wide-ranging standard, a working group of experts from 28 countries was formed by ISO to guide the development. The experts represent a broad range of risk management experience from many different sectors and have helped the ISO network to create the standard (Purdy, 2010).

The main purpose of an international standard for risk management is to create a common view of risk definition and risk management practices. This also includes a more consistent usage of terms in the area, in order to facilitate the communication. Although ISO 31000 is an internationally accepted standard by many countries, Purdy (2010) expects it will take time before it is entirely implemented. The standard is not mainly developed for project-based organisations, however it can be adapted and applied to managing risks in projects.

According to Purdy (2010), ISO 31000 has four main goals. The first goal is to create a common used risk vocabulary, and the second is to form a set of performance criteria for companies to adopt. The third goal is to create a common process to manage risks from the identification of risks to the treatment of them. Finally, the standard aims to provide guidance into how risk management should be integrated in the decision making process in the organisation. Although one purpose of this standard is to bring clarity to terms and definitions about risk management, Leitch (2010) argues that it on several occasions defines terms even more vaguely, which can lead to unnecessary irrational decisions.

3.4 The risk management process

According to PMI (2004), the main objectives of risk management in projects are to increase the probability and impact of positive events to occur, and to decrease the affect of possible unwanted events. Smith et al. (2006) argue that risk management is not about predicting the future; instead it is about understanding the project in order to make better decisions in the future.

Risks within the construction industry have, according to Potts (2008), historically often been either ignored or dealt with in arbitrary way. Moreover, Potts (2008) explains that this has often been handled with an additional percentage on the tender as a contingency fund, of example 10%, to use for unexpected project costs. Today, the practices of risk management are most developed within industries with large engineering projects or within projects with considerable technical risk elements (Maylor, 2010).

The risk management process is described in a range of different models in the literature. However, the general core from the models consists of activities where firstly risks are identified in order to know what has to be managed. The second stage involves the analysing of risks to get an understanding of how they can affect the project and interact with other risks. The next stage is to respond to the risks in a proper way. Further, the risks are to be monitored throughout the project life cycle. These activities can in a simplistic approach be described in a model by four stages illustrated in figure 1, with risk identification, risk analysis, risk response and risk monitoring (Winch, 2010; Smith et al., 2006). This model illustrates the risk management process as a learning loop over time, where the process continues during the whole project life cycle. Potts (2008) explains this is due to that risks constantly are changing.

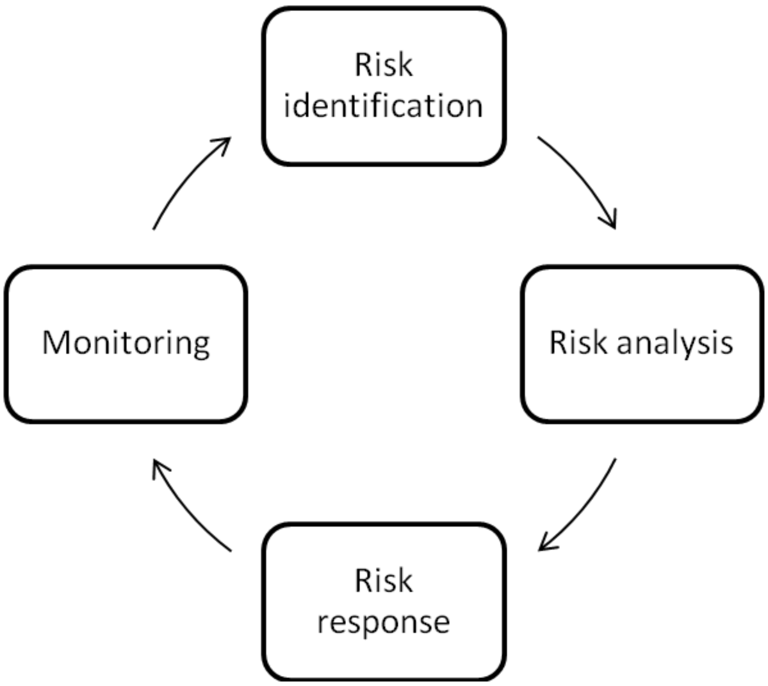

Figure 1 The risk management process (Based on Winch, 2010)

Smith et al. (2006) argue that one key factor in the risk management process is to gather key personnel for the single purpose of discussing and evaluating risks related to the project. This is also supported by ISO 31000:2009, defined as establishing the organisation’s context. This is vital both for to improve the chances of a high quality risk analysis and to get the project team fully involved in the risk management process. If members of the team feel they own the risks and fully understand why they are working with risk management, they will more likely do a high-quality job handling these risks during the project. For the same reason, it is essential that the team members also agree with the output from the risk analysis, otherwise they will most likely not be willing to work with the result from the risk management process (Smith et al., 2006).

3.4.1 Risk identification

Risk identification is the first stage in the risk management process. The main purpose of the identification stage is to establish a list of as many potential risks as possible that may affect the project (Potts, 2008). ISO 31000:2009 clarifies the importance of identifying risks, whether or not they are under control of the organisation, and include them in the risk register. The main reason for this is to not overlook some risks, regardless of whether they are judged to be out of control, because they can affect the project later in the process.

The clients normally have the primary responsibility of risk identification, since they want to be certain to reach the projects' objectives of completion within time, budget and to the right quality. However, the contractor will also need to identify risks in the project and the contract documents to be able to prepare an appropriate tender (Potts, 2008).

The risk identification process is, according to Winch (2010), one of the less formalised elements of the risk management process. It is usually performed through relying on the employees' experience from former projects. However, there are a number of tools and techniques to use in the risk identification stage. These are, for example, brainstorming, expert opinion, interviews, checklists, testing and modelling, use of historical data or evaluation of other earlier projects (Osipova, 2008). To ensure that the risk identification process is done systematically, a detailed list of risk categories can contribute to the effectiveness and quality of the risk identification. This list can be based on experience from earlier projects, see table 1, or use a risk breakdown structure as base for the identification (PMI, 2004).

Table 1 Categorized risks (Smith et al., 2006)

• Financial risks	• Legal risks	• Political risks
• Social risks	• Environmental risks	• Communications risks
• Geographical risks	• Geotechnical risks	• Construction risks
• Technological risks	• Production risks	• Completion risk
• Commissioning risk	• Supply risk	• Force majeure risk

The first risk identification event is regularly done in open-minded workshops, often headed by a specialised risk manager who is responsible for extracting the necessary information from the participants (Smith et al., 2006). The participants in the identification, often team members, should be key personnel for the current project. This process is normally supported with a software tool where all risks are documented in a register where each risk's root cause and project outcome are described. Moreover, Smith et al. (2006) recommend the use of a software tool for the risk management process for all projects, regardless the projects size, in order improve the process. Risk identification, as well as other parts of the risk management process, is typically done in an iterative loop throughout the project to secure verification and allow new risks to become known as the project progress through its life cycle (PMI, 2004).

3.4.2 Risk analysis

The risk identification stage leads to the risk analysis stage, where the identified risks shall be evaluated and analysed in a qualitative, quantitative or semi-quantitative method (ISO 31000:2009). However, the semi-quantitative approach will not be further addressed in this thesis. The main purpose of the risk analysis is to prioritise risks for management according to PMI (2004). There is a wide range of different techniques available for analysing risks in a project, with different focus and level of detail. While each project is unique, it requires a risk analysis technique that suits the needs of that specific project and its features. The use of the same analysis technique for all projects can be a waste of time and money since some of the techniques are too brief for some situations and too comprehensive for others. The main factors that often determine which technique to be used are the type and size of the project, accessible information and time available of involved personnel in the project (Smith et al., 2006).

Winch (2010) emphasizes the importance of understanding the problem with the available risk analysis techniques, described with the citation: “garbage in, garbage out”. Hence, it is important to take the available information into consideration when choosing which technique to use for the analysis. Despite the fact that there are sophisticated techniques to analyse risks, the result of a study performed by Simu (2006) show that use of simple techniques such as experience and gut feeling when evaluating risks are common in the Swedish construction industry.

Qualitative analysis

A qualitative risk analysis is considered to be a rapid and cost effective method of establishing prioritising for further risk response planning. This analysis values risks based on the probability of occurrences and the related impact on the projects objectives if the risks do occur. The qualitative analysis can also be a base for the quantitative risk analysis, if this is required (PMI, 2004). The primary aim with a qualitative risk assessment is to produce a prioritised risk list for identification of risks with the most negative impact. This list can be used as a basis when determining if a specific risk needs further treatment. A standard qualitative risk analysis usually includes a brief description of the risk, the expected stage of the project when it can occur, what parts of the project it can affect if it occurs, which factors that influence if it occurs, and finally, the likelihood that it occurs (Smith et al., 2006).

Quantitative analysis

The quantitative risk analysis relies on data and computer models with range maximum, minimum and most likely cost. When calculating expected outcome of a risk both the impact and the probability of occurrence are used. When using this approach, the first stage is to assess the risks into three categories of impact - optimistic, pessimistic and most likely (Potts, 2008).

Risk matrix

One of the most commonly used qualitative risk analysis techniques is the probability and impact matrix (Winch, 2010). A typical risk matrix is illustrated in figure 2, which includes threats. However, a risk matrix can also be used to illustrate positive risks, i.e. opportunities.

	Negligible	Minor	Moderate	Significant	Severe
Very likely	Low-Med	Medium	Med-Hi	High	High
Likely	Low	Low-Med	Medium	Med-Hi	High
Possible	Low	Low-Med	Medium	Med-Hi	Med-Hi
Unlikely	Low	Low-Med	Low-Med	Medium	Med-Hi
Very unlikely	Low	Low	Low-Med	Medium	Medium

Figure 2 Probability and impact matrix for threats (Based on PMI, 2004)

Decision tree

Decision tree is an analysis technique that allows taking more than one risk under consideration at the same time. In order to do this, the technique allows one risk to be dependent on another risk. Therefore, it can be useful in complex scenarios (Potts, 2008). Smith et al. (2006) argue that one important advantage of using a decision tree is that it simplifies the communication of the consequences of a specific choice.

According to Smith et al. (2006), the decision tree method can be handled either as a quantitative or as a qualitative risk analysis technique. This is to be decided depending on the project's complexity. The method is used quantitatively if probabilities are assigned to the technique, and can give indications of the likelihood of a risk, depending on different alternatives or courses. Otherwise, it is used qualitatively (Smith et al., 2006).

