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Geotechnical Risk Communication

A case study of communication between actors in infrastructure projects

Master of Science Thesis in the Master's Programme Geo and Water Engineering

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ABSTRACT

Infrastructure projects are developed, designed and built over a long period of time with many stakeholders involved at different stages. In the different stages risk analyses and assessments are performed by different actors. However, a considerable problem might be that information about identified risks, which would be useful for actors later in the process, are lost due to lack of risk communication. Studies conclude that geotechnical risks and uncertainties are among the largest risks in infrastructure projects and that these risks are dependent on the communication. Furthermore, research show that different procurement options affect the risk management in the construction industry.

The aim of this thesis was to provide a basis for improvement and give suggestions of tools or work procedures between involved actors in infrastructure projects in order to ensure a better transfer of information of geotechnical risks. A case study of three infrastructure projects from a geotechnical risk point of view gave a basis for interviews with key personnel in the projects. Interviews were carried out and analyzed in order to come up with suggestions for improvement of the geotechnical risk communication

Geotechnical risk management and risk communication in infrastructure projects work much better today than five years ago due to efforts made in the industry. Many problems today are seen as temporary before new work structures are properly established. However, just as in the rest of the construction industry, there are collaboration problems which can be related to the history of only counterpart relationships between actors in design-bid-build procurement. Experience from other procurement options such as design-build in infrastructure projects could not be ensured but the expectations are diverse. Inherited scepticism towards other actors is a big problem in infrastructure projects which limits the risk communication and will take time to change. The lack of a common structure is also a barrier to enhanced risk communication. Some of the recommendations to improve the risk communication are to ensure that a geotechnical start meeting takes place and to enhance the collaboration between designer and contractor in the production phase.

Key words: risk communication, risk management, procurement options, infrastructure projects, geotechnics

Geoteknisk riskkommunikation
En fallstudie om kommunikation mellan aktörer i infrastrukturprojekt
Examensarbete inom Geo and Water Engineering
ANDERS ENGSTRÖM, DAVID STÅLSMEDEN
Institutionen för bygg- och miljöteknik
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SAMMANFATTNING

Infrastrukturprojekt utvecklas, projekteras och byggs under lång tid med olika aktörer involverade i olika delar av processen. I de olika skedena så analyseras och utvärderas risker av de olika aktörerna och därför kan ett problem vara att information om identifierade risker, vilka skulle vara användbara för aktörer senare i processen, inte blir överförda på grund av otillfredsställande kommunikation. Undersökningar visar att geotekniska risker och osäkerheter är bland de största riskerna i infrastrukturprojekt och dessa risker påverkas av kommunikationen. Forskning visar också att olika upphandlingsformer påverkar riskhanteringen i byggindustrin.

Syftet med denna uppsats var att ge en grund för förbättringar och förslag på verktyg och arbetssätt mellan involverade aktörer i infrastrukturprojekt för att säkerställa en bättre överföring av information om geotekniska risker. En fallstudie av tre infrastrukturprojekt ur ett geotekniskt riskperspektiv gav en grund för intervjuer av nyckelpersoner i projekten. Intervjuerna analyserades så att förslag på förbättringar av den geotekniska riskkommunikationen kunde presenteras.

Den geotekniska riskhanteringen och riskkommunikationen i infrastrukturprojekt fungerar mycket bättre idag än för fem år sedan tack vare det arbete som lagts ner inom detta område i branschen. Många av problemen idag, relaterade till den geotekniska riskkommunikationen, ses som tillfälliga innan de nya arbetssätten är ordentligt inarbetade. Liksom resten av byggbranschen har infrastrukturprojekt problem med samarbetet mellan aktörer vilket kan ha samband med att projekt med motpartsförhållande så som utförandeentreprenad i huvudsak har använts. I studien var erfarenheterna från andra upphandlingsformer så som totalentreprenad för få för att kunna ge ett säkerställt resultat, dock skiljer sig förväntningarna mellan de olika aktörerna mycket. Den traditionella skepsisen gentemot andra aktörer är ett stort problem i infrastrukturprojekt vilket leder till försämrad riskkommunikation och kommer ta tid att lösa. Bristen på enhetliga arbetssätt med riskkommunikation är också en barriär. Några av rekommendationerna för att förbättra riskkommunikationen är att säkerställa att ett geotekniskt startmöte äger rum i alla projekt och att öka samarbetet mellan projektör och entreprenör produktionsfasen.

Nyckelord: riskkommunikation, riskhantering, upphandlingsformer, infrastrukturprojekt, geoteknik

Contents

Preface

This thesis has been written as completion of the studies at the Master´s programme Geo and Water Engineering at Chalmers University of Technology. The research questions of the thesis were elaborated in collaboration with Peab´s Infrastructure division West.

The thesis has given us an insight of the construction industry and the possibility to interview experienced personnel at different actors, which has been very interesting for us. We would like to thank all the companies and personnel who have taken their time to participate in the interviews despite their busy schedule.

We would also like to thank Peab´s Infrastructure division West and all of its personnel who allowed us to be stationed at their office and who answered all of our questions about the construction industry.

A special thanks is directed to the three persons who helped and guided us during these months: our supervisors at Peab, Johnny Wallgren and Johan Hedlund and our supervisor and examiner at Chalmers, Claes Alén.

Göteborg November 2011

Anders Engström & David Stålsmeden

Dictionary

English	Swedish
Administrative regulations	Administrativa föreskrifter
Branch manager	Arbetschef
Building estimator	Kalkylingenjör
Building meeting	Byggmöte
Building programme	Byggnadsprogram
Building support geotechnical engineer	Byggstödsgeotekniker
Client	Beställare
Client´s construction management	Beställarens (TRV) byggledare
Construction drawings	Byggritningar
Consultant	Konsulter
Continuous feedback	Erfarenhetsåterföring
Contractor	Entreprenör/Entreprenadföretag
Designer	Projektör
Design-bid-build project (DBB)	Utförandeentreprenad
Design-build-operate-maintain	Funktionsentreprenad
Design-build project (DB)	Totalentreprenad
Foreman	Arbetsledare
Functionality requirements	Funktionskrav
Geotechnical calculation memo	Geotekniskt beräknings-PM
Knowledge dissemination	Kunskapsspridning
Object specific technical description	Objektspecifik teknisk beskrivning
Procurement	Upphandling
Public Procurement Act	Lagen om Offentlig upphandling (LOU)
Site management	Platsledning
Site manager	Platschef
Site meeting	Platsmöte
Tender documents	Förfrågningsunderlag
Tenderer	Anbudsgivare
Uncertainty Analysis	Osäkerhetsanalys
Work preparations	Arbetsberedningar

1 Introduction

The introduction chapter explains the background to the study. Aim, goal and delimitations explain how and why the specific research questions have been chosen.

1.1 Background

Infrastructure projects are developed, designed and built over a long period of time with many stakeholders involved at different stages. In the different stages risk analyses and assessments are performed. However, a considerable problem might be that information about identified risks, which would be useful for actors later in the process, are lost due to lack of risk communication.

According to Swedish Geotechnical Institute's (SGI) research plan for 2010-2012, risks and uncertainties related to geotechnics are of great importance. SGI imply that the largest technical risks in infrastructure projects are related to geotechnical risks and uncertainties. Since infrastructure projects are large societal investments both in Sweden and abroad, these risks can become very expensive. (Swedish Geotechnical Institute, 2011, p. 8)

Royal Institute of Technology's (KTH) project "System for risk management in soil and rock work" asses that these constructional damages amount to 3.5 á 4.0 billion SEK every year due to inadequate geotechnical consideration. Some of the reasons are neglected knowledge about hazards in geotechnics, inadequate identification of technical and nontechnical hazards before the project launch and inadequate communication between different actors in the constructions process. (KTH, Royal institute of technology, 2005, pp. 1, translated)

In the survey "Savings opportunities through more effective communication in the construction process" from 2007, economical loss due to lack of communication in construction processes amount to 13% of total investment in the industry. The survey concludes that savings opportunities of 22 billion SEK, through clear and structured communication, are spread over all actors in the construction process. (Svensk byggtjänst, 2007, pp. 4, 20, translated)

Osipova (2008) conclude that different procurement options affect how risk management works in the construction industry. Her report also highlights that the communication of risks between actors works unsatisfactory irrespective of the procurement options. (Osipova, 2008, pp. 36-37)

Taking the information above in consideration, there is a need to improve the work procedure for risk communication in infrastructure projects. As one of the largest construction and civil engineering companies in the Nordic countries, Peab has concerns about today's work structures related to geotechnical risks. Therefore, their infrastructure department in the western region, with its headquarter in Göteborg, initiated this thesis to give support for improvement and suggestions for work structures that ensure a better transfer and communication of risks.

1.2 Aim

The aim of this thesis is to provide a basis for improvement and give suggestions of tools or work procedures between involved actors in infrastructure projects in order to ensure a better transfer of information of geotechnical risks.

Recent year's construction management research shows that different procurement options affect the risk management. (Osipova, 2008, p. 37) Since the contractor, in Sweden, tend to be involved earlier and have larger influence in design-build contracts than in design-bid-build construction contracts, flow of information about geotechnical risks might differ with different procurement options. (Osipova, 2008, pp. 35-36) The infrastructure industry is disreputable to develop slowly. (Statskontoret, 2010, p. 7) Therefore, integration of information about risk communication from other industries might be acquired.

1.3 Objectives

To achieve the aim, some objectives of this thesis are to:

- Highlight work structures in infrastructure projects that reduce the risk of geotechnical failure due to lack of risk communication.
- Highlight shortcomings in the risk communication process between actors.
- Highlight conditions in geotechnical projects where risk management needs extra attention.
- Suggest improvements to attain better communication and work structure related to geotechnical risks in infrastructure projects.

1.4 Research questions

Due to aim and goal these research questions are formulated:

- How does the different procurement options design-bid-build and design-build, used in infrastructure projects, affect how information about geotechnical risks is communicated between client, designer and contractor?
- How can improved risk communication between actors and decreased risk in infrastructure projects be achieved?

1.5 Delimitations

In the construction industry many different procurement options exist e.g. partnering, construction management and build-own-transfer. However, in this thesis only design-build- and design-bid-build with general contract projects are looked upon and only the geotechnical risk aspects of the projects are examined thoroughly. If the design-build projects include agreements about maintenance i.e. design-build-operate-maintain projects, the operational and maintenance phases are neglected due to lower geotechnical risks in these phases.

Risk communication in the projects only concerns the actors; client, designer and contractor, not risk communication to e.g. subcontractors.

Peab continuously work with work environment questions. This includes regular reporting and monitoring of high-profile risks, incidents and accidents. These are not studied in greater detail in this work.

All infrastructure projects studied have Peab as contractor and the Swedish Transport Administration as client which means that all projects are procured according to the Swedish Public Procurement Act legislation.

2 Method

The method chapter explains how the study is carried out. The methodology for literature and project studies and interviews are explained.

2.1 Design of the study

In the pre-study were literature studies carried out to give a basis for the thesis and to specify aim and delimitations based on existing research. The literature study also gave knowledge about research in related areas that could be implemented in this survey and used in recommendations to the infrastructure industry. A study of three infrastructure projects from a geotechnical risk point of view gave a basis for the preparation of interviews with key personnel in the projects. In the main study, interviews were carried out and then analyzed in order to come up with suggestions for improvement of geotechnical risk communication. See *Figure 1* below for design of study.

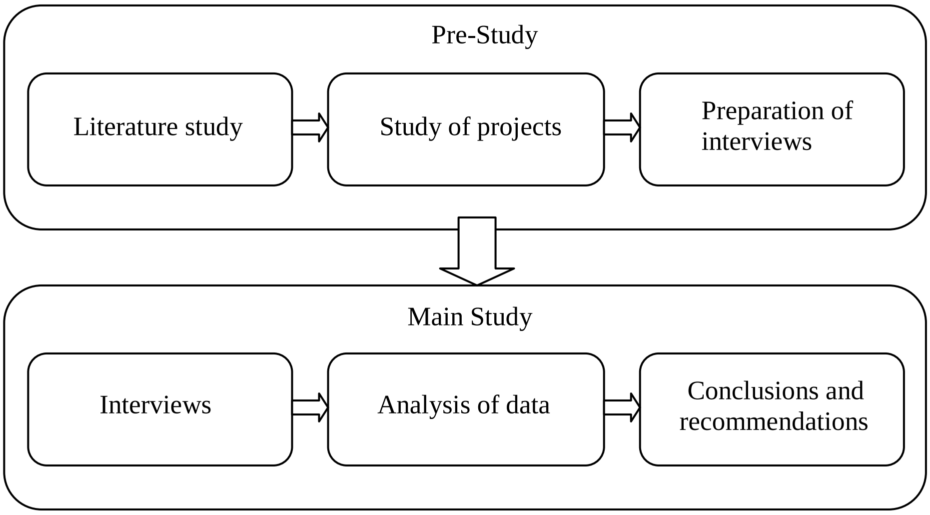


Figure 1. Design of the study.

2.2 Literature study

The literature study was mainly carried out within three different areas, i.e. Construction management process, Geotechnical risks and Risk management.

In the first phase, course literature from Risk management-, Construction process- and Geotechnical courses at Chalmers was reviewed. This covered most parts of the basic knowledge, otherwise main authors in the areas were studied. After this basic study was carried out, Chalmers databases where searched to find research e.g. doctoral, licentiate or master thesis and journals in order to find more information and specific references in the areas.

2.3 Study of projects

In order to analyze the differences in how geotechnical risks are handled, three infrastructure projects were reviewed as case studies. This also gave basic knowledge about the documentation and work structure in infrastructure projects. To be able to analyze differences with different procurement options two design-bid-build projects “E45 Älvängen-Ramstorp” and “E6 Knäm-Lugnet” were looked upon. In addition the design-build project “E45 Torpa-Stenröset” was analyzed. In these three projects, the management of geotechnical risks and how the documentation of geotechnical risks varies with different procurement options were looked upon.

The three projects were chosen by Peab due to the different procurement options used, their nearby location and that they were all in the production phase. The two projects that are along road E45 are part of the “BanaVäg i Väst” project.

2.4 Interviews

To examine more thoroughly how the different projects have handled risk communication and to be able to make suggestions for a work structure that all actors of the construction process approve of, key personnel at client, designer and contractor were interviewed. Key personnel were interviewed in an unstructured and informal way supported by a checklist with important keynotes. This method was chosen to acquire as much information as possible about the projects and the risk communication today without forgetting important questions. After analyzing the interviews the interviewees were asked to give reflections and comments on the analysis, conclusion and recommendations.

All interviews have been carried out in Swedish since everyone involved are native Swedish speakers. Interviews were recorded and then summarized in English in the result. In order to get a broader knowledge about risk management in infrastructure projects and the companies’ policies about risk management, other specialists at the companies were also interviewed.

All of the geotechnical engineers that were interviewed were male and had worked with geotechnics in infrastructure projects between two to forty years. They were, at the time of the interviews, employed by these companies: Peab, Geotechnica, The Swedish Transport Administration, Vectura and Sweco.

2.5 Improvement recommendations

Suggestions for improvements of information flow and enhanced communication of geotechnical risks were made after analysis of data in the study. These recommendations were discussed with as many people involved in the study as possible.