Sensitivity analysis

Sensitivity analysis is a quantitative non-probabilistic risk analysis technique, which can be used to explore the effect of economic changes in a project. The main purpose of the sensitivity analysis is, according to Smith et al. (2006), to answer "*what if*" questions concerning isolated key variables and to analyse the impact of the project's objectives from an incremental change of a variable. ISO 31000:2009 claim that the sensitivity analysis is an effective tool, and should be used for all project-based organisations. This type of analysis can pinpoint the critical areas of a project. The outcome from this analysis is often presented graphically on a spider diagram by a plot, which clearly illustrates the sensitive variables for the project that needs further management (Potts, 2008). Smith et al. (2006) recommend that sensitivity analysis should be used in the initial stage for new project where risk analyses have not previously been performed, in order to provide useful information about where the management should focus.

The strength for the sensitivity analysis is that it can illustrate that the same sensitivity variable varies over time. An example of this is if delays for the project only are sensitive until some parts of the project are complete, this will be shown in the plot (Smith et al., 2006).

Smith et al. (2006) claim that there are number of limitations of the sensitivity analysis technique, however the main limitation is that the technique assumes that all other variables remain the same when only one variable is changed. This limitation is also mentioned by Potts (2008) who emphasises the importance of showing caution when changing variables directly to assess the effects from combinations of risks.

3.4.3 Risk response

After risks are identified and the impacts are analysed, the next step in the risk management process is to decide what kind of response to make about each of the risks. During the response stage, new risks can appear, and these secondary risks should be incorporated in to the same risk response plan as the original risks (ISO 31000:2009). Gruneberg et al. (2006) emphasize the importance during the risk management process to consider how frequently a risk is encountered by a particular organisation. If the organisation often manages a particular risk, then it is often more economical to retain that risk instead of paying someone else to take care of it. On the other hand, if the organisation is infrequently responsibly for a particular risk, and therefore does not possess the required knowledge to manage it, it is wise to transfer the responsibility to another party.

Potts (2008) describes four main strategies of response to risks in order to reduce the risk exposure related to a project. These are to avoid the risk, to reduce the risk, to transfer the risk to another party, or to keep the risk without treatment. Bower (2010) argues that most construction risks are controllable by the contractor and should therefore be held by the contractor, independent of whether the project is financed privately or publicly.

Avoidance
If the consequences of risks associated to the project are judged to be significant, then the project's aim has to be revised to decide if the benefit from the project corresponds to the risk exposure. A risk with a too serious consequence can be reason enough to cancel the project (Potts, 2008; Smith et al., 2006). Another option with this strategy is to delay the decision until more information is available, especially for risks with a high impact of occurrence (Winch, 2010).

Reduction
The reduction of risks may include changing the procurement strategies, undertaking more investigations of ground conditions, redesigning the project to avoid, for example, the use of unproven construction techniques (Potts, 2008). This is usually the most suitable response to risks and is preferable done early in the project where the possibilities for change are relative high (Winch, 2010). Smith et al. (2006) argue that by changing some features of the project, it might be possible to reduce the total risk in the project, instead of trying to avoid the risks entirely.

Transfer
One common risk response strategy is to transfer the risk from one party to another, without changing the quantity of risks in the project. The transferring of risks is implemented through the conditions of contracts or by insurance and is usually done in construction projects by: client to contractor, contractor to subcontractor or to insurer (Potts, 2008). However, the transfer of risk can result in higher fees or additional payments for the client. Therefore, the party who best controls the risk should bear it. According to Winch (2010), transfer of risk to another party should only be done if that party is in a better position to manage the risk. Externalising too much risk to a party who cannot handle it can result, for example, in bankruptcy for

that party and consequently a delay for the project. Another argument against risk transfer is that the risk premium that would have to be paid to transfer the risk is larger than the consequence if the risk actually should realise (Smith et al., 2006).

Retention

Some of the risks can preferably be retained within the project. This is usually if the party that is holding the risk is the only party that can manage it, or can accept the consequences if it is realised (Smith et al., 2006). However, when possible, effort should be made to minimize the consequences and the likelihood of occurrence of the retained risk. When accepting a risk, the project should have a budget item to cover the possible impact of that risk (Winch, 2010).

3.4.4 Monitoring

The last event of the risk management process is to monitor the risk through the project's life cycle. According to ISO 31000:2009 and Winch (2010), it is important to define responsibilities for the monitoring of each risk, which is preferably the person responsible for decisions related to that risk. The purpose of this stage is to adjust the probability and impact register according to information that becomes available over time and to remove those risks that have passed the point at which it might have occurred. It is recommended that the monitoring is proceeded as a routine in the risk management process.

4 Construction contracts and risk

In this chapter two traditional procurement options are explained, design-bid-build (DBB) and design-construct (DC). Further, experiences from previous DC projects are presented and finally, performance criterion is explained.

The main difference between DBB and DC contracts is which party is responsible for the design. In a DBB project, the client is generally responsible for the design and the contractor for the production, while in a DC project, the contractor is responsible for both design and production (Lafford et al., 2000).

A construction project is often divided into four main phases, illustrated in figure 3. These phases are programme (brief), design, procurement and production. The first of these phases, programme, is where the client has an idea of what the project should include and a rough picture regarding the project. The next stage depends on which procurement option is chosen by the client, DBB or DC, with the design phase or the procurement phase respectively. The time for start of production differs depending on which procurement route is chosen, often with a shorter time for total completion in DC projects than DBB projects. The main reason for the shorter completion time is that the contractor can start the production before the design is finished (Osipova, 2008).

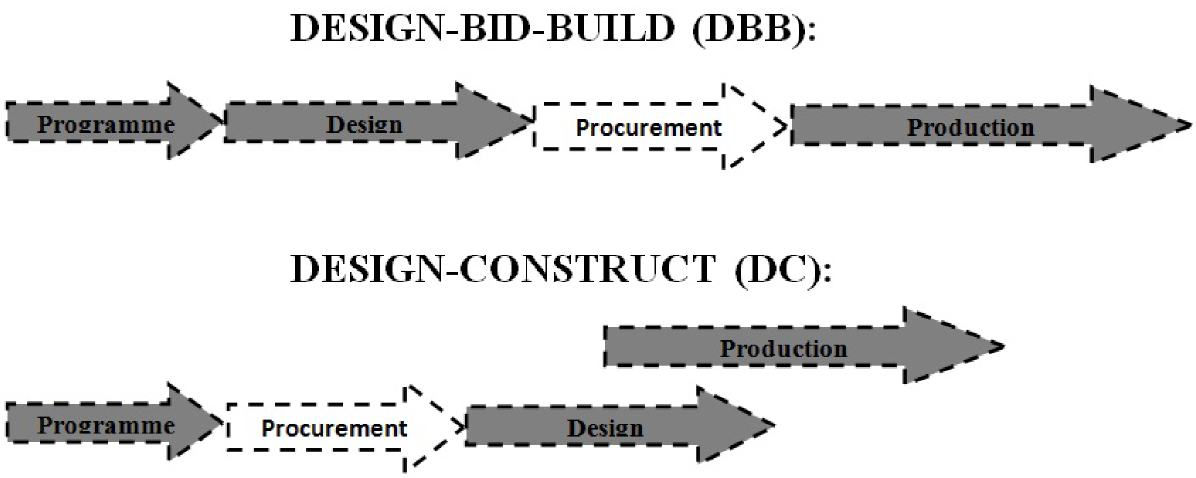

Figure 3 Design-bid-build and design-construct

How risks are shared among the actors in an infrastructure project is strongly related to the procurement option chosen by the client (Lafford et al., 2000). Bower (2010) states that there are three main functions of a construction contract between the client and the contractor, i.e. firstly to define what is to be done and by which party. Secondly, to clarify how and which risks shall be transferred to the contractor and, finally, to communicate an understanding of the projects objectives to the contractor.

According to Bower (2010), it is common that the client lists potential risks in the procurement document; the contractor is required to set a price for each of them in the tender. Therefore, when a risk occurs that is the client's responsibility, the client has to compensate the contractor to resolve the risk event. However, sometimes uncertainties regarding responsibility for a particular risk arise during the project. This can lead to claims from the contractor for additional payments, which sometimes leads to legal penalties (Bower, 2010).

4.1 Design-bid-build

In DBB contracts, or traditional contract as it is often referred to, the client normally has more responsibility and a more significant role compared to when working in DC projects. This is mainly because the client is responsible for the design. The DBB procurement route requires the client to separately appoint a designer to make construction drawings in order to proceed with signing a contractor for the project. After the procurement is finished and a contractor has been chosen, the production phase can start. The client must then manage the communication between the parties throughout the production phase (Murdoch and Hughes, 2000).

There are two main contract strategies to use in DBB, i.e. divided contract and general contract. In general contract only one contractor is signed for the whole production. However, the general contractor can contract sub-contractors if they prefer. The main advantage of a general contract compared to divided contract is, according to Osipova (2008), that the responsibility is often more straightforward and therefore more understandable from the client’s perspective.

Osipova and Eriksson (2011) argue that DBB often requires more effort and resources from the client than DC projects since the client is responsible for the design. Unlike the contractor, whose main responsibility is to execute the project based on provided construction document (Touran, 2008).

4.2 Design-construct

Depending on desired requirements and available resources, the client normally provides only a brief design and performance specification for a DC project. These requirements are described in the procurement document. The contractor is responsible for the final design according to to the requirements in the procurement document. In addition, the contractor is also responsible for the whole production phase of the project (Murdoch and Hughes, 2000).

Potential advantages with DC contracts are cost and time savings, due to improved constructability and possible innovations. Once the procurement phase is finished for the DC project, the contractor starts with the design phase and can be allowed to begin with the production before the design is completed; this can shorten the overall time for the project (Toolanen, 2004). Baynes (2010) describes a significant distinction between DBB and DC projects concerning the geotechnical risks, where in the latter, the contract stage and the agreement of the price of the project often occur shortly after a preliminary investigation of the ground conditions and hence the price is fixed based on limited information. This can result in a bid from the contractor with an excessive risk premium. One of the main advantages with DC, according to Lafford et al. (2000), is that the designer has better access to construction information from the contractor and therefore can get better understanding of what is buildable. This can result in a better design alternative. It has been shown that the clients often choose DC instead of DBB when time and resources are critical for the project. However, the time for procurement is often considerably longer for a DC project than for a DBB (Toolanen, 2004).

Lafford et al. (2000) argue that the greater possiblility to transfer risk to the contractor is a significant factor for choosing DC instead of the more traditional DBB. Typical risks can be e.g. design liability or physical conditions. Bower (2010) also mentions risks such as ground conditions, cost overruns and risk of delays as major technical construction risks that can be transferred by the contract. Lafford et al. (2000) highlight that a consequence of transferring inappropriate risk can be to discourage possible contractors from submit tenders. This can result in receiving only a few high bids or even total absence of bidders. Therefore, a separate traditional DBB contract within the DC contract can be used for some elements of particular risk of the project. An example of such an element can be that the client retains design responsibility for parts of the project (Lafford et al., 2000).

4.3 Experiences from DC projects

One example of a successful DC project is the upgrading of highway I-15 in the United States at Salt Lake City, Utah, before the Winter Olympic Games in 2002. For this project, time was a crucial aspect due to the impending Olympic Games. The client knew that giving up control also meant flexibility to the contractor, which could result in shorter completion time. The Utah Department of Transportation (UDOT) decided to use DC with performance specification rather than traditional contracts or prescribed solutions. In addition, in order to assure a high quality end product, UDOT determined to use best-value considerations rather than low bid in the tendering. The cornerstone for UDOT in I-15 and the use of design oversight program was collaboration between client and contractor, which consequently changed the risk allocation for the client. Hence, the role and the risk management for UDOT became significantly different from a traditional DBB project. An example of the changed risk management regarding reduction of esthetical risks is that UDOT regularly audited the DC contractor’s design quality systems to make sure they performed the necessary checks according to the procurement (Warne and Downs, 1999). On the whole, Warne and Downs (1999) argue that I-15 is a singular achievement in innovation and creativity.

Another example is a study by Ernzen and Schexnayder (2000) who investigated two projects, one DC and one DBB. The study showed that the profit margins were greater in the DC project than in the DBB project. Another positive experience from using DC was that the construction process was less time consuming than with DBB (Ling et al., 2004). However, it should be taken into consideration that the tenders generally are higher in DC projects than in DBB projects, since there is a wider range of responsibility for the contractor. This is mainly because the DC contractor generally has to accept higher risk exposure compared to in a DBB project, due to the responsibility for faults in the design and in the construction (Ling et al., 2004). Hence, the competence of the contractor needs to be higher in DC projects compared to DBB. This is also supported by Bröchner et al. (2006) who explain that these companies have to be clearly structured to be able to manage DC projects.

In a case study by Potts (2003), performed on a DC sewage work project in UK, a key factor to successful risk management was identified to be the compilation of a joint client/contractor risk register with regular reviews and adjustments. The project was carried out during five years with an arrangement where possible profit or loss was shared between the client and contractor. During the project, risks were identified on an unstructured methodology without restrictions. These risks were then listed on the shared risk register, with the aid of a risk matrix, past experience and checklists. The shared risk register was, according to Potts (2003), a dynamic control document that was further developed during the project.

Previous experiences with DC projects show that delays are often related to ground conditions that were not foreseen from the site investigation, according to Lafford et al. (2000). Further, Lafford et al. (2000) recommend a comprehensive site investigation in order to minimize the risks regarding unforeseen ground conditions. In addition, there should be flexibility in the design to allow for variations in the ground. This is also suported by Baynes (2010), who explains that ground conditions cannot be changed, but a proper site investigation can provide the necessary information for overcoming geotechnical risks.

4.4 Performance specifications and performance criteria

The use of performance specification in a DC infrastructure project is a way to ensure that the client's aspect on functionality for the finished construction is fulfilled (Gransberg et al., 2006). Lafford et al. (2000) claim that in order for the client to successfully implement the requirements the project definitions need to be clear for the contractor. Gransberg et al. (2006) argue that performance specification is often misinterpreted and the term performance criterion should be used instead and defines the term as following:

> *"A rule by which the effectiveness of operation or function is judged and its value measured".*

After the project's scope has been defined, the process of defining the performance criteria can start. The first stage for the client is to list the project's performance requirements. If these requirements have more than one technical solution, the client formulates performance criteria for that requirement (Gransberg et al., 2006). However, if there is only one acceptable technical solution for the requirement then it is wise to have it prescribed instead. Bröchner et al. (2006) state that with complex technical issues in a project it is important that the performance criteria are understood by all parties and that the responsibilities with the risks and uncertainty are well defined between the client and the contractor.

Gransberg et al. (2006) claim that there are essentially four different areas of performance criteria that need to be defined in the procurement for a DC project. These are management, schedule, cost and technical. Criteria involving management could for instance be plans to execute the project or seniority on the project members and requirements on experience in the same field or in DC projects. Schedule and cost could be criteria on deadline for the project and price for some part or the whole project. The technical criteria could be requirements for e.g. quality, which Lafford et al. (2000) claim to be necessary to specify for a DC project. Hence, the contractor is primarily motivated by profit and will try to succeed with the lowest quality accepted according to the construction contract. The specification should not only guarantee quality, but also increase the primary stakeholder's value for the product. Therefore, it is important that the contract not only provides assurance that the specification is fulfilled but also motivate the designer and the constructor (Lafford et al., 2000).

Bröchner et al. (1999) indicate that issues of esthetical objectives often are especially difficult to describe by performance specifications. Further, they argue that a project must carefully be reviewed to determine if it is suitable for the project to describe issues such as esthetical objectives in terms of performance specification, due to the scale of the projects objectives and the project's impact on society. Moreover, in ordern to manage and succeed with performance specification, it is essential for the client to invest in competence required to formulate and manage requirements expressed in terms of performance (Bröchner et al., 1999).

5 Risk management within STA

This chapter aims to briefly describe the risk management process in the Swedish Transport Administration (STA). First, the definitions regarding risk management for STA and specific guidelines for DC procurement are presented, secondly the risk management process. Thirdly, the risk management software that is used in STA is briefly described. Fourthly, one risk meeting concerning a single DC project is presented and finally, general observation from STA office in Göteborg is described.

The risk management processes are incorporated with STA operation management. The internal regulations regarding risk management are in accordance with STA strategy for reducing overall negative impacts as well as for seizing opportunities within projects. In addition, the risk management process standard is in compliance with ISO 31000:2009 (TDOK 2010:18).

The internal document TDOK 2010:18 states that risk management is essential in order for STA to successfully plan, monitor/lead and lastly control its activity. The risk management process is lead by the project managers, and they are responsible for ensuring that the routines are followed through (TDOK 2010:18; TDOK 2011:12).

5.1 STA definitions regarding risk and risk management

The definitions regarding risk and risk management are in accordance with ISO 31000:2009, however with further clarification from STA. Risk is defined as the uncertain effect on the specific objective, with the clarification on effect and objective. Effect is the deviation from the expected outcome, which can be either positive or negative. Secondly, objective is clarified as the organisational goal for the specific area interest. In addition, there are two types of risk category within STA. First static risk, which is defined as independent of the activity e.g. fire, vandalism and landslide; secondly dynamic risk which is related to the activity, such as organisational risks. Risk management is defined as the coordinated activities, with regard to risk, in order to control and lead an organisation (TDOK 2010:18). The activities are further explained in chapter 5.3.

5.2 Specific guidelines for DC procurement

The internal document TDOK 2010:29 states that the geotechnical site investigation in a DC project shall be of such extent that risks related to unforeseen ground conditions during production phase are greatly reduced or minimised. It is further explained in the internal documents that a comprehensive investigation will decrease risks for the contractor and therefore result in a lower tender because the contractor does not need to calculate with high risk reserves. In addition, it says that the client, STA, should not provide analysed geotechnical data in the procurement documents. However, in some occasions there may be reasons to provide such material produced for STA to the contractors in the procurement documents in order to facilitate the tendering process, and to decrease the burden in the estimating (TDOK 2010:29).

In the procurement documents, illustrations can be used either to clarify description regarding the construction or explain performance specification or criterion. However, when using illustrations it is important to describe in detail what is requirement and what are illustrations. Thus, the contractor can do inaccurate calculations based on the sketches, e.g. when designing a pillar for a bridge (TDOK 2010:29). According to the internal document TDOK 2010:29 is it more likely that the contractor will use the sketches from the procurement documents as a base in the design phase if they are more detailed.

5.3 Risk management process in STA

The routine regarding risk management process is mandatory for all STA projects (TDOK 2011:12). The overall objective for risk management in STA is to manage those risks that can influence the conditions to achieve set project goals in a manner that is cost efficient (TDOK 2010:163). Risk management is divided into five activities: initial value, risk identification, risk analysis, risk evaluation and risk treatment. The process is illustrated in figure 4.

Figure 4 Risk management process in STA (TDOK 2010:18).

The first activity in the STA risk management process is to determine initial values for the project. This stage is done early in the project and aims to identify risk regarding laws and regulation, stakeholders, client requirements and internal demands that may affect the execution of the project (TDOK 2010:18).

The second activity is risk identification, which uses a formal and structured method consistent with ISO 31000:2009 including action such as brainstorming. The identified risks are given a risk owner that is responsible for supervising the risk. The third activity is the risk analysis and is done according to criteria set by STA (TDOK 2010:18). The criteria for risks are illustrated in table 2 and the criteria for opportunities are illustrated in table 3.

The next activity is the risk evaluation. All risk assessment must take place based on applicable criteria for the consequence areas which have been established by STA. The risk matrix, illustrated in table 2, is used to estimate the undesirable events that may occur. The opportunity matrix, illustrated in table 3, is used to systematically estimate the potential of opportunities (TDOK 2010:163). When risks exceed the consequence area the risk needs treatment, which is the next activity. If the risk is estimated not to exceed the consequence area, then it is monitored during the time the risk can occur. In the final phase, risk treatment, proposed methods of treatment are documented in a risk treatment plan. The risk treatment plan requires cost and treatment to be clarified. Furthermore the proposed treatment needs to be revised regarding opportunities and cost efficient. The decisions regarding risk treatment are the risk owners' responsibility (TDOK 2010:18).

When the five phases in the risk management process are completed it is the risk owners' responsibility to continuously monitor the risk with regards to the decided risk treatment plan and update the risk register. In addition, the project manager is responsible for continuously following up on the total risk management process. Hence, the risk owner and the project manager may differ. When the project is finished there is a handover of risk. The information regarding the handover of risk is included in the final report and represents the actual cost of the risks and treatment, in addition it aims to represents a base for future work with risk management (TDOK 2011:12).