3 Theory

The theory chapter gives a theoretical background to our thesis. The terms risk and risk management are presented and defined. Different approaches to risk management are also examined. The construction process, how different procurement options works and some basic geotechnics are explained.

3.1 Risks

"risks and uncertainties surround every human activity and influence everything we do. Risks and uncertainties are therefore unavoidable in the design and execution of infrastructure projects." (Carlsson M. , 2005, p. 12)

As the citation states, risks and uncertainties are part of everyday life. There is however a difference in how people and organizations choose to deal with them. This chapter describes some of the existing research about risk, risk management and risk communication.

3.1.1 What is risk?

The word risk is interpreted and used with different meaning by different persons in different industries or sectors and also in everyday language. It can for instance be used to describe the state of something as well as properties and actions. Johansson (2011) gives the example that a person can for example take a risk (action), be a riskseeker (property), pose or be exposed to a risk (state). In addition to this, risk is also a concept of uncertainty (Johansson, 2011, p. 112). Because of this ambiguity there is no globally agreed definition of risk. In 2009 though, the International Organization for Standardization, ISO, published a new standard (ISO 31000:2009) which is intended to help solving the problems with the different and ambiguous definitions and approaches of risk and risk management.

Research has shown that there is a difference in how the public and experts define risk and perceive risks (Carlsson M. , 2005, p. 11). Some examples of factors that affect people's risk perception are familiarity, controllability, voluntariness and catastrophic potential (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 14). The risk perception is reflected by e.g. knowledge, belief and values of the stakeholder. Both experts and public have a tendency to underestimate risks of high-probability events, and overestimate the risks of low-probability events. For instance, most people overestimate the risk of living close to or working in a nuclear plant and underestimate the risk of riding a bicycle (Burgman, 2005, p. 15).

The word risk is often perceived as a threat or something negative but this is something that is questioned by some authors. One argument is that the consequences related to risk are not necessarily bad but can also be good or positive (Smith, Merna, & Jobling, 2006, p. 4). According to this view, risk can also be a possibility or opportunity. However, regardless if the consequences are good or bad, it is of interest to manage the risk efficiently in order to achieve specified objectives. According to Rosén (2007) efficient risk management not only protects us from hazards, but also creates opportunities;

"*If a risk is unknown this might restrain us from performing a specific project. However, if the risk is analyzed and understood, and it is possible to reduce or control the risk, then the project can be performed*" (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 9).

Due to the many separate views on risk in different areas there are also several definitions. Some examples of definitions by different organizations can be seen in *Table 1* below:

Table 1. Examples of definitions of risk from different organizations (Hopkin, 2010, p. 12).

Organization	**Definition of risk**
ISO Guide 73 ISO 31000	Effect of uncertainty on objectives. Note that an effect may be positive, negative, or a deviation from the expected. Also, risk is often described by an event, a change in circumstances or a consequence.
Institute of Risk Management (IRM)	Risk is the combination of the probability of an event and its consequence. Consequences can range from positive to negative.
"Orange book" from HM Treasury	Uncertainty of outcome, within a range of exposure, arising from a combination of the impact and the probability of potential events.
Institute of Internal Auditors	The uncertainty of an event occurring that could have an impact on the achievement of the objectives. Risk is measured in terms of consequences and likelihood.
Hopkin, P. Fundamentals of Risk Management (2010)	Event with the ability to impact (inhibit, enhance or cause doubt about) the mission, strategy, projects, routine operations, objectives, core processes, key dependencies and/or the delivery of stakeholder expectations.

According to IEC, risk analysis seeks to answer three questions (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 10):

- What can go wrong?
- How likely is this to happen?
- What are the consequences?

Correspondingly, a common description of risk is that it is a combination of the probability an event its consequence. According to this view the risk can be illustrated in a chart as a product of probability and consequence as in *Figure 2*. As seen in the figure, the risk increases with higher probability and higher consequence.

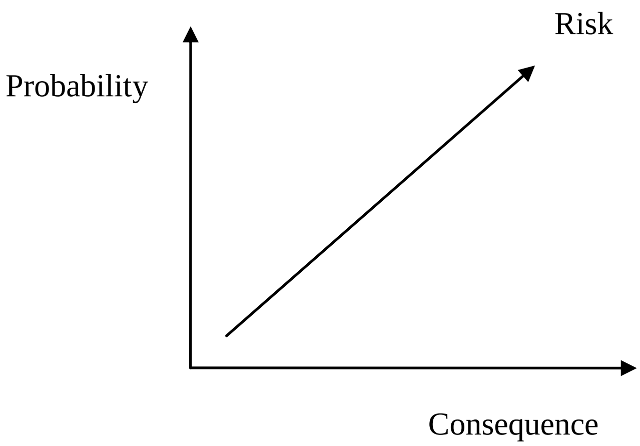


Figure 2. Risk described as a combination of probability and consequence.

The impact of a risk can then be measured as the product of the probability and its consequences according to the formula (Mills, 2001, p. 246):

$$RI = L * C \qquad (1)$$

Where:

RI = Risk Impact
L = Likelihood
C = Consequence

However, this risk value says nothing about how the risk should be treated but can be used as a basis for discussion and decision-making.

Risks can be divided and classified into different groups in various ways. One way is ranking of the risk sources. Taking probability and consequence in account, Smith et al. (2006) classifies project risks into four groups; trivial, expected, hazard and risk management according to *Figure 3*. Events with high impact and high probability are most important to manage but hazards with lower probability also need to be considered.

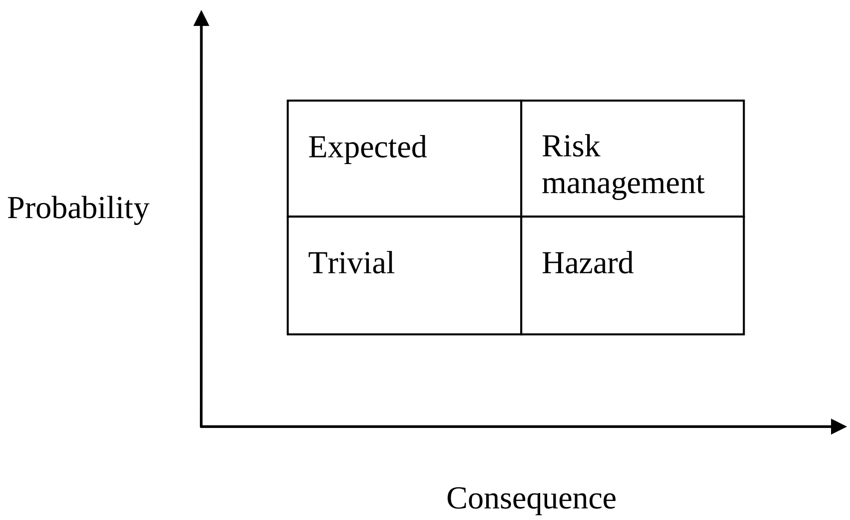


Figure 3. Classification of risk sources after Smith et al. (2006, p. 4).

Other ways of classifying risks is to divide them according to if they are specific to a project or global. Project specific risks are directly related to the planning, design and maintenance and can be e.g. technical, financial and organisational risks. Examples of global risks are political and environmental risks. In construction projects the risks can in general be divided into (Osipova, 2008, p. 21):

- Internal or controllable risks (e.g. design, construction, management and relationships)
- External or uncontrollable risks (e.g. financial, economic, political, legal and environmental)
- Force majeure risks (i.e. extraordinary events beyond control)

The subject of the types of risks and their sources within geotechnical engineering is discussed further in Chapter 3.5.

3.1.2 Risk management

Introduction and approaches to risk management

As mentioned in the introductory chapter, time delays, quality problems and increased cost are some of the damaging problems in infrastructure projects and many of them are due to the risks and uncertainties involved. To avoid these kinds of problems it is necessary to manage the risks and uncertainties properly. According to several authors, traditional risk management and risk analysis mainly depend on intuition, judgment and experience (Carlsson M. , 2005; Smith, Merna, & Jobling, 2006). They furthermore state that traditional methods are not enough to handle mentioned problems.

Smith et al. (2006) state that there are two basic types of approach to risk management; the informal approach and the formal approach. The informal approach is the one used traditionally and views risks in a subjective manner. One technique to manage the risk in this approach is the use of contingency funds. The contingency fund is a sum of money that is put aside, in the budget, in case extra money is required e.g. to handle unforeseen events. Another informal technique is involvement of experts or people with experience on similar projects and to consult their opinion on possible risks in a project. According to Smith et al. (2006) the danger with the informal approach is that it is considered sufficient but experience shows that it is not. The formal approach on the other hand consists of structured procedures that provide guidelines which formalize the risk management process. A systematic or formal approach thus describes and clarifies the risks and makes them easier to manage. (Smith, Merna, & Jobling, 2006, p. 38)

The concept of risk management

Just as for the word risk, there are different definitions of risk management and the processes it involves. The international risk management standard ISO 31000:2009; "*Risk management – principles and guidelines*", defines risk management as:

"*coordinated activities to direct and control an organization with regard to risk*".

The standard further states that the term risk management also refers to the architecture that is used to manage risk i.e. the risk management principles, framework and the risk management process (ISO, 2009, p. vi).

The aim of risk management is to control and minimize negative consequences of a risk event but also to maximize the opportunities. Some of the benefits of risk management are that it helps to (ISO, 2009, pp. v-vi; Mills, 2001, p. 245):

- identify, assess, and rank risks, making the risks explicit
- control the uncertain aspects of construction projects
- identify the opportunities to enhance project performance
- establish a reliable basis for decision making and planning
- improve stakeholder confidence and trust

There are many different views on the steps and procedures that should be included in the risk management process. Different disciplines have their own twist to the process. However, the major contents of the process are often quite similar. The standard, ISO 31000, structures the process as seen in *Figure 4* below.

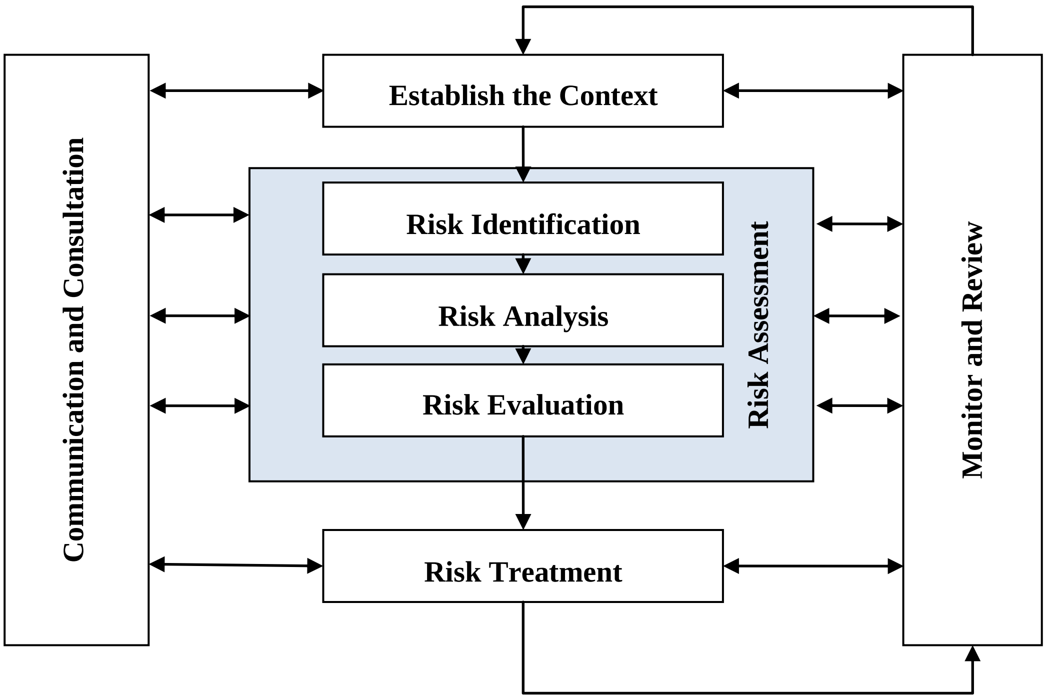


Figure 4. The risk management process (ISO, 2009, p. 14).

The process according to *Figure 4* is basically step like but ISO 31000 emphasizes that in order for the risk management to be effective the process should be dynamic, iterative and responsive to change (ISO, 2009). The two elements “communication and consultation” and “monitor and review” should for example be applied continuously and take place during all stages of the process (ISO, 2009).

The first step in the process is establishing the context which involves defining the objectives, defining factors that may influence the objectives and setting the scope and risk criteria (ISO, 2009). Factors that may influence the objectives are for instance stakeholders and contractual relationships, organization policies and standards etc.

After establishing the context follows the risk assessment which in ISO 31000 includes the three steps of risk identification, risk analysis and risk evaluation.

Risk identification

Burgman (2005) highlights that "a single hazard can lead to multiple adverse effects. Several hazards can have the same effect". Therefore is it important to use as many different risk identification methods as possible to identify as many hazards as possible. (Burgman, 2005, pp. 130-131) Common risk identification methods are checklists and brainstorming, structural brainstorming, hazard matrix, hazard and operability analysis (HAZOP).

One of the most common risk identification methods are checklists and unstructured brainstorming. Through checklists and unstructured brainstorming most of the hazards related to the project are identified, but the hazards identified are often restricted to previously experienced hazards. This is an easy way to identify the most common hazards, but does not encourage people to see new perspective or new possible risks (Burgman, 2005, pp. 131-132). Research by Hayes (2002) also finds that the most common risk identification is checklists. Furthermore it criticizes this method of not forcing the analyst to think about what can go wrong and of leading to false confidence (Hayes, 2002, p. 10). Burgman (2005) concludes that checklists and unstructured brainstorming is used best together with another method to check completeness of the risk identification.

In structured brainstorming techniques a facilitator leads the process. Burgman (2005) lists some of the steps:

- problem formulation and development of questionnaires,
- selection of experts,
- provision of background information, definitions and context to experts,
- elicitation of conceptual models and lists of hazards (often performed by participants independently,
- aggregation of results,
- review of results by experts and revision of answers, and
- aggregation of results, or iteration of feedback until consensus is achieved (Burgman, 2005, p. 132)

Burgman (2005) highlights that these methods may encourage uniformity but since some forms of unstructured brainstorming do not involve any meeting of participants, possibilities to learn from other participations might be limited. However, structured brainstorming techniques, e.g. the Delphi method, can be useful in risk identification, especially in large projects with many experts and stakeholders.

Hazard matrices as shown in *Table 2* combine how different actions in the project affect the geotechnical properties. Hazard matrices can be a good technique when one action can have many effects, since it enhances the probability that links between actions and consequences are not ignored. However, these matrices are often based on checklists and brainstorming and therefore inherit the same problems mentioned above. (Burgman, 2005, pp. 133-134)

Table 2. Example of a Hazard Matrix.

		Actions when building a new road			
		Excavation	LC-columns	Piling	Etc.
Geotechnical properties	Lower water pressure				
	Higher water pressure				
	Change in slip surface				
	Etc.				