Table 2 Risk matrix with criteria (TDOK 2010:163)

Likelihood/frequency	Extremely high, occurs, (>50 %)	**5**	Moderate	Serious	Serious	Very serious	Very serious
	High, will probably occur, (16-50 %)	**4**	Moderate	Moderate	Serious	Serious	Very serious
	Moderate, may occur, (6-15 %)	**3**	Low	Moderate	Moderate	Serious	Serious
	Low, will probably not occur, (1-5 %)	**2**	Low	Moderate	Moderate	Moderate	Serious
	Extremely low, will hardly occur, (<1 %)	**1**	Low	Low	Low	Moderate	Moderate
			1	**2**	**3**	**4**	**5**
			Very light	**Light**	**Considerable**	**Serious**	**Very serious**
			Consequence/loss/damage/disturbance				
Consequence areas	Customer and brand		Occasional negative media attention	Regional negative media attention	Regional negative media attention on several occasions	National negative media attention	Long-term national negative media attention
	Dependability		Damage with minimal impact on the function of the infrastructure	Damage with an impact on the function of the infrastructure which entails measures	Damage with an impact on the function of the infrastructure which entails significant measures	Damage which entails that it is not possible to use certain parts of the infrastructure	Damage which entails that it is not possible to use the infrastructure
	Health (employees, passengers, road users, third-parties)		Personal injury without sick leave	Personal injury with less than 14 days of sick leave	Personal injury with more than 14 days of sick leave	Serious personal injury resulting in permanent disability	Death
	Environment		Insignificant environmental deviation which does not breach laws and rules	Moderate or temporary environmental deviation which does not breach laws and rules	Moderate or temporary environmental deviation which might breach laws and rules	Permanent environmental deviation which might breach laws and rules	Permanent environmental deviation which breaches laws and rules
	Operations		Event with minimal impact on operations	Event with an impact on operations which entails measures	Event with an impact on operations which entails significant measures	Event which entails that certain parts of the operations do not function	Event which entails that large parts of the operations do not function
	Time		Very short delay, no negative impact on subsequent activity	Some delay, slight negative impact on subsequent activity	Moderate delay, considerable negative impact on subsequent activity	Long delay, large negative impact on subsequent activity	Very long delay, very large negative impact on subsequent activity
	Finances		<MSEK 10	MSEK10-50	MSEK 51-100	MSEK 101-200	>MSEK 200

Table 3 Opportunity matrix with criteria (TDOK 2010:163)

Likelihood/frequency	Extremely high, occurs, (>50 %)	**5**	Moderate	Large	Large	Very large	Very large
	High, will probably occur, (15-50 %)	**4**	Moderate	Moderate	Large	Large	Very large
	Moderate, may occur, (6-15 %)	**3**	Small	Moderate	Moderate	Large	Large
	Low, will probably not occur, (1-5 %)	**2**	Small	Moderate	Moderate	Moderate	Large
	Extremely low, will hardly occur, (<1 %)	**1**	Small	Small	Small	Moderate	Moderate
			1	**2**	**3**	**4**	**5**
			Very low	**Low**	**Moderate**	**High**	**Very high**
			Potential/gain/benefit/improvement				
Consequence areas	Customer and brand		Occasional positive media attention	Regional positive media attention	Regional positive media attention on several occasions	National positive media attention	Long-term national positive media attention
	Dependability		Minimal improvement of the function of the infrastructure	Considerable improvement of the function of the infrastructure	Improvement of the function of the infrastructure	Improvement of certain parts of the infrastructure	Improvement of large parts of the infrastructure
	Health		Eliminated personal injury without sick leave	Eliminated personal injury with less than 14 days of sick leave	Eliminated personal injury with more than 14 days of sick leave	Eliminated personal injury resulting in permanent disability	Saved lives
	Environment		Insignificant environmental improvement	Moderate or temporary environmental improvement with large environmental debt unless implemented	Moderate or temporary environmental improvement with small environmental debt unless implemented	Permanent environmental improvement with large environmental debt unless implemented	Permanent environmental improvement with small environmental debt unless implemented
	Operations		Event with minimal impact on operations	Event with an impact on operations which saves measures	Event with an impact on operations which saves significant measures	Event which entails that certain parts of the operations function better	Event which entails that large parts of the operations function better
	Time		Very small saving, no positive impact on subsequent activity	Small saving, slight positive impact on subsequent activity	Moderate saving, substantial positive impact on subsequent activity	Large saving, large positive impact on subsequent activity	Very large saving, very large positive impact on subsequent activity
	Finances		Potential saving <MSEK 10	Potential saving MSEK 10-50	Potential saving MSEK 51-100	Potential saving MSEK 101-200	Potential saving >MSEK 200

5.4 Risk management software

The risk management software that is used in STA allows for documentation of identified project risks and the determined treatment. The risk management processes for the software are in accordance with the process illustrated in figure 4. Furthermore, the risk management software allows for visualisation of the project’s exposure to risk, hence a basis for monitoring of risk. The purpose regarding the risk management software in STA is that the documentation and visualisation of risk will improve the life cycle perspective for a project. Moreover, it will give the organisation a common approach to the risk management process and as a result help the project managers with managing the risks that are in different geographical areas.

The manual version 2.2 for the risk management software used in STA states that the risk analysis in the risk management software is done according to the common criteria illustrated in table 2. Each risk identified in the software is evaluated with regard to time, functionality, health, environment and customer and trademark. Secondly, the probability for the risk and the cost is set according to table 2 and is used for the whole risk. Thirdly, the date when the risk falls out is set.

The risk management software allows the users to have privileges within the software for a project. The different privileges in the risk management software are:

- **Identifier of risk** can create new risk within the project and edit those risks. However, this privilege does not allow access to information that is not created by this person.
- **Supervisor of risks** can manage and change all the identified risks and the risk treatment plan for the project but nothing else. This privilege allows for access to all the information regarding the project.
- **Risk owner** has the privileges to create, modify or remove all the identified risks in the project.
- **Risk leader** has the same privileges as the risk owner but in addition can modify information regarding the project or change the privileges for the people in the project.
- **Manager of the organization** has the right to modify the organizational structure and the structure of the privileges. This person can also modify or remove entire projects.
- **Risk analyst** can read information regarding the project and the risks but cannot edit or create any new risks.

The risk management software allows for more than one of these privileges Identifier of risk, Risk manager, Risk owner and Risk leader to be allowed for one person in a single project. For instance, if a project member is given the risk owner privileges that member will also receive the risk treatment privileges and the identifier of risk.

5.5 Risk meeting

Most projects within STA have an initial risk meeting in the beginning of a project. The authors of this report had the opportunity to participate in one of these, which was for a middle size DC project run by STA. The meeting was chaired by two risk managers from STA who were responsible for leading the discussions forward and for formulating the initial risk register for the project.

The main purpose of the meeting is to identify and analyse as many risks as possible from different perspectives to generate a comprehensive risk register for the project managers to continue to work with. In order to get a wide perspective, the invited participants had different areas of expertise, e.g. environmental, structural engineer, geo hydrological, construction contracts, civil engineers and two project managers from STA responsible for the project. Most of the participants were external consultants. The meeting was divided in two parts where the first was dedicated for risk identification and the latter for analysing the identified risks.

The meeting started with a short presentation by the risk managers about how STA shall work with risk management. They further explained that this practice of work is based on the international ISO 31000 standard, and that the risk identification is performed as a brainstorming. The participants first got some time to write down as many risks as possible including the information: what kind of incident, the reason for the incident and what impact on the project the risk could have if it occurs. Most of the participants had a long list of risks after half an hour when the risk managers decided to proceed to next stage i.e. create a risk register. This was a process where participants shared their risks. Approximately 40 different risks were identified and documented in the risk register during the morning session.

During the afternoon, the identified risks were analysed by the participants. The analysis of risks was done through a qualitative approach where the organization relied on the participants' experience. This stage was more difficult and consequently more time consuming. As a result, only half of the identified risks were analysed. After this meeting it was the projects managers' responsibility to complete the risks analysis of the remaining risks and proceed with the risk management process.

The authors' experience of this meeting was that it was unclear for the participants how to evaluate and calculate the likely impact of these risks if they occur. Furthermore, the participants had difficulties in separating different risks when estimating the monetary impact. For example, environmental risks were connected to other risks and therefore calculated more than once. Moreover, the participants showed frustration when analysing some of the risks with more than one impact on the project, e.g. environmental, time and cost. The authors' general view from the meeting was that the participants did not share an aligned view when it came to estimating risk costs, however, they showed engagement in risk management and in the meeting in general.

5.6 General observations from STA

The authors of this report had the opportunity to perform this study at the STA main office in Göteborg during the spring of 2013. This allowed the authors to conduct general observations on the employees and in-house consultants, mostly project managers working with both DC and DBB projects. A great interest in risk management was perceived at STA since it is a common subject to discuss during, for example, coffee breaks. It can also be seen that many of the employees and consultants work daily with risk management within their projects.

According to our observations, it is a common opinion among employees and in-house consultants that this change to increased volume of projects procured as DC causes uncertainties regarding how to manage risks within these projects. This opinion is predominant among those working mainly with railway projects. Many of them argue that it is often not suitable to use this procurement route in railway projects due to the comprehensive governing safety regulations and that prescribed solutions are required in order to fulfil these regulations.

General observations from STA indicate that risks are often referred solely to the negative consequence of an event. This can be seen among both the interviewees and others within STA.

6 Risks in three projects

In this chapter, the three projects investigated in the thesis are presented. Furthermore, findings from interviews are presented and divided into the risk categories of particular interest in DC projects, the respondents' attitudes towards risk management and the respondents' opinion towards the risk management software used at STA.

6.1 The projects

The organization of STA is divided into six geographical regions in Sweden, see figure 5. In this study, three projects are investigated from two regions. Project 1 is located in the Region Väst and Project 2 and Project 3 are located in Region Syd. A brief description of each project will be presented in this section in order to provide the reader with some background information, which will make it easier to follow the discussions in chapter 7.

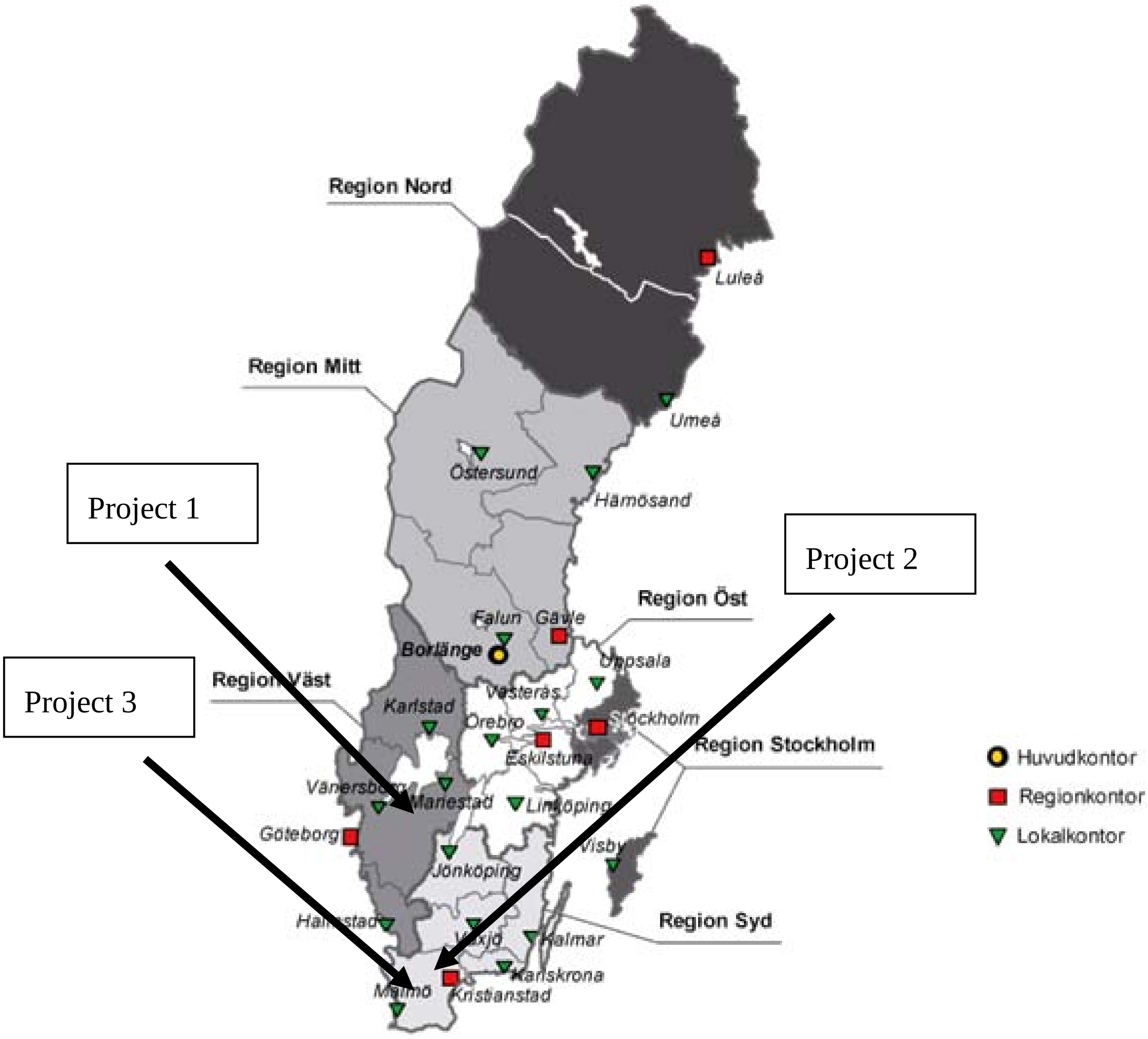

Figure 5 Location of the three studied projects (Svensk kollektivtrafik, 2009)

6.1.1 Project selection

Each project for this study was selected from the criterion that it had to be a DC project, which preferably was in the production phase or would be in that stage soon. Another criterion was that all projects for this study were to work with risk management according to current guidelines of STA. Therefore, the projects for this study had to be rather newly started due to changes in guidelines in April 2010 (TDOK 2010:18).

6.1.2 Project 1

Project 1 consists of a 6.2 km new road section of the route 27 between two small communities close to the city of Borås. Due to the project's geographical location, it is run by STA Region Väst, see figure 5. The new road will be built with a higher capacity and with a greater safety. In addition, the new road section will be shorter because of decreased curves. According to STA, this new section will be built through a sensitive environmental area that has never been built before. Therefore, two different passageways for animals will be built over, respectively under, the road. During the writing of this report, the project was in the late procurement stage. The contractual sum for Project 1 is 211 MSEK.

6.1.3 Project 2

The second project investigated in this report is the development of the European Highway 22 (E22) through Skåne, in the southern part of Sweden. This highway project is divided into a number of sections. This report focuses on a 4.7 km part procured as DC, here referred to as Project 2. However, the interviewed project manager for Project 2 has been highly involved in two other adjacent parts of E22, also procured as DC. These other parts started earlier and are now completed. Therefore, experiences gained from these projects will also be considered for this study. Project 2 is in the middle of the construction stage during this study and is estimated to open for traffic in December 2013. The contractual sum for Project 2 is 190 MSEK. The project consists of construction of mainly new road, but some part of it is upgrading of the existing road. The project includes three bridges, a new walk and cycle path and noise barriers.

6.1.4 Project 3

The third project is also located in Skåne, although on a smaller road named route 108. Project 3 consists of widening of an existing road in order to provide two separated traffic lanes in each direction. The length of the road section for this project is 5 km, and is procured as DC with elements of DBB for the existing road. The contractual sum is 103 MSEK. This project is at the time for of this study in an early construction stage, and the road shall be open for traffic in July 2014.

6.2 Risk categories of particular interest in DC projects

Findings from the interviews are divided according to the chosen risk areas: Geotechnical risks, Esthetical risks and Environmental risks. Additional risk areas and the interviewees’ attitude towards risk management as well as their view on the risk management software will also be presented in this chapter. The following abbreviations will be used to identify the person interviewed:

- PM1=Project manager, Project 1
- PM2=Project manager, Project 2
- PM3=Project manager, Project 3
- CM2=Construction manager, Project 2

6.2.1 Geotechnical risks

Geotechnical risks are risks from the geotechnical site investigation, e.g. analysis of data from the investigation and interpretations from both the client and the contractor. All the interviewed project managers confirmed that the geotechnical risk category is of particular importance in a civil engineering project. For instance, PM3 argues that this area is the risk area with the greatest financial impact. However, each of the studied projects had good geotechnical conditions without any considerable problem so far, and the managers do not think it will become a significant problem in these projects.

PM2 argues that it can be a problem with data interpretation from the geotechnical investigation that is provided by STA. In the studied projects, all the contractors who are tendering have to analyse data given from STA, even though PM2, CM2 and PM3 advocate, that STA should do the analysis of the geotechnical investigation. In contrast, PM1 argues that STA should definitely not provide analysed geotechnical data to the contractor. He claims that the risk for the client would be higher though STA would be responsible for the accuracy in the analysed geotechnical data in possible upcoming disputes.

PM3 explains that the result of a geotechnical analysis often depends much on the person behind it. If the contractor does not have the same description of the ground conditions in the procurement as the client, it often leads to higher risks for STA in disputes: PM2 states that it may be more difficult and time consuming to negotiate. PM2 and PM3 say that in their experience from previous DC projects this was a problem, and that they would definitely recommend that STA provide analysed data for future projects. They further explain that if STA instead provides analysed data, all the contractors will have the same analysis of the ground conditions. Hence the process through the project will be smoother with fewer disputes since all are using the same interpretation regarding the geotechnical conditions. Nonetheless, according to the internal policy of STA, analysed geotechnical data shall not be provided to the contractor. However, PM3, PM2 and CM2 argue that by providing the contractor with analysed data, the geotechnical risk is reduced for both the client and the contractor.

All of the interviewees emphasize the difficulties when deciding the extent of ground investigations that will be performed. On the one hand, you want to investigate as much as possible to reduce the risk of contingencies related to ground conditions. On the other hand, investigations are expensive and should be performed in moderation. PM3 explains, moreover, that he decided the extent of the geotechnical investigations in his project, although with consultation from internal expert support. However, he explains that according to STA policies it should be the consultant’s assignment to decide the extent of the investigation. PM3 further expresses concern with this since there is a risk that the consultant will decide to perform an unnecessarily comprehensive investigation because that person invoices per hour.

PM3 clarifies that it is considerably easier to use DC when building new roads than it is to use DC for widening and upgrading an existing road. In addition, PM3 explains that it is particularly difficult to describe the current conditions of the road that is about to be rebuilt, which consequently leads to more disputes between contractor and client. In his project they tried to solve this problem by splitting the project into elements of both DC and DBB where the latter is mainly applied to parts where it has been difficult to describe ground conditions and the road structure. Another reason to use this approach was to retain risks of unforeseen ground conditions for the existing road in order to receive more and lower tenders. However, PM3 says he would never do it again. This divided contract has led to many disputes and confusing discussions, often regarding the vague border between the DC and DBB project. He further argues that if he could redo it, he would have done more investigations of the current conditions for the road and procured the whole project as DC.

PM3 also mentioned the slope expansion of the existing road when widening the road as a risk that was underestimated from the start of the project. He stated that this is especially difficult because of the DC procurement route, where the responsibility for this issue is unclear.

In the tendering documents for Project 1 it is written:

> *”5 days before the concreting of the bridge foundation, the client shall be informed for an inspection.”*

This is, according to PM1, a way to reduce the risk of a future problems, for example, if the contractor is trying to do the concreting when the ground still is frozen, which can result in future subsidence when the ground is thawing. If the client sees this early, they can reduce the risk by telling the contractor to wait. PM1 further explains that although construction defects are the contractor’s responsibility in a DC, it is STA that most likely will get bad publicity for the faults.

PM3 explains that in order to reduce the geotechnical risk in his project they have asked the contractor to continuously excavate test holes during the project for early detection of deviant ground conditions compared to the data from the tendering. This is also an advantage both for the client and for the contractor as they can redirect resources in case of a production stop.

6.2.2 Esthetical risks

Esthetical risks include risks that the client will not receive a satisfying end result with the project and the contractor’s interpretation from the design. All of the interviewees agree that if the esthetical objectives of projects are not properly described in the tendering documents in performance terms or as prescriptive, it is possible that STA will not be satisfied with the end result. PM3 further explains that in many DC projects within STA the design objectives are described nearly as in a DBB project, which he thinks is wrong. He further argues that this detailed description generally increases the esthetical risk. For this reason, PM3 argues for transferring more design responsibility to the contractor for the whole project, instead of describing in detail everything the contractor shall do. Therefore, the allocation of responsibility to contractors is clearer, and PM3 further argues that this should reduce the risk for STA.

Although PM3 argues for more design responsibility to the contractor, he explains that a detailed design program has been used in his project to communicate the esthetical objectives of the project. He expresses a great deal of uncertainty whether this was a good way of managing the esthetical objectives or whether it was too detailed for a DC project. Since the construction work has not started yet in this project, he does not know the risk outcome for the detailed design program. Moreover, he explains that he is unsure concerning how this design program should be understood contractually. That is, if the contractor should build exactly according to the program or if it instead should be understood as an indicator of project design intentions. He admits that this certainly is a project risk that needs to be managed. PM3 further explains that:

> *"We are all inexperienced in DC projects, and this is in a way an experimental project for better DC project management in the future."*

In Project 2, there is also a detailed design program, but it has been decided within the project team not to use this program in the procurement. Instead, the project team have integrated parts of this detailed information with performance specifications in the technical procurement documents. However, PM2 mentions that for some parts of the project, for example the bridges, the design is managed as in a DBB project while for other parts it is the contractor who is responsible for the design.

In Project 1, the esthetical objectives are described by performance specifications, but with some exceptions. One of these is a bridge where design is described in a high level of detail. PM1 explains that it was possible to give the contractor a high level of design control for most of the project due to the limited number of stakeholders close to the road.