Hazard and operability analysis often referred to as the HAZOP technique is a structured brainstorming technique that encourage experts to think beyond their own experience. (Burgman, 2005, pp. 135-137) This is achieved by analyzing parameters of the system with what if questions, see *Table 3*.(Kletz, 1999)

Table 3. Example of a HAZOP table.

Process: Excavation				
1.Process parameter: Change in water pressure				
Guide word	Deviation	Causes	Consequences	Action/solution
No	No change			
More	Too high pressure	Increase of load	Possible landslide	
Less	Too low pressure	Decrease of load Lowering of GWT	Possible settlements	

Burgman (2005) lists the steps in the process after Kletz (1999)

- A group of experts is assembled.
- A list of key words is compiled that describes the system, its components and operational characteristics.
- If the list is large (usually it is), the words are split into manageable sections associated with different subsections of the system.
- The list is distributed to the experts. They discuss potential problems in the system.
- A facilitator (or a computer program) prompts the use of keywords and guide-words to stimulate thinking.
- Potential problems are recorded as they are discussed.

- The group aims to reach consensus on hazards associated with each part of the system to specify what needs to be done. These deliberations are summarized in an action sheet that summarizes cause, consequence, safeguards and actions for each hazard.
- Action sheets including deadlines for implementation are distributed to relevant operational personnel.
- Personnel are required to submit response files that document implementation feedback and any recommended additional actions. These are available for review and audit.
  (Burgman, 2005, p. 136)

Risk analysis

The purpose of risk analysis is to develop an understanding of the risk. Information about the sources and causes of risk, positive and negative consequences, and likelihood of occurrence is gathered and considered. The level of risk is also estimated. This information is then used as input when evaluating the risk and deciding whether risk response or treatment is necessary. The detail of the analysis can vary depending on the risk, purpose and information available. The analysis can further be either qualitative, quantitative, semi-quantitative or a combination of these (ISO, 2009, p. 18).

There are many different analysis techniques available and Smith et al. (2006) state that it is important to choose the appropriate technique for the project. Using the same technique for every project can be waste of both time and money e.g. by being too detailed for some situations but not enough detailed for others (Smith, Merna, & Jobling, 2006, p. 46). According to Carlsson (2005), the risk analysis should be a living document and updated whenever changes in the project occurs. Carlsson further states that one of the major advantages of risk analysis is that it increases the risk awareness of everyone involved (Carlsson M. , 2005, p. 17).

Risk evaluation

In the risk evaluation phase, the results from the risk analysis are compared with risk criteria established when setting the context in order to determine if the risk level is acceptable or not. This evaluation assists in decision making regarding which risks need treatment and their priority (ISO, 2009, p. 18).

There are different evaluation principles for defining risk tolerability. One example is the ALARP (As Low As Reasonably Practicable) principle. In this principle, risks are divided into three categories; acceptable, acceptable with restrictions (ALARP region) or unacceptable, see *Figure 5*.

Unacceptable risks need to be treated under any circumstances, acceptable risks do not require any further action. Risks in the ALARP region may be accepted if they are economically and/or technically unreasonable to reduce (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 12).

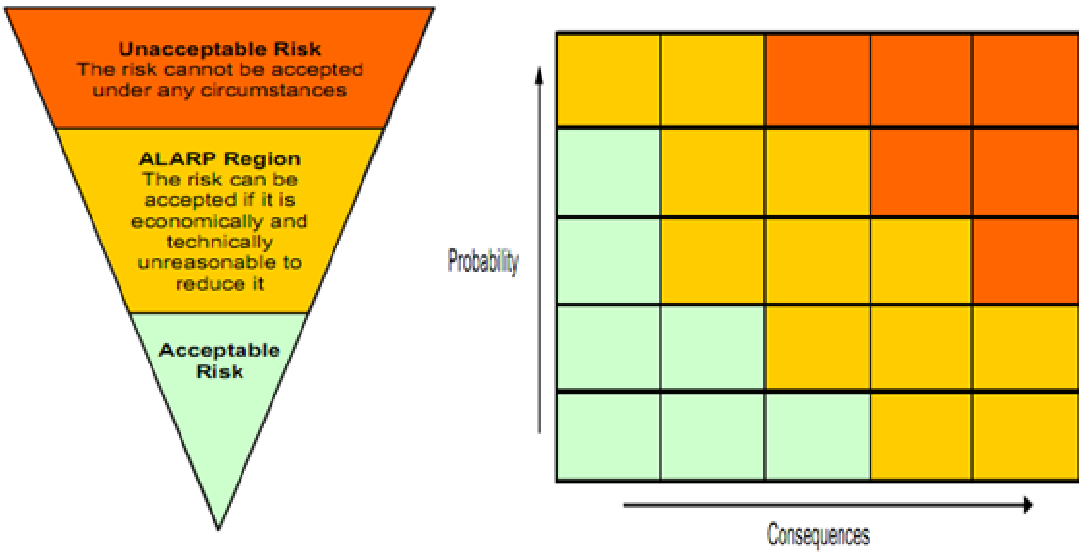


Figure 5. The ALARP (As Low As Reasonably Practicable) principle (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 13)

Other examples of principles that can be used are for example: "Principle of reasonableness", "Principle of proportionality", "Principle of allocation" and "Principle of avoidance of disasters" (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 13).

In the evaluation and decision-making it is important to take a wide context of the risk into account. Rosén et al. (2007) means that it is very important that the criteria and principles used in the evaluation of risks and in the decision-making are agreed upon by the affected stakeholders. Thus it is important to consider all stakeholders which in risk decision-making basically can be described as consisting of three categories (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007, p. 12);

- Decision makers
- Those exposed to risk
- Those benefiting from risk generating activities

Risk treatment

The risk treatment phase concerns how to deal with risks that are not acceptable. It involves selecting one or more options for modifying the risk and also implementing those options (ISO, 2009, p. 18). The treatment options are often said to be of four types; *risk avoidance*, *risk retention*, *risk transfer* and *risk reduction* (Carlsson M. , 2005; Osipova, 2008; Simu, 2006)

Risk avoidance means that the risks are avoided by deciding not to start or continue with the activity that gives rise to the risk.

Risk retention means accepting the presence of risk and leaving it untreated. It is a conscious choice of taking no action and is sometimes called passiveness (Carlsson M. , 2005).

Risk transfer means that the risks are transferred to another party which is willing to take the risk (Carlsson M. , 2005). The risk might be transferred to someone better equipped to deal with it. Another way to transfer risk is through insurance.

Risk reduction is about decreasing the probability, the consequences or a combination of those. Through preventive or limiting actions the risks are reduced or eliminated. This is the most common risk treatment option used in the construction industry (Osipova, 2008, p. 22; Carlsson M. , 2005, p. 43).

Another option can be *risk sharing* which means that risks are shared between individuals or organizations. This option is a combination of risk transfer and risk retention.

In the treatment phase a critical part is to identify in what way a risk should be treated but it is also important to identify when to treat it and find out who is most suitable to do so (Carlsson M. , 2005, p. 42). It is often easier and less costly to treat risks in an early phase than later in the project.

ISO 31000 points out that risk treatment itself can introduce risks e.g. through failure or ineffectiveness of the risk treatment measure. Therefore monitoring that the measures are effective is important (ISO, 2009, p. 19).

Risk management barriers

The predicted benefits of risk management are very promising but it might not always be very easy to implement. There are a lot of aspects, for instance both technical and social, that has to be considered for successful and effective risk management. Considering the benefits, Staveren (2007) finds it remarkable that the adoption of risk management is so slow in the construction industry and its geotechnical sub-sectors (Staveren, 2007, p. 8). In a research project about the implementation of risk management he identifies hurdles or barriers that obstruct or hinder successful risk management. Considering the social systems of project organizations he state that developing the technical aspects such as more risk management frameworks, protocols and tools does not seem to be sufficient for adopting risk management. Three identified aspects that according to his research can create barriers and need extra attention are (Staveren, 2007, p. 9):

1. *Motivation* of individual professionals to apply geotechnical risk management.
2. *Training* required to apply geotechnical risk management.
3. *Tools* required to apply geotechnical risk management.

The *motivational* aspect includes hurdles such as *lack of risk management awareness* and *lack of clear risk management benefits.* Another hurdle is *fear of risk transparency.* In some organizations for example risk equals problems and making them visible creates problems instead of solutions. This leads to risks being neglected instead of managed. *Difficulty to apply risk management* is one hurdle and reflects that risk management requires additional efforts in the daily work which in turn requires additional motivation. (Staveren, 2007, p. 18/26).

The *training* aspect has to do with *lack of knowledge and understanding* of concept and application of risk of risk management within infrastructural projects. Knowledge about for instance the activities and scope of risk management, the roles and responsibilities of the people involved is necessary for effective risk management. (Staveren, 2007, p. 18/26)

The third aspect, *tools*, refers to a perceived *lack of risk management methods, protocols, tools and data*. Even if the motivation and knowledge is there, an argument for not performing risk management can be that the organization does not have the appropriate risk management tools. However, Staveren (2007) state that there are many existing technologies and tools that can be used easily but also that just paper and pencil is sufficient for starting any risk management process. Therefore, the lack of tools argument, according to Staveren, is sometimes just a kind of alibi for a lack of real motivation. (Staveren, 2007, p. 9)

3.1.3 Risk communication

"Without effective communication, risk management cannot operate. Indeed, one of the biggest risks on any project is a lack of communication which can lead to a lack of shared understanding of the project and its objectives." (Smith, Merna, & Jobling, 2006, p. 238)

Carlsson (2005) states that all risk management activities are worthless unless they are properly communicated to the actors involved in the project. This is because awareness and knowledge of potential risks is essential for the result of the risk management (Carlsson M. , 2005, p. 54).

As seen in *Figure 4* above of the risk management process, communication and consultation is an important part of effective risk management and should take place during all stages of the process. The reason for this, according to ISO 31000, is to ensure that stakeholders and those responsible for realizing the risk management process understand the basis on which decisions are made and also the reasons why particular actions are required (ISO, 2009, p. 14). Communication of the project and risk management goals between different stakeholders increases the opportunities to cooperate with the risk management instead of working against each other because of different points of view.

In order to ensure proper communication, planning of how information will be communicated to all actors involved should be a part of the project plan. According to the guidelines of ISO 31000, the organization should establish internal communication and reporting mechanisms and also develop and implement a plan on how it will communicate with external stakeholders (ISO, 2009, p. 12). Effective communication is also necessary to make participants in the project feel involved in the process. If the project participants realize the benefits of risk management they become more motivated to implement it in a thorough way.

ISO 31000 state that accountability is an important part of the framework for effective risk management (ISO, 2009, p. 11). One way to facilitate this is to identify risk owners that have the accountability and authority to manage risks. According to Staveren (2006), it is of major importance to allocate all identified risks to the parties involved e.g. by appointing one or more risk owners to each identified risk (Staveren, 2006, s. 50). Communication and reporting mechanisms are important in order for all relevant information to be available at the appropriate levels and are a way to support and encourage accountability and ownership of risk (ISO, 2009, p. 12).

Risk communication can be complicated and it is important to know that there are obstacles that can prevent good communication. One important factor is how the risk is presented. Different ways of presenting the same risk information can lead to different interpretations by the receivers even though the logical content of the information is the same (Rosén, Hokstad, Lindhe, Sklet, & Røstum, 2007). According to Carlsson (2005), the characteristics of the sender and receiver of the information as well as the decision situation and the environment determine if the communication is successful or not. Peoples different risk perceptions is one aspect that complicates risk communication and the risk information should be adjusted to the receivers.

3.2 Peab's risk management

Peab is one of the Nordic countries´ leading companies in construction and civil engineering. They have 15.000 employees at over 100 locations in Sweden, Norway and Finland. Peab aim at having a decentralized organization and want to be "the obvious partner for community building in the Nordic region". (Peab, 2011)

In the construction industry risk is continuously present and therefore different levels of risk management as well. Since Peab is a decentralized organization structures differ a lot inside the organization but below are some of the common structures for risk management related to geotechnical issues.

According to Peab´s "skallsatser", which are internal focus areas that Peab as a corporation have decided to implement in all projects, a risk analysis should be carried out in the procurement phase of all projects over one million SEK. Depending on the size of the project, different levels of detail of the risk analysis is chosen. The risk analysis is performed in order to study the projects uncertainties in an economical point of view.

In the infrastructure department of Peab this risk analysis method is not used. Instead a document called "risks and possibilities" is created by the building estimator who analyzes the uncertainties of the project in an economical view. This document functions as their "notebook" during the calculation phase and is later used in the production. The document is discussed together with superiors before the bid is submitted to the client. The work structure with this document is similar to the risk analysis in Peab´s "skallsatser", but without the checklist. The geotechnical engineer is only involved in the procurement phase if the building estimator finds it necessary. This document is very dependent on the experience of the personnel and therefore the work structure for improved continuous feedback has been enhanced in recent years.(Norgren, 2011)

The Swedish Work Environment Act requires actors in the construction industry to follow legislation concerning the work environment. Since 2009, work environment responsibility has been divided as BAS-P and BAS-U in the different phases of a project. BAS-P is responsible in the planning and design phase to ensure that the production and use phases are possible to carry out according to the Work Environment Act. In the production phase BAS-U inherits the responsibility and has to follow and control that the production team is abiding the Work Environment legislation.(Östman, 2011)

Before the production phase a work environment plan and a project plan, also known as the quality and environmental plan, are made according to Peab´s "skallsatser". In order to get an overview of all planned supervisions related to work environment, quality and environment a control programme is established. The client still has a control responsibility and in order to meet that demand a common strategy from the client is to demand the contractor to do work preparations which the client can review before hazardous operations are started. (Östman, 2011)

Work preparations are also, according to Peab´s internal production handbook, made to find the optimal way to carry out an operation and in advance identify risks and shortcomings that can be avoided through an active action.

3.3 The Swedish Transport Administration’s risk management

The Swedish Transport Administration is the agency in Sweden responsible for all modes of traffic; traffic on roads and railways, on the sea and in the air. They are also responsible for building, maintaining and operating all national roads and railways. The agency’s overall aim is to ensure and provide nationally economic efficient and long-term sustainable transport for citizens and industry all over Sweden (Trafikverket, 2011).

Some quick facts about the Swedish Transport Administration (Romin, 2010):

- Annual grant of about 37 billion SEK.
- About 6200 employees.
- About 3000 investment objects with an annual budget over 20 billion.

According to Swedish decree, all Swedish authorities have to perform risk analysis as part of their operation. They are obligated to identify and value their risks and also to take appropriate measures to prevent damage or loss (Kammarkollegiet, 2011). This constitutes one of the external requirements of risk management that the agency have to follow. There are also other decrees, for instance (translated from Swedish); *internal management and control* (2007:603), *crisis management and increased state of readiness* (2006:942) and *government authorities risk management* (1995:1300). As a Swedish authority, the Swedish Transport Administration also has to follow the Swedish Public Procurement Act. This means for instance that they must strive to procure goods, services and contracts in competition and treat all tenderers equally. (Trafikverket, 2010)

The reasons for performing risk management are not only external but also internal. One of the main reasons is to increase the conditions and possibilities to achieve the agency’s goals. According to the Swedish Transport Administration, the purpose of risk management is: to be a support for effective business and economization of governmental resources and also to comply with external requirements of risk management, internal management and control. The overall aim of the risk management is to identify and, in a relevant and cost-efficient way, treat the risks that can affect the agency’s possibilities to achieve its goals (Trafikverket, 2010).

The Swedish Transport Administration (previous National Road Administration and Railway Administration) have worked with risk management for a long time. Different risk management systems or procedures have been used. However, these have not always been successful and their use therefore questioned (Johansson, 2011, p. 130). The difficulties of finding a useful system led to the risk management being performed in different ways in different areas and projects, thus there was no uniform structured process. It was therefore also difficult to follow-up and review the risks and a more systematic approach was sought after. When ISO 31000:2009 "*Risk management -- Principles and guidelines*" was published by the International Organization for Standardization, the Swedish Transport Administration were therefore quick to implement it in its operations. The work to introduce the new system and procedures has been going on since the autumn of 2010 and there is a deadline for it to be introduced in all projects by the end of 2011. New computer software has also been developed and is intended to be possible to use for all involved actors when working with the risk management (Jansson, 2011).

The risk management today is based on three internal documents (translated from Swedish); TDOK 2010:18 *internal provisions of risk management,* 2010:163 *strategy and governing criteria for internal regulation, control and risk management* and *Routines for risk management*. These are based on and follow ISO 31000. The agency's risk management framework and process are thus the same as the standards, see *Figure 6*. This process involves all the steps that are considered necessary for effective risk management according to the ISO standard.

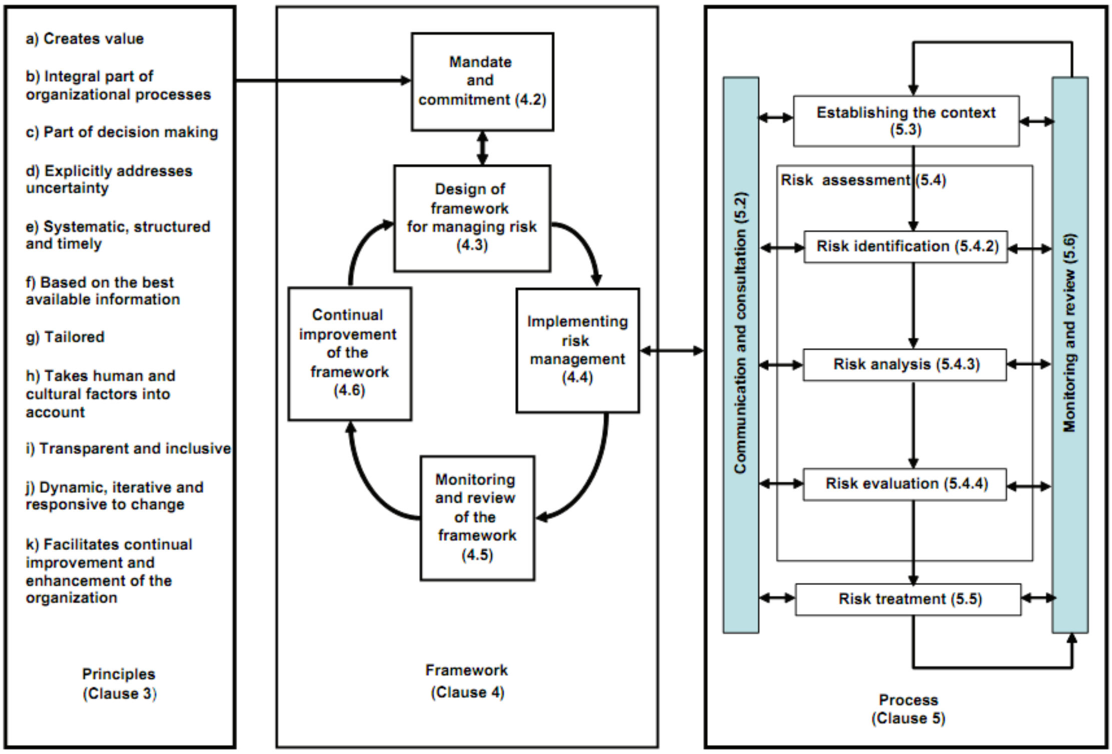


Figure 6. Risk management principles, framework and process (Trafikverket, 2010).

The Swedish Transport Administration states that the application of joint risk management processes in a comprehensive framework based on joint principles contribute to ensure that risks are handled effectively, appropriately and accordantly within the entire organization.

Some of the Swedish Transport Administration's policies for risks and risk management are for instance:

- Risk management is an integrated part of the operation management that contributes to the agency's result and long term development.
- To have work procedures to actively identify, analyze, document, handle, communicate and follow up all essential risks. –We act to minimize negative consequences and to seize opportunities.
- Everyone have relevant knowledge of risk management and feel the responsibility for- and lifting risks and possibilities to the appropriate person.

The risk management in the Swedish Transport Administration's investment projects is based on the framework seen in *Figure 7* below.

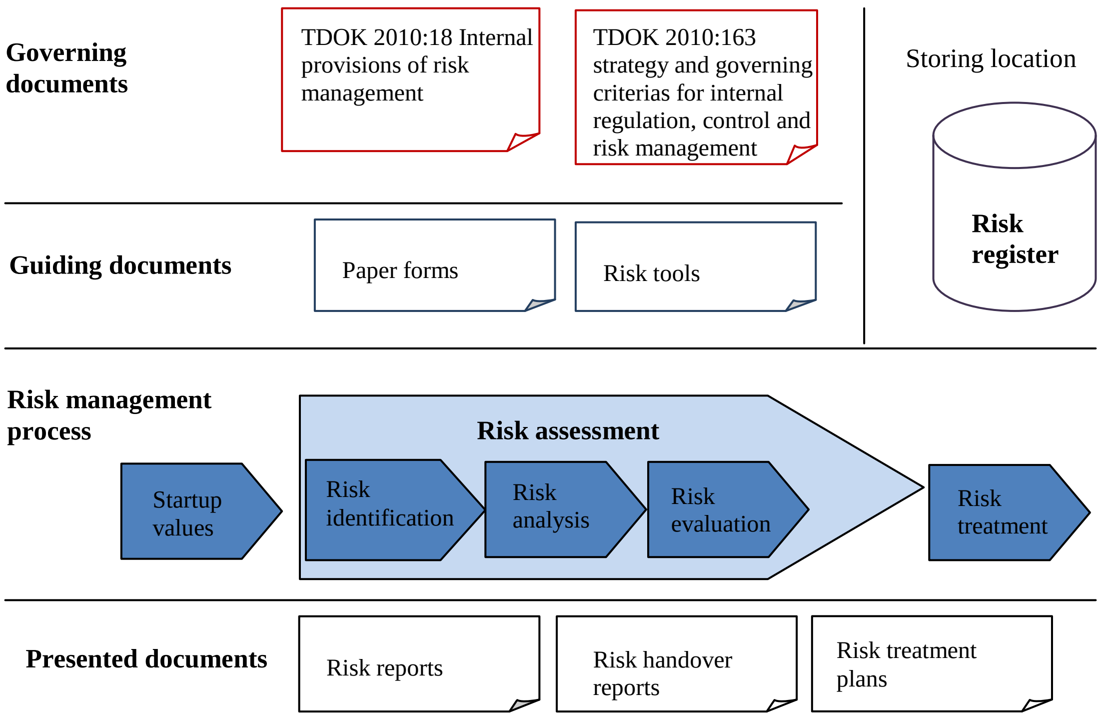


Figure 7. Framework for risk management in investment projects (Trafikverket, 2011).

Project leaders and other responsible managers in the project organization are responsible for the risks in their project and also to establish and maintain the risk management process. This includes engaging all involved actors such as contractors in the process and to continuously identify risks and appoint risk owners. They must also see to that risks continuously are analyzed, evaluated, treated, monitored and reported. Risk management and risk identification will be recurring subjects on the agenda of all start-, construction-, design- and coordination meetings. (Trafikverket, 2011)

According to the Swedish Transport Administration, systematic risk management will be applied in all phases of a project. Risks that are identified in early phases, before they are expected, are documented and handed over to later phases. The risk management will also be the same in all phases of a project.

The risk management process will in all projects and levels of management result in (Trafikverket, 2011):

- A gathered and updated view of the risk exposure.
- A gathered and updated view of the risk cost.
- A basis for decision-making regarding further risk treatment.
- A basis for strategical, tactical and operational organization decisions.
- A basis for the organization analysis of the Swedish Transport Administration.

When finishing a phase of a project, a risk handover report will be established and handed over the actor continuing the next phase. This report will form the basis of the risk management of that actor.

3.4 The construction process

In a construction project three major actors are involved: clients, contractors and consultants. The client can be a person, company, organization or authority that demands the construction and initiates the process. The client can be either private or public and often owns the construction after the project has ended. Contractors produce the construction at the client's request. (Nordstrand, 2008, pp. 7-8, 54) Consultants are hired to assist clients and contractors with expertise they do not possess e.g. design from engineers and architects. (Schaufelberger & Holm, 2002, pp. 3-5)

According to Nordstrand (2008, p. 13), the construction process can be simplified into four activities; the program phase, design phase, procurement phase and the production phase. Depending on whether the construction project is design-build or design-bid-build the procurement phase takes place before or after the design phase, see *Figure 8* below.

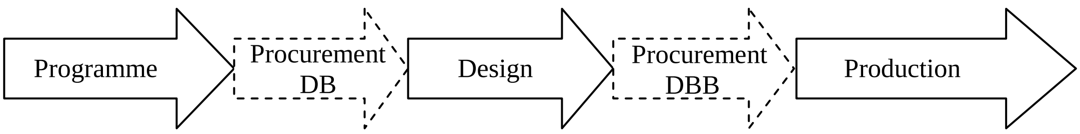


Figure 8. The four phases in a construction process.

In the programme phase the client carries out different investigations to be able to compile a building programme. In the building programme the client's demands on the construction are specified and conditions and terms for the project are listed.

Whether the tender documents contain construction drawings or not depends on which procurement option the client wants. If a design-bid-build project is preferred, the client hires consultants to produce the construction drawings before the procurement of the contractor. (Nordstrand, 2008, pp. 60-63) In *Figure 9*, contractual relationships between different actors in design-bid-build projects are shown.

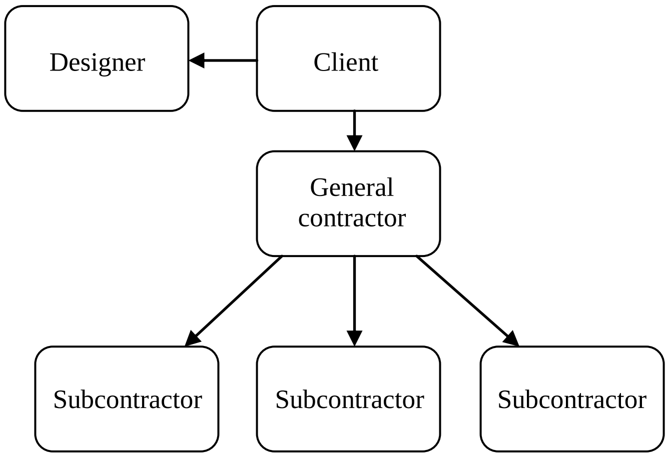


Figure 9. Example of contractual relationships between actors in design-bid-build project with general contractor.

If a design-build project is chosen, the tender documents for procurement of the contractor are mainly based on the building programme. (Nordstrand, 2008, pp. 62-63) See *Figure 10* for contracts between actors in design-build projects.

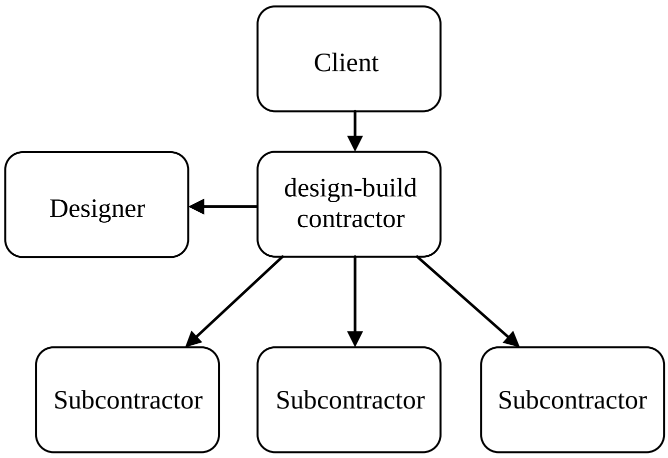


Figure 10. Example of contractual relationships between actors in a Design-Build project.

Cost, time and quality are the three most important factors when the client chooses procurement option (Ratnasabapathy & Rameezdeen, 2006, pp. 474-475). Schaufelberger and Holm (2002, p. 3) claim that the experience the client´s personnel possess and how much risk the client is willing to be responsible for, are the main factors when procurement options are chosen. In the Swedish construction industry, time and price are stated to be the most important factors (Osipova, 2008, p. 35). Time and price with the addition of uncertainties are the factors that influence the choice of procurement option most (Toolanen, 2006, pp. 572-582). Through a study of construction companies in Sweden Toolanen (2006) shows that in projects where uncertainty, complexity and time are regarded as well-known, simple and not short of time, design-bid-build procurement are favored. When projects tend to be more complex, the uncertainties increase and there is a shortage in time, design-build procurements are preferred. Above-mentioned research concludes that design-build projects certainly allow the project to start earlier but also that they might be more expensive for the client. The contractor might choose cheaper solutions in order to decrease his own costs, which may lower the quality of design-build projects. Possibilities for better control and decreased project costs open up if the client has the knowledge and the resources to carry out a design-bid-build project

Sweden has, as many other countries, developed standardized contracts for the construction industry. These contracts are used in the majority of all construction projects in Sweden and are developed and issued by the Building Contracts Committee (BKK). In Design-Bid-Build projects “General Conditions of Contract for Building, Civil Engineering and Installation Work” (AB) are often referred to. ”General Conditions of Contract for Building, Civil Engineering and Installation Work performed on a package deal basis” (ABT) are in general used in design-build projects. BKK develops and issues other standard contracts that concern agreements which include other actors in the construction industry as well, e.g. consultants and subcontractors. In all of these standardized contracts responsibilities and liabilities of the actors concerned with the contract are provided, e.g. job performance, timeframes and errors. (Byggandets Kontraktskommitté, 2011)

Osipova (2008) researched about differences in risk management between design-bid-build and design-build projects in the Swedish construction industry. Results from the research conclude that degree of satisfaction in the risk management and different procurement options have a clear connection. If responsibilities for design and construction are divided, as in design-bid-build projects, transfer of information and knowledge might be unsatisfactory since the open communication about risk is low. Risk management in design-build projects works more satisfactory due to earlier involvement of the contractor. Furthermore it is stated that risk communication between client and contractor is very low in the procurement phase. One reason for this can be the pursue to keep the bid price low at the expense of not raising or analyzing risks. According to Osipova this can lead to the consequence that risks are not avoided, which they could have been with better risk communication. Avoiding the risk would benefit more than one actor. (Osipova, 2008, pp. 33-38)

According to Tengborg different procurement options also affect how responsibilities of risks are divided between client and contractor. *Figure 11* shows how the contractor has larger responsibilities in design-build projects and in design-bid-build the client carry the largest responsibilities. (Tengborg, 1998)

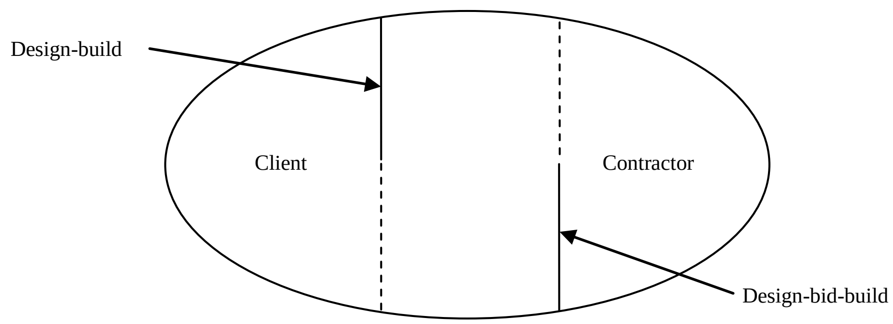


Figure 11. Distribution of risk responsibilities in different procurement options (after Tengborg, 1998).