PM1 does not think the esthetical risk is particularly high in Project 1, although it could be expensive if STA interferes and wants design changes during the project. Further, he says that there is a risk of dispute because the design specification is difficult to formulate. To reduce these risks, Project 1 requires that the client shall be given the opportunity to have inspections after e.g. blasting of rock to view if the design is pleasing. The client shall then decide in cooperation with the contractor how to continue. PM1 explains that this is not really the idea of a DC project. However, he is unsure about how to formulate some of the esthetical aspects of the project with performance specifications, without steering the contractor too tightly.

PM2 has experience from a previous DC project where a dispute occurred regarding an esthetical aspect which STA was unsatisfied with. Here, the contractor claimed they had fulfilled the performance specification and therefore fulfilled the contract. This ended up with STA having to pay for the modifications. Therefore, PM2 argues for the use of DBB in the esthetical parts of a DC project in order to reduce the risk for costly changes. PM2 further explains that although this category of risk is complicated, the financial consequences are much smaller than for geotechnical risks. All the interviewee's claim that contractors generally do not put more effort in the esthetical part of the project than the minimum required, i.e. what is described in the tendering document. All the project managers furthermore agree that it can be difficult to avoid steering the contractor in the esthetical aspect. PM2 moreover explains that a consequence of steering the contractor strictly in order to reduce the risk can require a larger design group within STA, which is contradictory to STA's ambition when using DC instead of DBB.

PM3 mentions stakeholder issues when explaining why they cannot give the contractor greater flexibility in the esthetical design, and in particular regarding bridges. This is because STA has to announce a work plan in advance to show stakeholders what shall be built. He further explains that if the product differs distinctly from the design previously communicated to the stakeholders, the risk of appeals against the project is high. This can delay or even stop the project. PM3 thinks this is going to be a problem in future projects, if it has not already occurred. This view is, however, not supported by PM2, who claims that it should be possible to give the contractor much more design flexibility. He further argues that this could result in savings for STA due to possibilities of innovations. Both PM3 and PM1 argue for lower esthetical ambitions regarding, for example, bridges or when it comes to low priority roads like in Projects 1 and 3. They further argue for more standardized bridges, which could bring benefits for both the contractor and the client.

6.2.3 Environmental risks

Environmental risks include risks with laws and regulations that the contractor will not fulfil but also risks of delays that are caused by environmental permits. All project managers say that the environmental area does not generally contain additional risks in a DC project compared to a DBB- project, although it can be a problem if STA is too quick to procure a contractor for their project. Hence, this can lead to environmental permits that are not properly handled, with possible delays later in the project as a consequence. For this reason, PM1 argues that it should be the client's responsibility to handle the environmental permits in a DC project, which is typically the clients' task to solve, but also since the contractor often does not have experience enough for this task.

In all of the studied projects, a detailed environmental control program is attached to the procurement documents, which the contractor has to follow during the project. All project managers think this is a good method for DC projects, despite the fact that this procedure does not differ from a DBB project. PM1 argues that a future intention for a DC project should be to let the contractor take more responsibility over the environmental area. However, he argues that there is a high risk in implementing this major change so fast. PM1 explains that STA has been a client with high level of control for a long time, and that immediately transferring this control to the contractor implies a high risk.

PM1 mentions that one environmental risk that was identified early in the project became realized, endangered wild bees. This can lead to problems in the time schedule for the project, due to the need for a comprehensive inventory of these bees. PM1 expresses concern about how this will affect the project and what kind of compensation measures they might have to carry out. He further explains that they started the inventory prior to the procurement, which would not have been possible to do if the whole environmental responsibility and control were transferred to the contractor, which is recommended by STA. However, PM1 claims that this risk would have been the same regardless if the project were procured as a DBB or DC.

6.2.4 Additional risk areas

Areas of additional risk vary between the persons interviewed depending on their experience. Firstly, PM3 mentions the operation phase of the road as an essential part of the contract where it is important to be clear in order to minimize risks of disputes during the warranty time. Moreover, PM2 explains that it has been the contractor's responsibility to formulate a prescription for the operation phase regarding maintenance to STA. PM2 claims the contractor has seen this as a loophole in the contract and taken the opportunity to formulate an unreasonable prescription of maintenance that STA almost certainly cannot satisfy. As a consequence of this, the contractor can claim that maintenance prescription has not been followed if there is a warranty dispute in the future.

PM1 and PM2 mention concern regarding engineering risk, such as whether STA has specified a bridge that is unfeasible for the contractor to build. For instance the criterion or prescription could be wrong and the contractor cannot proceed according to what is decided, which could lead to additional cost for STA.

Uncertainty with the documents such as the work plan could be unsatisfactory when the production phase starts. PM2 mentions the surrounding area to the worksite could be too small which can lead to insufficient space for the required slopes. During this phase, negotiating with the landowners could be difficult, which is STA's responsibility to solve. PM2 further explains this problem often is a result of the lesser possibility that STA have to review the design documents in a DC project compared to in a DBB project. PM2 states that these mistakes in the tendering documents have a larger impact when using DC compared to DBB. PM2, however, notes that an explanation for these errors may be that consultants have an objective to minimise the environmental impact of the project, which often leads to a tight work plan that does not fulfil the requirements in the production phase.

It is a common view of all the interviewees that contractors often have more legal resources available to examine the tendering documents for errors which they can take advantage of in disputes. This is a risk that needs to be managed. CM2 emphasizes the importance of a thoroughly prepared tendering document and contract to minimise this problem.

6.3 The respondents' attitudes towards risk management

The respondents' attitudes towards risk management were explored by questions concerning how they feel about working with risk management and what significance it has in their daily work. All of them agreed it is an important part of their work as project managers and they are mainly positive to risk management. In addition, all of them consider that it has been an increased focus the last years on risk management and especially on a more systematic execution. However, PM1, who has a recent background as a contractor, argues that although they work more systematically with risk management now, he still does a lot of risk management every day without writing it down on paper.

6.4 Risk management software

Both PM2 and PM3 state that the risk management software used within STA, is suitable for the purpose in risk management. However, PM3 mentions a problem – that the total calculation of the risks cost in general is too low. He claims this is a common problem in most projects. PM3 further explains that in his project, the total risk calculation was approximately 5 per cent of the contract sum. It should be closer to 10 per cent instead, which he thinks is the common outcome of a project. According to PM2, this problem with a risk calculation that is too low is one reason why he does not use the risk management software to the extent that he should. He explains that his trust in this tool has decreased due to this incorrect calculation.

PM3 and PM2 mention another problem with risk management within STA, which is not directly related to the software tool. That is the knowledge level on risk management. He claims it is not enough with only one day of training in the risk management software to be able to analyse risks. The consequence is that perception differs too much, which reflects in the quality in the risk register.

PM3 and PM1 mention that it would be helpful to be able to share the risk register, excluding the calculated risk reserve, with the contractor and manage these risks together. Nevertheless, PM3 thinks that it is a utopian dream due to the public procurement act.

7 Analysis and discussion

This chapter presents an analysis of the findings from the performed study, and discusses and compares the findings with the theories presented in Chapter 3 and Chapter 4 as well as the internal documents from Chapter 5.

7.1 Observations

This section is divided into two parts containing general observations from STA followed by an analysis from the risk meeting that the authors had the possibility to take part in. In this section an analysis will be given of how the organization works in practice, and attitudes towards risk management.

7.1.1 General observations

The findings from the general observations within STA show that many of the employees and in-house consultancies work daily with risk management in their projects. Further, many of them show hesitance regarding how to manage risks in DC projects, and especially in railway projects. The observations indicate that it is a common opinion that most railway projects should not be procured as DC because of their special features. Due to these findings, further investigation is recommended regarding which projects should be procured as DC.

The results indicate that most employees and in-house consultants regard risk solely as the negative effect of an event. This finding corresponds with other studies in the same subject (Winch, 2010). However, the internal documents, which are based on ISO 31000, state that risk management within STA shall reduce the overall negative impact as well as seize opportunities within projects. This lack of focus on opportunities can lead to risk with a positive outcome to be neglected or not treated in a systematic manner.

7.1.2 Observations from risk meeting

Smith et al. (2006) argue that one key factor in the risk management process is to gather key personnel whose sole purpose is to discuss and evaluate project risks. This is also supported by ISO 31000. The finding from the observation corresponds to this statement where team members with a wide variety of competence participated in the initial risk meeting. However, most of the participants in this meeting were external consultants, and the majority of them had no or little experience with STA internal risk management process.

Two specialized STA risk managers chaired the risk meeting, which is also recommended by Smith et al. (2006), who further state that the risk managers are responsible for extracting the necessary information from the participants.

The risk identification in the risk meeting was performed using brainstorming technique in order to identify project risks, where all participants were asked to individually write down as many risks as possible from their individual experiences during thirty minutes. This method corresponds to the risk identification process described by Smith et al. (2006). However, PMI (2004) recommends the use of a detailed list of risk categories, which can contribute to the effectiveness and quality of the risk identification. In addition, it can enable a more systematic identification process. This list of categories can preferably be based on experience from previous projects (PMI, 2004). Therefore, we recommend STA to develop a detailed list of risk categorise as a support tool in the risk identification process.

The risk analysis was performed using a qualitative approach, where the organisation relied on the participants' experiences. This approach corresponds to the qualitative method described by PMI (2004). Further, Smith et al. (2006) argue that the primary aim with the qualitative method is to produce a prioritised risk list with the most negative impact as a basis when determining if a specific risk needs further treatment.

The risk meeting's moderator explained that the risk management process is an ongoing process throughout the project's life cycle and that the project managers are responsible for its continuous work after this initial meeting. This corresponds to Potts (2008) who further argues that risks are constantly changing and therefore the risk management process should be performed as an iterative loop.

The authors' experiences from this risk meeting were that it was unclear for a majority of the participants how to evaluate and calculate the likely impact of a particular risk. It is clear that the participants lack an aligned view towards how to analyse risks. In order to establish a common view we recommend further effort in developing clear objectives regarding the analysis of risks. More internal risk management education in the used technique during the analysis of risks is advocated by us. However, it should be mentioned that most of the participants were external consultants, and this could be a reason for the explained problem. Therefore, we think that external consultants that are team members also should be included in the education. As a result, such education should enable the risk meetings to be more efficient and to increase quality of the analysis.

7.2 Geotechnical risks

Results from the interviews and the literature indicate the geotechnical risk category is of particular importance in a civil engineering project. In fact, one of the interviewed project managers states that geotechnical risk is the risk category that has the greatest financial impact for a project, which often is a reason for delays or cost overruns in infrastructure projects. This is also supported by Lafford et al. (2000) who demonstrate that delays are often related to ground conditions that were not foreseen from the site investigation. In addition, Lafford et al. (2000) argue that a comprehensive site investigation is needed in order to minimize the risks regarding unforeseen ground conditions, and that there should be flexibility in the design to allow for variations in the ground. However, all of those interviewed emphasize the difficulties when deciding the extent of the ground investigations for a project, due to the high cost of such investigations.

Furthermore, almost all of the respondents recommend, based on their experience, that STA should analyze the geotechnical data from the ground investigation for the procurement document in order to reduce geotechnical risks. An argument for the client to analyse geotechnical data is, according to Bröchner (1994), that the client often has more information about site conditions than can be seen from documents submitted to tenderers. The results from interviews show that one reason for several complicated and time consuming discussions was the absence of analysed geotechnical data given to the contractor. According to the respondent, many of these disputes probably could be avoided if STA had provided the contractor with analysed data. Therefore, the respondents strongly recommend that STA provide the contractor with analysed data in future projects; however this is not aligned with how STA is supposed to work according to the internal documents, which state that it is the contractor's responsibility to analyse this data. This statement causes a conflict between what most of those interviewed want and what the internal document says. The background for STA's decision not to analyse the investigations is probably because they want to reduce the risk of future disputes and delays concerning incorrect analysis of the ground investigation. This approach is also supported by Bower (2010) who recommends transferring risk to the contractor through the contract in order to reduce the risk of cost overrun and delays.

However, one of those interviewed thinks that it would be a greater risk for STA if STA is responsible for the analysed data, because they then are responsible for the interpretation. The reason not all of them agreed on analysing the data could depend on the different experience they have towards working in DC projects, but also due to their belonging to different geographical departments within STA.

Lafford et al. (2000) claim that when parts of a DC project are perceived as particularly risky and therefore are estimated to result in high bids, those parts could be performed as a DBB within the main DC project. Our findings illustrate an example of this in one of the projects where parts of the existing road were procured as DBB and all other parts were procured as DC. This was done mainly in order to reduce the contractor's risk related to unforeseen ground conditions and uncertainty of the road's underpinning, in order to receive more and lower tenders. This method also corresponds to the theory on retention of risks, that the party that is holding the risk is the only party that can manage it (Smith et al., 2006). In this example, it can be argued for this way of retaining this risk instead of transferring it to the contractor even though the contractor does not have enough information about the existing road; letting the contractor retain the risk would probably lead to fewer and higher bids. However, the outcome from this project indicates that this divided contract led to many difficult discussions and disputes. Therefore, PM3 strongly advises against the use of DBB for parts of a DC project. On the other hand, the respondents claim themselves to be inexperienced in DC projects, and that this project was a kind of an experimental project. Therefore, it can be discussed that despite the problem with DBB within the DC project explained above, it can be a solution for some DC projects within STA.

The findings indicate that there are uncertainties within STA regarding how much control should be transferred to the contractor in a DC project, although on most occasions this is thoroughly described in the internal documents. An example of this kind of conflict in how one of the projects retains some control from the contractor can be seen in Project 1 where the contractor is required to invite STA for an inspection before concreting of the foundation of the bridges. The reason for this inspection is explained that risks of faults in the final bridge can be reduced by this inspection. Further, it is explained that these possible faults would be the contractor's responsibility, however, STA recognise that it is STA that will receive bad publicity in media. This finding corresponds to the risk response method reduction (Potts, 2008). The findings generally indicate that most of those interviewed have difficulties regarding the transfer of control to the contractor.

An attempt to reduce the risk of production stop caused by unforeseen ground conditions can be seen in Project 3, where STA asked the contractor to continuously excavate test holes to achieve early detection of deviation in exciting ground conditions compared to the performed investigations. Potts (2008) also argues for undertaking more ground investigations if the risk is considered to be high. An example of how to reduce the risk of unforeseen ground conditions in a cost effective approach during the project can therefore be to ask the contractor to continuously excavate test holes. However, it may not be feasible for all DC projects, and it requires good relations with the contractor.

7.3 Esthetical risks

The findings from the performed study indicate that design programmes need to be detailed in the procurement document in order to guarantee that the client will be satisfied with the project's end result. Lafford et al. (2000) argue that the contractor is primarily motivated by profit and will try to succeed with the lowest requirements according to the contract. This corresponds to one of the respondent's statements that the contractor generally does not put more effort than the minimum regarding the esthetical objectives.

One way to reduce risks regarding the esthetical objectives can be seen from the successful DC project I-15 where the Utah Department of Transportation (UDOT) regularly audited the DC contractor design quality systems in order to make sure they performed the necessary checks in accordance with the procurement. A similar approach can be seen in Project 1, where STA shall be given the opportunity to have inspection after e.g. blasting of rocks to view if the design is pleasing. The client shall then decide in cooperation with the contractor how to continue. PM1 states that this is not aligned with the idea of DC projects, but argues that the esthetical objectives are hard to describe in the procurement document without steering the contractor too tightly. He further argues that this risk is of such magnitude that it needs to be controlled by STA.

The results indicate that the usages of DBB within DC projects regarding the esthetical objectives may be preferred. Experience involving a dispute between STA and the contractor shows the difficulty in describing the performance specification clearly for all the involved parties regarding the esthetical objectives for a project. The disagreements that resulted from the dispute were that STA was not satisfied with the esthetical aspect for the finished project while the contractor claimed they had fulfilled the performance specification according to the contract and were not obligated to do the additional work. The dispute ended with STA having to pay for the modification. Lafford et al. (2000) argue that a separate DBB contract can be used within a DC project in order to reduce risks, which we think can be suitable for some projects.

A major part of those interviewed state that by describing the design in excessive detail, STA increases the esthetical risk rather than reducing it. The respondents argue for transferring more responsibility to the contractor; thus allocation of responsibility becomes clearer. Lafford et al. (2000) state that the contract should not only guarantee quality, but also increase the primary stakeholder's value. Therefore it is important that the contract not only fulfils the performance specification but also motivates the designer and the contractor.

The results indicate stakeholders as an issue, and a reason why the contractor cannot receive comprehensive flexibility in the design. STA has to present a work plan to the stakeholders regarding the design of the product. PM3 argues that if the finished design differs distinctly from the work plan, the risk of appeals is high. However, the majority of those interviewed argue for lower esthetical ambitions when it comes to low priority roads such as Project 1 and Project 3, or low priority bridges.

7.4 Environmental risks

Results from the interviews indicate that the environmental risk category does not in general represent particularly difficult risks to manage in a DC project in comparison with a DBB project. However, this is most likely because all the studied projects handle environmental risks in almost the same manner as they do in a DBB project.

The reason for this is explained by the respondents to be that they believe the contractor generally does not have the knowledge required to take the whole environmental responsibility. Bower (2010) claims that it should be the party that best can control the event that should be given the control. Today, STA is in a better position to manage these risks due to their great experience in managing environmental elements of a project. Nevertheless, we believe that the contractor should be given the possibility to take responsibility for environmental risks in future DC projects. Otherwise, there will never be a change in who is best able to manage them. This statement is supported by the interviewees who explained that they strive to transfer more environmental risks and responsibility to the contractor in the future, but they believe it is a high risk to implement this change too fast. The respondents further explained that regardless of whether or not STA would transfer all the environmental risks to the contractor, the risk for bad publicity still remains for STA. This statement is in some way true, although it is a risk that can be handled by being clear about responsibility and to communicate this to all stakeholders.

An argument against the transfer of environmental responsibility and risks to the contractor can be seen in Project 1, where endangered wild bees appeared in the area for the new road. These bees were seen as a risk that could cause delays in the time schedule for the project, possibly resulting in extra costs. Due to the retained environmental responsibility and control, STA had the opportunity to start the inventory before the procurement. This approach decreased the risk of delays for the project because of the early action, which would not have been possible if the environmental control had been transferred to the contractor.

7.5 Additional risk areas

During the interviews, two additional risk areas were mentioned that the respondents thought should be given attention. These were firstly a problem regarding maintenance of the completed road build as DC. Due to an experience from PM2, the contractor was given the responsibility to formulate the prescription for the operation phase regarding maintenance to STA. In this case, the contractor saw this as a loophole to take advantage of. The result has been that the contractor has formulated an unreasonable prescription of maintenance that STA cannot satisfy. Therefore, there is a major risk that the contractor will claim that maintenance prescription has not been followed if there is a warranty dispute in the future. To avoid this risk, STA is recommended to highlight this issue and formulate maintenance prescriptions of the road instead of letting the contractor have this responsibility.

The second additional risk area was explained as problems with insufficient space for worksite specified in the work plan. The consequence of this risk can be that STA has to start over again with a new negotiation with landowners during the production phase, which can be difficult, time consuming and expensive. An explained possible reason for this consequence is that the consultants that are working with this aspect often have minimizing the environmental impact of the project as a main objective, which can too often lead to a tight work plan that results in problems in the production phase. In addition, STA usually has less possibility to review these documents for such errors in a DC project then in a DBB project. This risk area needs to be given more attention in future projects; however a simple solution to avoid this risk is not identified.

7.6 Risk management software

A majority of those interviewed say that the risk management software tends to calculate a considerably lower risk reserve than what they have experience from the outcome of other projects. This explains a cause for scepticism towards the use of the software.

Smith et al. (2006) say that it is important that the team members of the project are fully involved and agree with the output from the risk analysis, because they are then more likely to do a high-quality job handling the risks during the project. For this reason, it is essential to solve this calculation issue in the risk management software in order to increase the trust. Nevertheless, there are, of course, more reasons than this for reducing the calculation problem.

Smith et al. (2006) claim that if the team members fully understand why they are working with risk management, they will be more motivated and do a better risk management job. This issue of insufficient knowledge regarding risk management within STA has been mentioned in the results, where a project manager argues that sometimes inadequate education in the risk management software and risk management is a difficulty. It is argued that this lack of training may lead to great differences in various persons' perceptions; these differences may result in difficulties when comparing projects and is reflected in the quality of the risk register.

Some of those interviewed state that it would be useful to be able to share the risk register from the risk management software with the contractors, excluding the calculated risk reserve; PM3, however, thinks this is not possible due to the public procurement act. Nevertheless, according to an STA internal document, it is possible to allocate different levels of privileges. This could enable sharing some of the information with the contractor regarding the identified risks for the project. We recommend STA to further investigate the possibility and legal consequences of sharing some of the information in the risk register.

The main objectives of risk management in projects are, according to PMI (2004), to increase the probability of occurrence and the impact of positive events, and to decrease the effect of possible unwanted events. The internal documents at STA stipulate that both opportunities and threats shall be managed in the risk management process (TDOK 2010:18). However, in the risk management software, focus is on managing threats while focusing on the possibility to manage opportunities in projects is limited. Therefore, we recommend that STA further develop the risk management software in order to better handle opportunities within projects. Winch (2010) argues for a separation of threats and opportunities when managing risks. For this reason, we think this further development of the software should not be integrated in the existing software model; it should be possible to handle the positive risks separately.