Communication in the construction process

A construction process in general proceeds sequentially, and the organization can be compared to a relay race in which communication between the various project phases is limited. Several actors are only involved in certain phases where they tend to focus only on their own part rather than the project as a whole. This leads to loss of information and knowledge, including information of identified risks, between the phases. (Carlsson B. , 2006, pp. 58-60)

A study about the Swedish construction industry by Carlsson and Josepson (2001) concludes that the major cause of problems in construction projects is lack of communication between actors (Carlsson & Josephson, 2001, p. 9). They report that although the communication work properly in many aspects, the potential for a more efficient construction process is dependent on better communication. The client´s effort is of significant importance to enhance the communication. Their study also shows that more than a third of all communication is about changes, errors or defects. Especially in design-bid-build projects, the communication in different phases is inadequate due to the limited contact between contractor and designer, which increase changes, errors and defects that needs to be communicated. Lack of communication in different phases of a project also prevents experience feedback and knowledge building between actors. The study also suggests different actions that would improve the construction process and the two most important improvements were that "Actors should be chosen by competence and not by money" and "Always have a start-up meeting when the project change phase". (Carlsson & Josephson, 2001, pp. 66-72)

In a follow up study carried out by Carlsson (2006), the estimated amount of communication related to changes, errors or defects is fifty percent. The study also highlights that this type of communication often is time consuming and therefore results in less time available for other issues which in turn can lead to more errors and defects. This type of communication is also often connected to economic regulation which is not beneficial for the end product. Solutions to the issue of too many changes, errors and defects can often be connected to the availability of correct competence and time in planning phase which is mostly the client's responsibility. To be able to decrease the knowledge loss in the changes between different project phases as much as possible the start-up meetings are very important, see *Figure 12*. The study shows that successive meetings with participants from more specific knowledge areas and also a meeting after the completion of a project with exchange of experiences enhance knowledge dissemination and communication both during and after the project. (Carlsson B. , 2006, pp. 57-60)

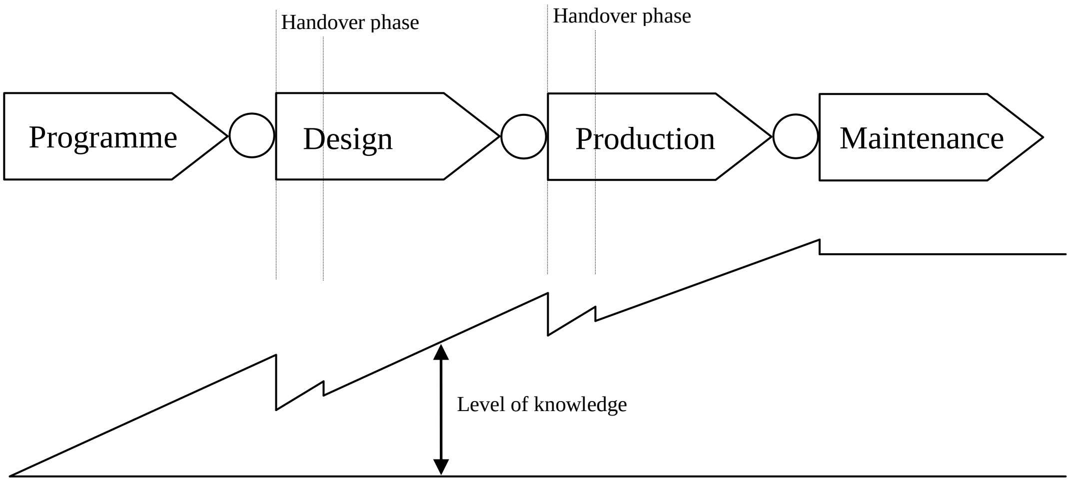


Figure 12. Level of knowledge in a construction process (after Carlsson & Josephson, 2001).

Furthermore, Carlsson conclude that the counterpart relationships that exist in design-bid-build projects prevent the actors from using their full professional competence. Therefore, usage of procurement options that limits the barriers between actors to a greater extent is recommended. Then more communication can be focused on knowledge sharing and the level of ambition. (Carlsson B. , 2006, pp. 57-60)

One way to divide risks associated with the production phase of a construction process is seen in *Figure 13*.

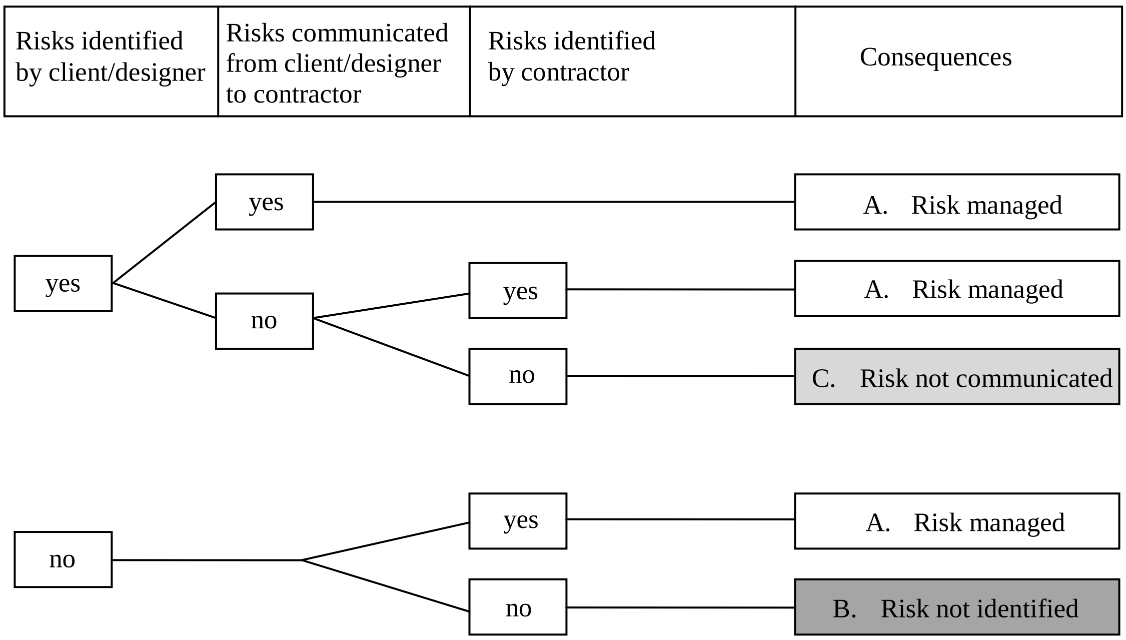


Figure 13. Consequences of risks dependent on risk communication and risk identification.

Through better risk communication to the contractor, risks identified by client or designer can be avoided, see consequence C. Hopefully, enhanced risk communication also improves the cooperation between client, designer and contractor in identification of hazards, which decreases the risks that fall into Consequence B.

A well known graph is shown below in *Figure 14*. The graph shows how the cost of changes and the possibility to implement them highly depend on the time elapsed in the project (Platen, 2009, p. 41).

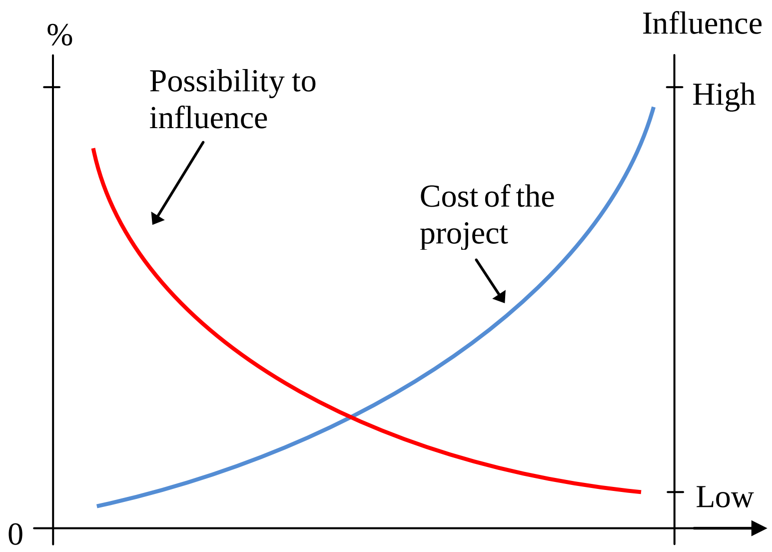


Figure 14. Illustration of cost and influence of changes in a project over time (after Platen, 2009).

3.5 Geotechnics and geotechnical risks

The purpose of this chapter is to briefly introduce the subject of geotechnics, discuss the sources of geotechnical risks and also to give some examples of common geotechnical problems that need extra attention in infrastructure projects.

Geotechnics is often wrongly mistaken for geology but geology is the science of the earth, a science that explores, investigates and describes the structure and evolvement of the earth. Geotechnics on the other hand is the science about the technical properties of soil and rock and their application in design and construction, including technical solutions and building methods. (Swedish Geotechnical Institute, 2011).

Sällfors gives an easily understood description of geotechnics (Sällfors, 2001, p. 1.1):

"All kinds of building and construction work that humans perform, it may be houses, bridges, roads etc., means that loads from these constructions must be transferred to the ground. These loads must be transferred in a way that does not cause fractures in the ground or settlements that threaten the function of the construction. Geotechnics deals with the knowledge necessary for safe construction in and on the ground."

Before building on the ground, a geotechnical engineer investigates the site to evaluate the type of ground, its stratification in layers and the properties of the different layers in terms of deformation and strength. Based on this knowledge the bearing capacity must be estimated and a suitable foundation method chosen, which includes deciding the reinforcement needed for the structure to be able to support the loads it will be exposed to (Swedish Geotechnical Institute, 2011). According to

Sällfors, the most suitable foundation method is often considered to be the one that fulfils the requirements to the lowest cost (Sällfors, 2001). One difficulty that Sällfors points out is that while a building designer works with materials with well defined properties, a geotechnical engineer has to consider a variation in properties that can be up to a thousand times greater (Sällfors, 2001).

This variation in properties is difficult to assess and manage which results in uncertainty about the geotechnical conditions. Van Staveren (2007) states that one of the challenges of geotechnical engineering is the inherent uncertainty of ground conditions. No matter how extensive investigation programs are made, information of ground conditions always to some degree remains random, fuzzy and incomplete (Staveren, 2007). One way of trying to manage this uncertainty is by applying safety factors in the geotechnical design. Van Staveren argues that suitable safety factors are necessary but at the same time notes that we need to be critical about them as well. He points out that "*just sticking to the ruling design codes and standards with their recommended safety factors is not sufficient anymore in today's demanding construction industry"* (Staveren, 2007, p. 10). According to Staveren, the application of risk management and development or risk aware attitudes must be improved in the construction industry.

Uncertainty of ground conditions is not the only difficulty in geotechnical engineering. Based on research from Clayton, McMahon and Trenter among others, Baynes (2010) summarizes types of geotechnical risks, associated hazards and the primary sources of these hazards in *Table 4*. According to Baynes, geotechnical risks can be divided into three categories: those associated with project management and those that relate to technical and contractual matters. Clayton notes that technical risks arise from problems on a site for instance soft ground or contaminated land, contract risk concerns the type of contract that the developer/client chooses to use, and project management concerns how the project manager chooses to manage the project. (Baynes, 2010, p. 321)

Table 4. Sources of geotechnical risks (Baynes, 2010).

<table>
<tr><th colspan="2">Type of geotechnical risk</th><th>Hazard</th><th>Source</th></tr>
<tr><td colspan="2">Project management</td><td>Poor management of entire geo-engineering process</td><td>An inadequate understanding of the importance of ground conditions resulting in poor management of the entire geo-engineering process e.g. a decision to submit a tender price with no risk weighting for geotechnical factors.</td></tr>
<tr><td colspan="2">Contractual</td><td>Poor management of site investigation and contract documentation</td><td>An inadequate understanding of the importance of ground conditions resulting in poor acquisition, understanding and/or communication of site investigation information; this often leads to claims based on contractually unforeseen ground conditions.</td></tr>
<tr><td rowspan="5">Technical</td><td>Analytical</td><td>Unreasonable analytical model chosen</td><td>An inadequate understanding of ground conditions and analytical methods, resulting in an unreasonable choice of analytical models.</td></tr>
<tr><td>Properties</td><td>Unreasonable design values chosen</td><td>An inadequate understanding of ground conditions and field and laboratory testing, resulting in an unreasonable choice of design values.</td></tr>
<tr><td rowspan="3">Geological</td><td>Unforeseeable geological details</td><td>Geological conditions that are very variable, and because investigations of all geological details is impractical.</td></tr>
<tr><td>Inherently hazardous ground conditions</td><td>Geological conditions and geological processes that involve hazards such as large ground movements, voids, aggressive chemistry, erosion, etc.</td></tr>
<tr><td>Unforeseen ground conditions</td><td>An inadequate understanding of geological conditions resulting in unforeseen ground conditions being encountered during construction, often because of an inadequate site investigation due to poor project management.</td></tr>
</table>

Baynes states that various risks are inter-related and therefore the sources are also inter-related. *Table 4* indicates that there are only two ultimate sources of geotechnical risks (Baynes, 2010, p. 324):

1. Project staff responsible for the geo-engineering process who have an inadequate understanding of the ground conditions and/or who do not appreciate the importance of ground conditions.
2. Geological conditions or geological processes that are difficult to investigate or inherently hazardous.

Technical risks can further be divided into those associated with the engineering analysis, those associated with the geological model and those associated with the engineering properties used in the analysis (Baynes, 2010). The most frequent sources to ground related risks in construction according to Clayton can be seen in *Table 5*. A problem identified by Clayton is that even though the conditions with good methods for site and laboratory investigations exist, the pre-knowledge of the geotechnical conditions is in general still poor. Two reasons for this are that only a minor part of a total project budget is spent on geotechnical site investigations and also that they often are procured according to the lowest bid (Carlsson M. , 2005, p. 66).

Table 5. Sources to ground-related risks in construction (Carlsson M. , 2005, p. 66).