8 Conclusions

This chapter summarises the most important conclusions from the performed study.

Employees of STA are generally enthusiastic towards risk management. However, many of them show hesitance concerning how to manage risks within DC projects. A common opinion is that some projects are less suitable to be procured as DC, especially railway projects because of their special character. This observation indicates that an established common approach is preferable towards the selection of projects procured as DC.

STA should develop a detailed list of risk categories based on experience from previous projects, as a support tool in the risk identification process. According to the literature, this list can contribute to more systematic risk identification processes.

Observations from the risk meeting indicate uncertainties regarding how to evaluate and analyse risks. Therefore, we recommend further efforts toward establishing the already existing guidelines with clear objectives for this process. This can be done with more compulsory internal education on risk management for all team members, including consultants. According to the literature, a positive effect of the increased understanding of the risk management process gained from such training is increased commitment on the part of the team.

The geotechnical risk category has emerged as the most significant risk area from this study, as well as from the literature. A specific difficulty in DC projects has proved to be who should be responsible for the interpretation of geotechnical data. STA documents state that STA should not analyse; however, analysis is highly recommended by most of the respondents based on their experience. Therefore, we recommend STA to further investigate which party shall be responsible for geotechnical interpretations in future DC projects and establish this decision on the project level.

In the literature, the use of DBB within a DC project for some parts which are assessed as particular risky and difficult to describe as performance specification, is advocated. However, this study shows that this is not appropriate for the geotechnical risk area. On the other hand, respondents argue that DBB is suitable for the esthetical aspect in a DC project in order to reduce risk of insufficient end result regarding the esthetical design.

The interviewees state that the esthetical objectives in a DC project are particularly difficult to describe in the procurement documents. The study indicates that the projects investigated do not use an aligned approach towards how they describe the esthetical objectives in the procurement documents. These differences in how the objectives are described in the projects are particularly clear between the two geographical regions. This indicates that there is a deviation between practice and internal policies.

It has been shown that in DC projects, the environmental risk area is often treated in the same manner as in a DBB project; the reason, according to the respondents, is that the contractor generally does not have the knowledge required to take the whole environmental responsibility. We believe that the contractor should be given the possibility to take responsibility for environmental risks in future DC projects. Otherwise, there will never be a change in who has the best ability to manage those risks, and consequently, should control them. However, we suggest this change should be gradually implemented in future DC projects.

The study also shows that there is an argument to consider against the transfer of environmental responsibility to the contractor. The risk for delays in DC projects can be decreased if STA acts prior to the signing of a contractor.

There is a problem that the risk reserve generally is calculated too low in the risk management software. One of the important reasons for solving this problem is that it will increase trust among the employees regarding the software and risk management in general.

Being able to share some of the information in the risk register with the contractor, excluding the calculated risk reserve, is shown to be useful for DC projects. However, concerns from the respondents concerning the legal consequences need to be further addressed by STA. We recommend that STA further investigate the possibility to share the risk register with the contractor.

Both theories and internal documents at STA state that opportunities and threats should be managed in a systematic manner. This study indicates that opportunities most often are managed in an arbitrary manner. Therefore, there is a risk of missing out on opportunities. However, we do not recommend managing risks with both positive and negative outcomes in the same risk management software because it can cause confusion among the employees.

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Appendix: Interview questions

Contents of the appendix:

1. Interview questions, first phase

The aim for this interview phase is to get an understanding in how the employees at STA views risk management. In addition, the aim is also to investigate which risk categories that are of particular interest in a project procured as DC.

About the interviewed project managers:

- What is your current role in the company?
- How long have you been working in the construction sector and in the company?
- How much experience do you have in project procured as design-construct?

Risk management:

- What does risk management mean for you?
- How do you work with risk management?
- What is your opinion about the change in risk management in the last three years?

Risk management in DC projects:

- What is the main difference between DC and DBB, regarding risk management?
- How do you produce the risk register for your project?
- Is there any risk category that you think is of particularly importance?
- Do you think geotechnical risks, esthetical risks and environmental risks are of particular importance to manage?
- Do you want to add any risk categories?
- How do these risk categories affect your way of formulating the performance specification?

2. Interview questions, second phase for Project 1

Questions regarding the procurement documents in the category geotechnical risks:

- Unforeseen ground conditions are a common reason to increased cost for infrastructure projects. How do you think this risk is best managed?
- In the appendix to technical procurement documents it is in detail described how the contractor should present the results from the geotechnical investigation, explain?

- For this project, interpretation regarding the geotechnical data is presented. Why did you choose to do this? How does this affect the risk exposure for both the client and the contractor?

"The client shall be notified no later than 5 days before the laying of packed filling so that the client can attend the inspection of the shaft bottom before laying the filling" – page 91 in the technical procurement document
Is there a risk to this event?

"The contractor should form their own opinion of the amount of blocks through field visits" – page 19 in the technical procurement document
What's your opinion towards this type of description?

- Which type of risks connected to the geotechnical area do you consider to be of importance for this project?

Questions regarding the procurement documents in the category esthetical risks:

"The open landscapes and low embankments: Slopes should be designed so that railings is avoided, if possible with regard to the roads extent" – page 75 in the technical procurement document
Do you think this description is enough, or is there a risk the contractor chose railings in order to reduce cost and increase profit?

"Potential supporting walls should be performed in-situ concrete" – page 84 in the technical procurement document
Do you think this is too much steering from the client?

"Slopes shall be designed and constructed so that they harmonize with the surrounding terrain shape, vegetation and soil. Flat slopes and soft, rounded transitions to the adjacent land should be performed." – page 74 in the technical procurement document
Do you think this is a good description regarding the slopes for the road?

”Noise Barriers should be designed according to Figure (DB32)” – page 79 in the technical procurement document
Why is the noise barriers design described in detail?

- Project 3 used a design program in their procurement documents, why did you choose to have a technical procurement document instead?
- Risk nr 51,*”design is neglected”*, what is your opinion regarding this risk?

Questions regarding the procurement documents in the category environmental risks:

- In this project you describe in detail the monitoring steps for the environmental aspect. Is this necessary for a project procured as design-construct?
- Has Borås stad steered the environmental aspect for this project, considering the detailed description in the technical procurement documents?

Questions regarding the risk management software:

- How much have you used the risk management software in your project?
- Has the software been helpful in the project?
- Have you had exchanges of risks with other parties?
- How has the external access worked?
- What are the pros and cons concerning the software?
- Do you have recommendations for further development of the software?

3. Interview questions, second phase for Project 2

Questions regarding the procurement documents in the category geotechnical risks:

”Failure to do your own additional investigations in the execution of their design should not be a basis for reimbursement for the design or additional expenses in the performance in general. Additional studies will therefore be included in the contract.”– I §1.3 The contract
Is this a method for STA to transfer risks to the contractor, regarding the amount of geotechnical investigations?

From the risk register, risk nr 28: *”Geotechnics; soils differ from Ffu. Cause: Errors in the submitted documentation”*
What is the outcome from this risk? Based on your previous experience, are you satisfied with the amount of geotechnical investigation that is done for this project?

- Project 3 has use a DBB contract for the existing road, do you think this is a good way to manage uncertainty regarding the existing road?
- Unforeseen ground conditions are a common reason to increased cost for infrastructure projects. How do you think this is best managed?

Questions regarding the procurement documents in the category esthetical risks:

- Project 3 has decided to use a design program in the procurement document, why did you not use a design program?
- There are no risks regarding the esthetical category in the risk register. Is this because it is not a significant risk category in this project?

"Design and design standards should be uniform for all parts in road construction." – page 26 in the technical procurement document
Is this an interpretation that often leads to disputes between the contractor and the client?

"Where side slopes are not provided, it shall be designed to fit within established road area, with inclination to weigh facility is aesthetically pleasing ..."- Page 40 in the technical procurement document
What is your opinion, connected to risks, regarding this description?

In the technical procurement document page 44:

- There is a detailed description regarding vegetation, what is the outcome for the finished part of the project?
- Has this approach been viewed as a successful approach, regarding the performance specification for vegetation?

Questions regarding the procurement documents in the category environmental risks:

"Existing land, environment, and structures such as buildings, bridges, roads, [...] shall have unchanged functionality during the execution and after it has been put into use." - the technical procurement document page 10.
Do you think this was a suitable description in the performance specification for the environmental risk category?

"Roads should be designed and activities shall be conducted so that the levels and water quality in existing groundwater wells are not affected" – page 12 in the technical procurement document *"Feature for ground irrigation enterprises, natural ditches, etc. shall be maintained."*- page 13 in the technical procurement document *"The natural environment may not be negatively affected by road paving, except to the increased noise"*- page 14 in the technical procurement document
How do you, connected to risk nr 3 from the risk register, manage these types of hand-over to the contractor?

Questions regarding the risk management software:

- How much have you used the risk management software in your project?
- Has the software been helpful in the project?
- Have you had exchanges of risks with other parties?
- How has the external access worked?
- What are the pros and cons concerning the software?
- Do you have recommendations for further development of the software?

4. Interview questions, second phase for Project 3

Questions regarding the procurement documents in the category geotechnical risks:

- Will the use of divided contract, DC and DBB, reduce geotechnical risks?
- Have this been a successful approach? Is this a common approach within STA?
- Unforeseen ground conditions are a common reason to increased cost for infrastructure projects. How do you think this risk is best managed?
- Are you satisfied with the amount of geotechnical investigations?
- What is your opinion towards the risk regarding how the contractor interpreters the geotechnical investigation?

Questions regarding the procurement documents in the category esthetical risks:

- For this project, there exists a detailed design program, with reference images. Is this an approach in order to manage and reduce esthetical risks? Do you think it could be done in another way, e.g. by giving the contractor a higher degree of freedom?
- In the risk register, there are no risks regarding the esthetical objectives. Is this because these risks are reduced with the design program?
- In Project 1, the client shall make sight and approval after each blast and thereafter, jointly with the contractor, come up with at a suitable design of embankments etc. Do you think this is this a suitable approach to deal with esthetical risks?

- The design of slopes and side surfaces seems to be more controlled in Project 3 compared to Project 2 and Project 1. Why?

Questions regarding the procurement documents in the category environmental risks:

- There is a detailed control program that describes which types of inspection the contractor should do regarding the environmental area. This includes, for example, sight and measurement for a number of buildings, checking water levels in wells and in a nearby lake. What do you think about this approach?

- In the previous interview you explained that the environmental risk category is not of particular importance in a DC project. There are five different risks in the risk register (18, 13, 12, 4, and 15). Explain?

Questions regarding the risk management software:

- How much have you used the risk management software in your project?
- Has the software been helpful in the project?
- Have you had exchanges of risks with other parties?
- How has the external access worked?
- What are the pros and cons concerning the software?
- Do you have recommendations for further development of the software?