Risks related to	**[%]**
Soil boundaries	22
Soil properties	20
Groundwater	13
Contamination	11
Obstructions	10
Site investigation	9
Services	6
Detailed design	5
Other	4

Baynes (2010) also studies the rates of occurrence of different geotechnical risks but states that there is very little information available. He presumes this is because a natural disinclination to discuss failures. From his studies he however concludes that based on past performance the likelihood of experiencing a significant geotechnical risk in the form of a cost or time over-run on a major project is somewhere between 20 and 50%. The likelihood of a physical failure however is much less, as low as 1 or 2% for civil engineering projects. He also concludes that "*the ground conditions and the project staff responsible for the geo-engineering process are both significant sources of geotechnical risk and the project staff may actually be the largest source*" (Baynes, 2010, p. 330). Tengborg indentifies similar types of risk as those in *Table 4* and also means that organizational and contractual risks are not as obvious as risks related to technical issues and therefore often neglected (Tengborg, 1998).

3.5.1 Example of a common geotechnical problem; landslides

One important geotechnical issue that can cause great damage if not properly considered are landslides, which are quick mass movements in the soil or bedrock. These are often due to a natural erosion process, but can also be triggered by human activities (Swedish Civil Contingencies Agency, 2010). Two different types of landslides are shown in *Figure 15.*

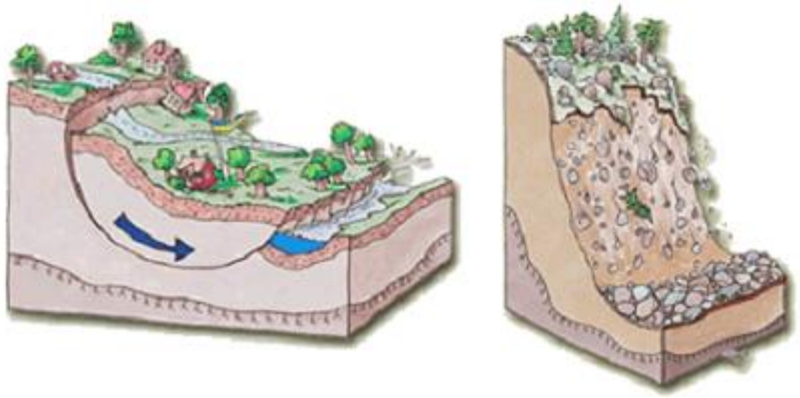


Figure 15. Different types of slides (Swedish Civil Contingencies Agency, 2010).

There are different types of landslides depending on the type of soil, ground- and topography conditions. The most common types in the Region of Västra Götaland, where the three projects studied in this thesis are located, are slides in clay. This is because the region is part of the area that is below the so called highest coastline where the clay in Sweden mainly is located; see *Figure 16* (Swedish Geotechnical Institute, 2011). Clay areas with a slope greater than 1:10 and steep slopes in silt- and sand areas are generally considered to fulfil the prerequisites necessary for slides to occur. They can also occur in more flat areas but are then often triggered by human impacts. When we build houses, roads and dams etc. we change the natural geometry of the ground with excavations, mass fillings and loading of the ground. Nowadays, this is a common trigger of big slides.

Figure 16. Location of the highest coastline in Sweden (Swedish Geotechnical Institute, 2011).

The stability of a slope is determined by the properties and structure of the soil, the groundwater- and topographic conditions. A slide occur due to failure along a slip surface in the soil and the soil layers above the surface are affected partly by driving forces and partly by resisting (stabilizing) shear forces (Swedish Geotechnical Institute, 2011). Before a slide, the slope and these forces are adapted to a state of equilibrium by natural erosion but when the equilibrium is disturbed a slide can occur. The disturbance can be an increase of load, reduced counterbalance or reduced soil strength, see *Figure 17* (Swedish Geotechnical Institute, 2011).

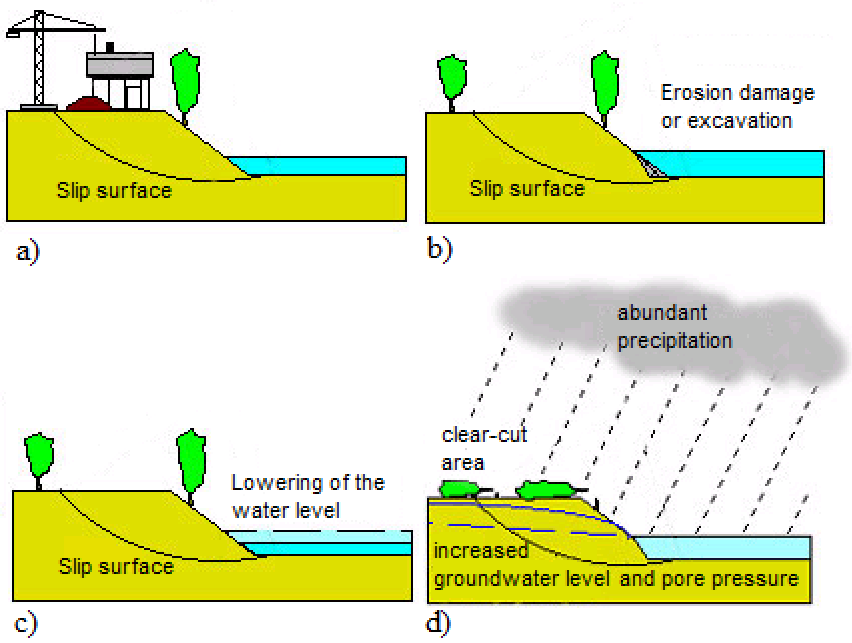


Figure 17. Sources of slides: a) increased load, b) and c) reduced counterbalance, d) reduced soil strength (Swedish Geotechnical Institute, 2011).

a) Increased load can for instance be new development or filling of masses on the crest of the slope which results in an increase of the driving forces.

b) Part of the counterbalancing masses at the slope bottom can e.g. be eroded by water or excavated which lowers the stability.

c) In streams or lakes the load from the water functions as a resisting force against the slope. If the water level is lowered the stability decreases.

d) An increased water level, due to e.g. abundant precipitation, increases the pore pressure which lead to reduced soil strength and reduced stability.

To avoid landslides due to these sources there are preventive measures that can be taken. For clay and fine-grained soils some of the measures are presented below, see also *Figures 18-21* (Swedish Civil Contingencies Agency, 2010).

- Put out erosion protection along streams and lakes.
- Decrease the load on the slope through excavation or flattening.
- Reinforce the slope through supportive embankments, lime/cement columns, anchoring of soil etc.
- Redirect streams in other directions or into culverts.
- Lower or limit the pore pressure.

The lower part of a slope exposed to erosion can be restored with replacement fillings and by putting out erosion protection along the stream, see *Figure 18*.

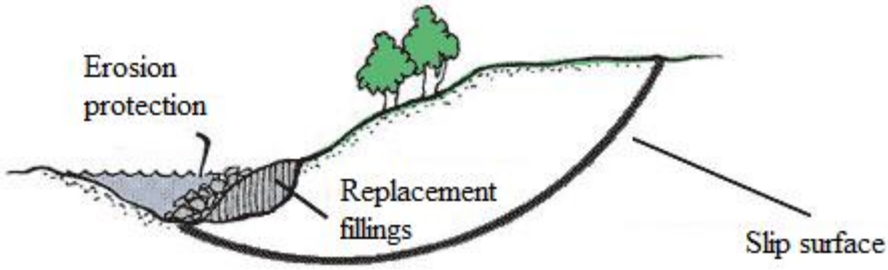


Figure 18. Slope restoration with erosion protection (Swedish Civil Contingencies Agency, 2010).

On steep slopes, embankments that support and flatten the slope can be made. The load on the slope can be reduced by excavation of the upper part of the slope or by making it flatter, *Figure 19*.

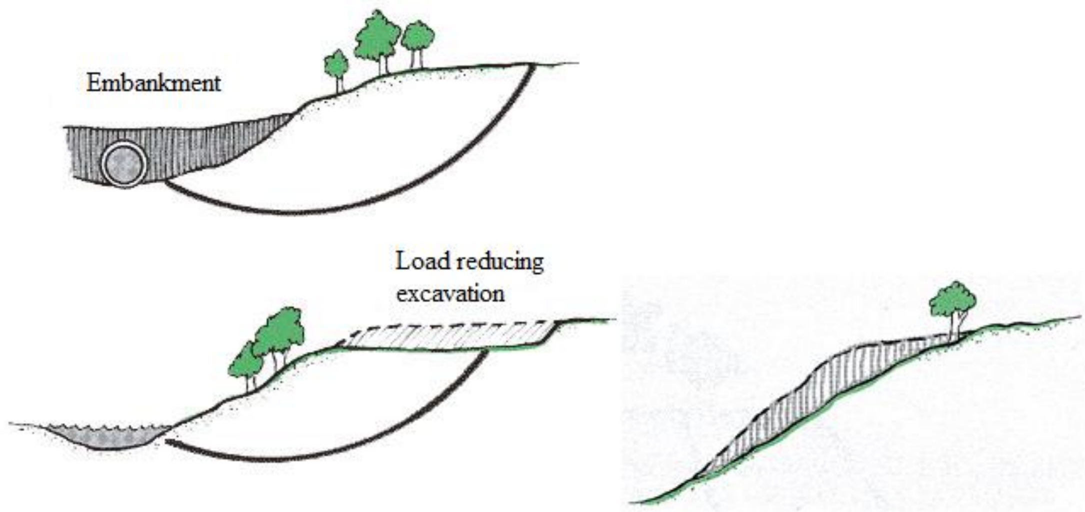


Figure 19. Support embankment, excavation of slope crest and flattening of the slope (Swedish Civil Contingencies Agency, 2010).

The slope can be reinforced by installing lime/cement columns, *Figure 20*. These are installed into the soil layers down to a depth well below the predicted slip surface and improve the strength and stability of the soil.

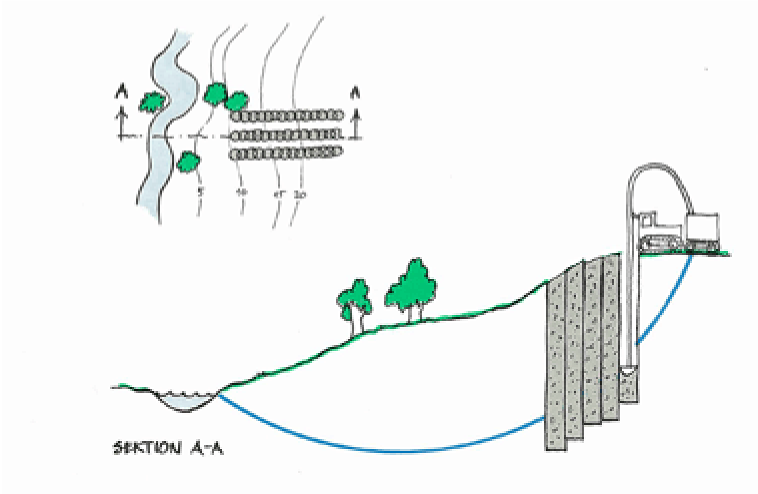


Figure 20. Reinforcement with lime/cement columns (Swedish Civil Contingencies Agency, 2010).

Slopes can also be reinforced by anchoring the soil. The anchors or nails go into the layers below the slip surface and thereby improves the stability, *Figure 21*.

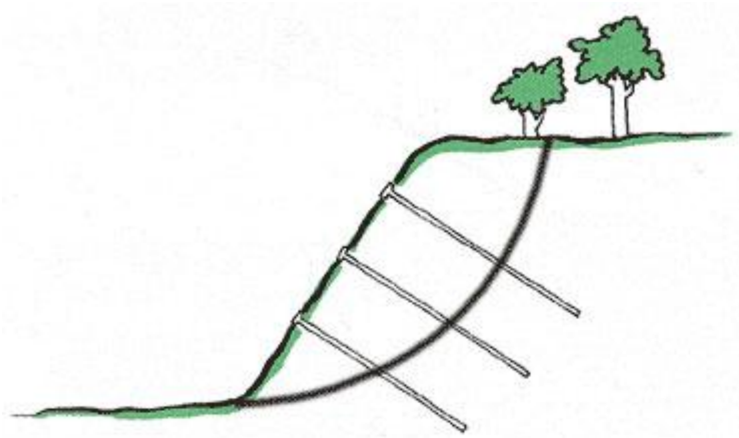
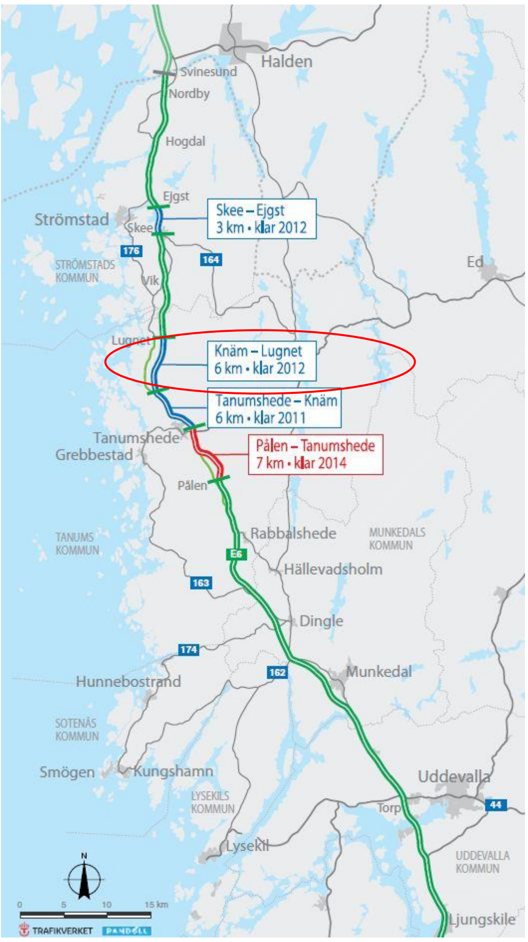


Figure 21. Anchoring of slope (Swedish Civil Contingencies Agency, 2010).

4 Case study

This chapter briefly introduces and describes the three infrastructure projects examined.

4.1 E6 Knäm-Lugnet



Stretch: E6 Knäm-Lugnet

- Client: The Swedish Transport Administration
- Designer: Vectura
- Contractor: Peab
- Procurement option: Design-bid-build
- Cost: 310 million SEK
- Standard: 6km motorway
- Width: 18.5m with 1.5m central reservation
- Schedule: 2010-2012

Figure 22. The stretch of Knäm-Lugnet (Trafikverket, 2011).

Road E6 north of Uddevalla is, in areas not expanded, mainly only a two-lane road. Therefore currently both availability and traffic safety are unsatisfactory. The new road E6 will be a four-lane motorway with central reservation and have speeding limit in accordance with Swedish motorways. The stretch will have a new orientation and the old E6 will therefore be used as local road. The new orientation results in five new bridges, often built to avoid barriers in the environment, and a new interchange, Knämmotet. The landscape is characterized by changes between rocky ground and forest. Due to the ancient remains dated to the Stone Age in the area, archeological excavations precede production. (Trafikverket, 2010)

4.2 E45 Älvängen-Ramstorp

Stretch: E45 Älvängen-Ramstorp

- Client: The Swedish Transport Administration
- Designer: Sweco
- Contractor: Peab
- Procurement option: design-bid-build
- Cost: 340 million SEK
- Standard: 5km motorway
- Width: 18.5m with 1.5m central reservation
- Schedule: 2011–2012

Figure 23. The stretch of Älvängen-Ramstorp(Trafikverket, 2011).

At the E45 stretch between Älvängen and Ramstorp, the two-lane road is to be replaced by or extended into a four-lane motorway. The new motorway will be 18.5m wide with central reservation mainly of gravel or grass and wire rope barriers. The orientation of the stretch is in some places new and there the old two-lane road will be used as local road when the new one is completed. Two new interchanges, Södra Skepplandamotet and Norra Skepplandamotet, and one bridge over Grönån will be built. A small stretch of the river Grönån will be redirected and erosion protection on the river valley slope and the bottom of the river will be placed out. The arable land between Grönån and the new road will be constructed with low inclination, thus work as protection against high flows in Grönån. In the area around Grönån there are deep layers of clay and therefore soil stabilization of lime-cement columns are needed. At the northern parts of the stretch, rock cuts needs to be done. This stretch is one part of "BanaVäg i Väst", which is a big infrastructure project in the western part of Sweden. This project will, when it is completed, heighten the capacity for both railway and roads through its new two-track railway and four-lane highway all the way from Göteborg to Trollhättan. (Trafikverket, 2011)

4.3 E45 Torpa-Stenröset

Figure 24. The stretch of Torpa-Stenröset (Trafikverket, 2011).

Stretch: E45 Torpa-Stenröset

- Client: The Swedish Transport Administration
- Designer: WSP/Geotechnica
- Contractor: Peab
- Procurement option: design-build
- Cost: 360 million SEK
- Standard: 6km motorway
- Width: 18.5m with 1.5m central reservation
- Schedule: 2011–2012

Road E45 between Göteborg and Trollhättan is heavily trafficked and has reached its capacity limit. Therefore, in the stretch between Torpa and Stenröset, the two-lane road is to be replaced or extended by a four-lane motorway. The new motorway will be 18.5m wide with central reservation of gravel and wire rope barriers. To a great extent the orientation of the stretch is new and therefore the old two-lane road will be used as local road when the new one is completed. The new motorway will get a new bridge over Slumpån, funding of this is however not cleared yet, and a new interchange where it crosses Sjuntorpsvägen. In addition, the new road will go through pipes to allow a fauna passage over the road near Rämje. In the beginning of the stretch, in the valley around Slumpån, the stability of the clay is very low. Excavation, stabilization with lime-cement columns and placement of erosion protection are carried out to enable the construction of the road. In those places where the new road has to be constructed near existing buildings, noise-reducing ground modeling will be carried out. Throughout the entire stretch focus is to minimize the visual impact of the new road in the landscape. Means to achieve this is through restricted use of rock cuts, a smooth road line and re-planting of vegetation. This stretch is also a part of "BanaVäg i Väst".(Trafikverket, 2011)

5 Result

In the result, information related to geotechnical risk in the case study is presented and the answers from the interviews are summarized in English. See Appendix 1 for the interview questions.

5.1 Result from study of projects

Projects of this size and cost contain enormous amounts of documents in the tender documents and since all of these projects are road stretches much of the information are related to geotechnics in some way. There is of course a big difference in the tender documents in general since the design-bid-build projects are designed before the procurement phase but in the design-build project there are only functionality requirements. We have tried to examine if there has been any difference in the material given for the design-bid-build projects and the design-build project related to geotechnical risks and demands for supervision.

5.1.1 Geotechnical information in the tender document

As mentioned above geotechnics is interconnected with many parts of infrastructure projects e.g. work environment and quality. We have tried to sort out some of the information in the tender documents of importance for the geotechnical engineers.

Uncertainty analysis

In all projects an uncertainty analysis has been attached in the tender documents. These documents cover a variety of risks e.g. work environment, economy, quality, company image and time.

In the Knäm-Lugnet project different risks has been listed very generically and then they have been assigned a number of probability and consequence. The risks that are relevant for a geotechnical engineer are: terrain modelling of surplus material, extreme rainfall obstructs excavations, deep excavations and high embankment. No further information is stated in the document.

In the Älvängen-Ramstorp project's uncertainty analysis there is an introductory text that states that "this paper is a preparation of risks and risky operations identified in the design phase" furthermore it states "the contractor should continuously follow up identified risky operations through work preparations and notify the client". The risks are more thoroughly explained and some areas of concern for a geotechnical engineer are: permanent mass storage, temporary mass storage, quick clay in the area, settlements of bridge due to lime-cement columns. All of these risks have been divided in sub-risks dependent on location on the stretch. Measures to the risks are also stated. Some blank pages are attached in the end intended to be used by the contractor to write down identified risks.

In the Torpa-Stenröset project the uncertainty analysis risks are described quite generically and given a probability and consequence. There have however also been noted measures and what kind of measures it is e.g. risk reduction, risk avoidance and transfer of risk. Furthermore some risks have been assigned an owner through risk allocation. Some risks that can be of interest for geotechnical engineers are: failure of slopes outside road area during production, settlements due to short lay times, contractor´s handling of excavations and transportation of masses leads to landslides.

Demands of supervision and risk management related to geotechnics specified in tender documents

In the tender documents for the design-bid-build projects demands of supervision related to geotechnics are listed in the object specific technical description and administrative regulations. In the design-build project it is listed in the functionality requirements or administrative regulations. Most of the requirements are the same for the three projects such as:

- In the contractor´s organization a qualified geotechnical engineer should design and make calculations when necessary according to geotechnical conditions in the production phase.
- Work preparations should be done by contractor and reviewed by client for operations concerning existing constructions, public traffic and operations that can affect time schedule or cost of the project.
- Work preparations should be done by contractor and reviewed by client for all operations where difference between excavation and embankment >2m.
- Work preparations should be done by contractor and reviewed by client if the soil has shear strength <10kPa. (projects in "BanaVäg i Väst")

In all projects the client demands that the contractor perform risk management with a structured work procedure that include risk identification, risk valuation and risk treatment in all phases of the project... regarding quality of the product, safety, work environment and environment. The tender document further states that the client´s uncertainty analysis should be the basis for the risk management and be the minimum level. The risk management should be documented in a risk management plan and be part of the project plan. It should be updated and reviewed continuously at building meetings". "The client should in collaboration with the contractor be given the possibility to identify and value possible risks."

In the two design-bid-build projects it is stated that geotechnical meetings should take place every month, however there is no information about whom of the actors that should call for the meeting. The contractor´s geotechnical engineer and site manager should be present. The contractor´s geotechnical engineer should attend site meetings as well. In the design-build project the contractor´s geotechnical engineer should attend design meetings and building meetings instead.

In the two projects that are part of "BanaVäg i Väst" it is stated that all personnel on-site should be attending a geotechnical education about the conditions on-site.

5.2 Result from the interviews

The answers from the interviews were summarized in English and sorted into the different areas of the study; Opinions and experiences of design-build projects, Lack of structured risk management, Individual responsibility for the success of the project and Attitudes and focus in the business.

5.2.1 Opinions and experiences of design-build projects

Few of the interviewees have worked much with design-build projects before and therefore find it difficult to compare between design-build and design-bid-build projects. Experienced differences in geotechnical risk management, due to different procurement option, among the three different projects have therefore been very limited. The results, however, reflect other experiences and views they still have about the contract form.

Design-build advantages

“You can get more road for the money in a design-build project” –Contractor

One of the advantages mentioned with design-build projects is that the time needed for the project can be shortened. This can of course also be seen as a disadvantage which is mentioned in the disadvantages below.

One of the client's geotechnical engineers considers one advantage with design-build projects to be that when the contractor is responsible for the design, more knowledge of the production phase can be considered in the design phase. He thinks that the client hopes that closer cooperation between the designer and contractor will lead to new ideas and solutions. Another geotechnical engineer from the client side also believes that one advantage is that the cooperation can result in new building-solutions. He believes, however, that the quality of the result will depend on how times of guarantee or functionality responsibility for the contractor are applied in the project.

A contractor´s geotechnical engineer believes that designers appreciate to work closer to the production in a design-build project. Also, he believes that cooperation between designer and contractor may contribute to new technology being developed. All of the contractor´s geotechnical engineers also see an advantage in that you get a better transfer of knowledge and experiences between the designer and contractor, which can be useful in the design phase. This will hopefully lead to a design that take in consideration in which way the specific contractor wants to operate the production. In addition, design-build projects may be a way to optimize what you get for your money.

To get the same quality for a lower price is also considered to be the advantage by a client´s geotechnical engineer. However, he thinks that it is necessary with periods of guarantee for the function of the road and tells of a project where it had been necessary to repave the road after only eight years.

Disadvantages

“Who says that it is the contractor that will come with new ideas in the construction industry?” –Designer

A disadvantage with design-build projects that both client and designer mention is that it is believed that the contractor give quality and aesthetics low priority. A geotechnical engineer from the client says that some project managers within the organization compare design build projects with buying "a pig in a poke" because they have no right to ask how the road construction should be performed, they can only set a cash prize of what it should cost to build the road from point A to point B.

From both the client-side and design-side it is argued that the designers are more regulated when they are hired by the contractor compared to when they are hired by the Swedish Transport Administration. A designer says that it is only money and time that govern when working for contractors. The Swedish Transport Administration pays better and is easier to get along with so disputes are not as common when working with them.

At the client-side it is also believed that the designer probably will be more controlled and under pressure in a design-build project, which can be a disadvantage. A client´s geotechnical engineer, who previously has worked as a designer, says that when he as a designer was given the possibility to thoroughly work through the design, he felt that the result was improved. Another of the client´s geotechnical engineers who also previously worked as a designer is sceptical of design-build projects and believes that a designer contracted by the Swedish Transport Administration has fairly decent conditions. With a contractor as a client on the other hand he believes that the conditions are tougher and the designer is more controlled and pressured to finish in time. He therefore does not believe that design-build project automatically induce a better exchange of experience, which is often considered one of the benefits. In addition, the harder control does not give the designer the same opportunities to examine different possible solutions to find the best.

A designer´s geotechnical engineer considers it a problem that design-build projects today are too regulated already by the client. The contractor should be freer to manage the project in his own way. However, he deems that design-bid-build projects should be more regulated in certain aspects to simplify for the contractor and to ensure that the safest approach is used. However, he thinks it is difficult to say where to draw the line for how much control there should be.

The client-side mentions the problem that sometimes the contractor’s knowledge is insufficient for design-build-contracts. A client´s geotechnical engineer finds that the contractor sometimes asks the Swedish Transport Administration about things in the planning meetings that they themselves should know since they are the ones responsible in a design-build project. He also believes that a problem is that contractors sometimes do not try to come up with a solution proposal that can then be discussed, although it is their job to do so. He believes this is because the contractor is not used to work in this manner since in a design-bid-build project they just manage the production. An additional problem can be that the contractor is unaccustomed to see to the whole of the design process which he considers is very important.

A problem mentioned by a contractor´s geotechnical engineer is that, since a design-build tender requires extensive calculation and is therefore more costly, many small firms cannot afford spending millions on calculating on a tender if they are not compensated or certain to receive the contract. When only bigger, wealthier firms can participate in the bidding the competition is threatened.

Product quality in design-build project

"The contractor has no incentive to achieve a better quality" –Client

Regarding the quality, a designer´s geotechnical engineer considers design-build projects to be an inexpensive solution where you get what you pay for. He is very doubtful to the argument of new technology being developed thanks to design-build projects. He believes that the contractor might have new knowledge but that they in design-build projects do not have time to develop and implement the knowledge into the projects.

Also among the client´s geotechnical engineers there are questionmarks regarding environment and quality of design-build projects. One approach of trying to solve these problems is through long periods of warranty, but they yet lack experience of how well it works. A client´s geotechnical engineer believes that if you manage to write good functionality requirements and have longer periods of warranty or maintenance you can probably get good control of the quality of the product. He means that even though the road is planned to be used for 50 years, they can see much sooner than that if the quality is good enough.

A client´s geotechnical engineer states that it is by optimizing the operation of a project and finding the cheapest solution that contractors compete with each other. He believes that the contractors' incentive is to optimize and develop technology in order to make money. He also believes that the bigger contractor companies have more resources than designer companies and thus greater ability to develop new techniques. Another interviewee, also from the client-side, is however more sceptical. His point of view is that contractors never look for quality improvements but rather that for them everything is about saving money.

One of the contractor´s geotechnical engineers states that if warranty or maintenance time is long and the contractor get sufficient time to work with the design, he thinks the quality will be better in design-build than design-bid build. His opinion is that the Swedish Transport Administration will have more risk on their table in design-build projects than design-bid-build projects.

Risk in design-build projects

“There is a substantial risk that safety will have a lower priority in design-build projects!” –Designer

A designer´s geotechnical engineer suspects that the contractor in a design-build project, where the client has less control, might work with lower security and higher risk-taking which might lead to landslides and other risks. He further states that in worst case, the regulations of the work environment might not be complied with in full either. He however believes that the number of controversies will probably be less since the contractor must clean up after himself when the responsibility is his.

Another designer´s geotechnical engineer also believes that the risk taking increases with design-build projects and that this is difficult for the client to control. He also means that the counterpart relationships in design-bid-build contracts can be good when it comes to risks. This is because you get a kind of dual controls when the documents are reviewed by the separate parties.

According to a client´s geotechnical engineer the Swedish Transport Administration, in order to avoid too large uncertainties, decided that there should be as many surveys and test drillings performed in the tender documents of design-build projects as in design-bid-build projects. Otherwise you get too large uncertainties. These uncertainties are not fair to the contractor and may lead to high increase in project cost. He believes that the Swedish Transport Administration does preliminary investigations and risk assessments as thoroughly irrespective if the contract is design-build or design-bid-build.

Another of the client´s geotechnical engineers does not think it is appropriate to have design-build projects where there are too difficult geotechnical conditions. There, he believes the risk with design-build projects is that the design is too hurried which can result in dangerous solutions both during production and for the finished product. He is also doubtful that the Swedish Transport Administration has the same strict controls that the continuous safety work is followed in a design-build project.

Two of the contractor´s geotechnical engineers says that they experience that the Swedish Transport Administration are equally strict or even stricter in design-build projects when it comes to control over safety.

5.2.2 Lack of structured risk management

All the different actors in an infrastructure project work with risk management. The structure is however not uniform between different projects or different personnel, therefore the quality also differs.

Many documents, little use or system

“We have always been working with risk analysis, with about one hundred different systems of them, either one are worse than the other” -Designer

Common views from all the different actors are that the risk analysis is made, but there is no structured way that is same in all projects. In both the contractor´s and client´s organization are risk analysis made on a higher organizational level with more focus on the economical hazards associated with geotechnical problems than the technical problems. These different problems are in some way connected but the work structure to connect economical problems and technical problems have no common basis throughout different projects. In the client´s organization geotechnical engineers from their own organization or from designer’s organization are often involved in the risk analysis process. In the contractor´s organization geotechnical engineers are only involved if some part of the process needs special attention.

In all projects studied, an uncertainty analysis is attached in the tender documents. However, the quality of this document differs substantially. The opinion of the use of this document also differs but its main purpose seems to be to give the contractor a material of highlighted areas where a building estimator should not forget to calculate costs for different infrequent operations and some areas where special attention should be paid to the work environment, quality and the environment. This document has not been used by the contractor´s geotechnical engineer in the two design-bid-build projects and is according to all contractor´s and designer´s geotechnical engineers often too general to be of any use in geotechnical risk management. However, in the design-build project a" risk analysis day" was held after the procurement where the Swedish Transport Administration presented risks in the uncertainty analysis that was made earlier in the project. There was not so much collaboration in this risk analysis day though. The uncertainty analysis can however, according to one of the contractor´s geotechnical engineers serve the purpose of a basis for where work preparations should be done.

Projects in the western parts of Sweden, where the Swedish Transport Administration is client, have the last years started with mandatory work preparations for advanced operations which the contractor´s geotechnical engineer must prepare. These work preparations should be reviewed and signed by the client´s geotechnical engineer before this operation takes place. A general opinion of these work preparations is that they have heightened the quality of the geotechnical work substantially. The big project "BanaVäg i Väst" has been carried out without any big incidents so far, which both designer´s and client´s geotechnical engineer do not think would be possible otherwise. As a consequence of the introduction of these work preparations, the workload on the client's geotechnical engineers has increased considerably due to reviewing of documents.

There has also been a desire from contractor's geotechnical engineer and especially designer´s geotechnical engineer that designer´s geotechnical engineer would be more involved in the production phase. In the "BanaVäg i Väst" project a building support geotechnical engineer position has therefore been introduced. The building support geotechnical engineer is a support to the client´s geotechnical engineer and was supposed to solve the two above mentioned problems. All involved actors see this building support geotechnical engineer as a successful initiative in general. However, this person has not always been from the company that designed the project. This depends on various reasons such as: deficit on people with sufficient geotechnical expertise in some designer companies and benefits from having the same person on many projects. Even if this has been a positive initiative, the problem with no continuous feedback from the production phase to the designer is not solved in the projects where building support geotechnical engineer is from another company than the designer. One of the contractor´s geotechnical engineers also highlights that even when the building support geotechnical engineer is from the same designer´s company it is often not the person who designed. Often this person does not have experience from the specific project and can therefore not be of great help. This is however seen as a problem that will be solved over time.

A common point of view that all geotechnical engineers at the different actors have is that everyone would identify the same hazardous areas of a project. Of course there are some extreme cases where water pressure or extreme geological conditions can cause unidentified hazards that lead to occurrence of unwanted consequences. Furthermore the collective opinion is that if the geotechnical problems are identified, they are often handled in secure way if work preparations are made and followed.

A problem with a document that clearly states the largest risks in the project are according to both designer´s and client´s geotechnical engineers that risks not written down would indirect be seen as negligible.

The Swedish Transport Administration had many systems, but hopefully the new one is good

"This is not an uncertainty analysis, this is a risk analysis...someone probably just changed the name because they been told that they had to do an uncertainty analysis in the project" -Designer

The Swedish Transport Administration has been working with risk management in many years. These different systems has been questioned both by the people working with them and by internal revision. Because of skepticism from people working with these analyses and confusion due to the many changes in the work procedures, no real structure exists. The only document attached in the tender documents which specifically points at different risks is the uncertainty analysis, which in many projects seems to be only a name change of the risk analysis made in the design phase. This document has not been used for management of geotechnical risks in a structured way in the production phase in any of the projects.

The Swedish Transport Administration has been developing an entirely new system the last few years where risk analysis is made in computer software developed only for this application. This software is intended to be continuously used from pre-study until the road is built. This work structure will, if successfully implemented, also involve contractor´s on-site management and client´s construction management more in the risk management. The new risk analysis has only been tried on trial in a few projects and even in-house the awareness about it seems very limited. According to the geotechnical engineers there are as many risk management structures as there are project managers today. This will hopefully change with the new system.

The Swedish Transport Administration tries to work with other preventive risk measures as well. Measures such as mandatory education about the geotechnical difficulties in the clay and the environment in the area is carried out in one project for all the people involved in the construction phase. This education has received both positive and negative response according to client´s geotechnical engineer. Often the younger people involved are more positive to this kind of education, whereas older people tend to think that they already have experienced everything. Special extended collaboration meetings have also been part of the Swedish Transport Administrations strategy to increase the collaboration between actors.

Handover meeting

"Handover meetings tend to have a very broad agenda, therefore they are not proper for geotechnical risk communication" -Contractor

All projects reviewed had some kind of handover meeting. The involvement and opinion of this meeting differed between the different geotechnical engineers though. The general idea of a meeting, where designer and client present the area and their thoughts on the designed material and where the contractor can raise questions on the designed material, is overall positive from everyone. This is a good way for different areas of technique to get an understanding of each other's problems and for contractor to get a general understanding of the project. Some contractor´s geotechnical engineers found the handover meeting to be too general which leads to not enough time or focus on specific technical geotechnical problems. Both designer´s and client´s geotechnical engineers were unsatisfied with the level of preparedness of the contractor´s geotechnical engineer on this meeting. One contractor´s geotechnical engineer agreed with this but also declares that there is always too little time to prepare, and that the designer and client has worked with this material for so long that they clearly should be in charge of that meeting. Circumstances that lead to the designer sending a geotechnical engineer without any knowledge about the project was also unsatisfactory according contractor´s geotechnical engineer in one project. Furthermore, some client´s and designer´s geotechnical engineers questioned the choice of personnel that the contractor sent to these meetings.

Geotechnical meetings

“It has been very helpful that designer´s geotechnical engineer has been involved …this leads to straight communication” –Contractor

In all the reviewed projects there have been geotechnical meetings during the production phase. These kinds of meetings are very common in most projects where the Swedish Transport Administration is client today. General impressions of this meeting are very positive from all actors, but which actors and personnel who attend these meetings differ in different projects. In the projects that are a part of “BanaVäg i Väst”, both building support geotechnical engineer and client´s geotechnical engineer are present at this meetings. In addition, the contractor´s geotechnical engineer, the client´s construction management and often some of the contractor´s site management are present. The intervals between these meetings vary in different projects depending on the site management, the Swedish Transport Administration’s project management and how geotechnically difficult the project is, but intervals often increase as the project progresses. The idea of involving the designer´s geotechnical engineer as building support geotechnical engineer is very good according to all actors, especially contractor and designer. There was an idea that both the client´s and the contractor´s geotechnical engineer should attend all the building meetings, but in most projects this has been replaced by specific geotechnical meetings. The design-build project has geotechnical meetings but the client´s and contractor´s geotechnical engineers are also attending the parts of the building meetings that discuss geotechnical problems. This solution has worked out very well according to client´s geotechnical engineer.

In some projects they had a specific geotechnical start meeting, but it´s different how clarified the start meeting it is. All actors see this kind of meeting as good way to inform about risks handled by designer and discuss problems in the area. Difficulties, raised by a designer´s geotechnical engineer, to implement this meeting with success are always the preparedness of the contractor´s geotechnical engineer this early in the process and the client´s willingness to pay for the designer´s participation. One of the contractor´s geotechnical engineers has the opinion that it is very important that designer´s geotechnical engineer attends the first meeting and preferably the second meeting as well. The preparedness for the first meeting is often very limited, especially if the geotechnical engineer has not been involved in the procurement phase, therefore the possibilities to discuss difficulties with the designer´s geotechnical engineer at the second meeting are very helpful. Opinions of whom of the actors that should call for the geotechnical meeting and who does it today differ between the different geotechnical engineers.

Too many problems are solved after something happens and often economically. In infrastructure projects in general, many economical disputes are discussed progressively, therefore all actor´s geotechnical engineers are very satisfied that this meeting in general is free from economical issues and only focus on the technical problems.

Geotechnical calculation memo

"If all calculations are forwarded to contractor, we end up discussing the wrong things" -Designer

On the matter if the geotechnical calculation memo and information related to it should be forwarded to contractor during production phase, the opinions differ between the different actors. In all projects reviewed, the geotechnical calculation memo has been forwarded, but not additional calculations. There is a common agreement that in most projects today, where the Swedish Transport Administration is the client, this is the common work structure. However, the disagreement concerns if this is a good structure and also how the contractor uses this material.

Among the contractor´s geotechnical engineers there is an agreement that they benefit a lot from the procedure today where the geotechnical calculation memo is forwarded to contractor in the production phase. If they would benefit from a work structure where all calculations from designer are handed over the opinions differs though. They however have the same opinion that they are countered very unpleasantly by both the client´s and the designer´s geotechnical engineer if they have located an error in the calculations. One of the contractor´s geotechnical engineer also feel that it is a problem that the geotechnical calculation memo is not handed over until the first geotechnical meeting. This structure limits the possibility for the contractor to be well prepared on the first geotechnical meeting.

The designer´s geotechnical engineers agree on the opinion that it is extremely unusual that the contractor´s geotechnical engineer actually comes with any real corrections in the designed material. Furthermore, they say that the contractor´s people only suggest solutions that they can make money on, and very often these suggestions are not gaining the client at all. All the designer´s geotechnical engineers also agree that the focus from contractor is on the wrong things, often finding small corrections that can lead to economical benefits for the contractor instead of technical improvements. Another problem highlighted, by all designer´s geotechnical engineers, concerning the transfer of all calculations is that they have worked with many different technical solutions during the designing phase, and also before that in many projects, that has been rejected due to different reasons. If all of these calculations should be forwarded it would result in an extended workload for designer and cost for client to explain all assumptions and it would often also be very confusing for the contractor with many solutions that are not current. The different projects designer´s geotechnical engineers do not agree if they think that forwarding the calculations would lead to more or less risk. The different arguments are that the contractor´s geotechnical engineer could review the designed material and maybe find some errors or that the contractor´s geotechnical engineers only would copy the designed material for the work preparations and therefore not identify any new risks. Due to this difference they also disagree on how many documents should be forwarded.

The client´s geotechnical engineers all think that the structure today with a geotechnical calculation memo that is forwarded separated from the tender document is a good solution. None of them think that there is any information of any relevance that is left out. They have different experiences of how the contractor uses the calculations, some agree with designer that the contractor uses it for economical benefits in a way not unintended but some have no experiences of this. One of the client´s geotechnical engineer states very clearly that it is the designer´s task to choose the best technical option for design-bid-build projects and that there is no time in these projects to change everything in the production phase.

5.2.3 Individual responsibilities for the success of projects

The different actor´s geotechnical engineers all point out that the success of the projects, compliance of work preparations and collaboration in general, depend greatly on the personnel involved in the projects.

Work preparations

"At worst there is a pressure from site management that force a work structure that is unacceptable from a work environment point of view, but I think this is less and less usual today" –Client

The different actor´s geotechnical engineers all highlight the lack of obedience of work preparations in the production phase as a major risk in infrastructure projects. The Swedish Transport Administration demands work preparations from contractor to be reviewed and signed before hazardous operations are started, and in all of these projects this has been followed in a satisfactory way. The concern is however how these work preparations are followed on-site.

According to a contractor´s geotechnical engineer the work preparations are delivered to everyone on-site, so if they are not followed it is due to the machine operator's or on-site management's own decisions. A general opinion among the contractor´s geotechnical engineers are that once you start working with a project group and learn to cooperate it also runs smoother the next time. One of the reasons for this is that the contractor´s geotechnical engineer learns which personnel he needs to do stricter work preparations for. Furthermore, a common view was that there are some site managers that do not think that they need any help and therefore do not ask for any geotechnical help, however once they ask for assistance a first time they often do it again. One of the contractor´s geotechnical engineers thinks that they maybe can learn from other divisions of their company where work preparations connected to difficult operations are briefed in a structured way together in the on-site office, instead of out by the machine. This would maybe make it easier to explain why in some areas a more secure, and perhaps slower, operation path needs to be chosen. A contractor´s geotechnical engineer feels that some machine operators almost wants to prove the managers wrong by trying to make it work even if the work preparations are neglected.

The different designer´s geotechnical engineers highlight the problem with on-site management making own decisions that are not elaborated with geotechnical engineers. They also highlight the problem with costs for the security since the contractor makes money as long as nothing goes wrong but also have the responsibility for security themselves. One of the designer´s geotechnical engineers also sees the issue with geotechnical problems that the more knowledge and information you have the more hazards you find. However, it will hopefully in the long run be the company with most competence that can produce the best quality to the lowest price. The Swedish Transport Administration, according to the Swedish Public Procurement Act, has to procure the contractor with the lowest bid. This means that the contractor who might have calculated with the least geotechnical security and extra competence often gets the projects today. Two other questions raised by the designer´s geotechnical engineers are; what happens on-site when work preparations are not accurate to reality and who will make the decision regarding further operations?

The client´s geotechnical engineers say that disobedience of directions is a problem which they are trying to manage. In the Design-Build project "Torpa-Stenröset" all personnel involved on-site have to enroll in a geotechnical and environmental course which highlights the hazards in the area. In this course they talk much about both the rights and obligations of all the machine operators to see and understand the work preparations. All the client´s geotechnical engineers highlight that the problem is due to both lack of knowledge about the problem when making own judgments on-site and economical benefits of lower security. In the worst cases machine operators feel the pressure from site management to operate in a way that is unacceptable from a work environment point of view.

A general view from all actor´s geotechnical engineers are that the quality and obedience of work preparations have increased substantially the recent years and are still improving in most projects. There is a big difference between different companies in how good they are working with it though. There is also a shared view that without any accidents the quality of security work decreases until an accident happens again. Some discussions are going on whether the work preparations are made for the operators on-site to read or for the different actor´s geotechnical engineers. All of the contractor´s geotechnical engineers have experienced that the focus of the review of these work preparations sometimes is wrong.

Structures and meetings are often made for a reason

"It doesn't matter how good the work preparations are made, if they are not followed in the production" –Contractor

All actor´s geotechnical engineers points out that work structures and other papers from meetings should not be "shelf warmers" or a check in a protocol but rather used for a purpose. However, both designer´s and client´s geotechnical engineers feel that contractors sometimes send the wrong personnel to meetings and that the geotechnical engineer is unsatisfactory prepared.

There is a common skepticism expressed by all actors that there is very much paper work today. According to a contractor´s geotechnical engineer this sometimes entices behavior from machine operators to prove e.g. work preparations wrong.

In all of the projects have personnel changes inside of the designer´s or client´s company been present. This might be caused by change of jobs, paternity leave or internal restructuring. If there is not any structured system to ensure that all information is transferred to the right persons after this kind of change, it causes information loss which contractor´s geotechnical engineer expressed experience from in one of the projects. One of the designer´s geotechnical engineers have experienced problems in other projects when the client decided that the designer's work was completely finished before the production phase but then the contractor wanted to ask questions later. The designer cannot work for free and the client does not pay for the extra hours. This is very much dependent on how the client wants to work with the project.

Realize that you do not know everything

"It´s reasonable to think that the contractor knows the production phase best and the designer the design phase" -Designer

All actor´s geotechnical engineers agree that the communication about corrections in the designed material often work unsatisfactory. Contractor´s geotechnical engineer feel badly treated when they counter client and designer with any corrections. Designer´s and client´s geotechnical engineers say that contractors often have a very unconstructive way of communicating problems. However, all geotechnical engineers say that they think that contractor has better knowledge about production phase and designer better knowledge about designing phase. Although this insight exists, only one interviewed person specifically expressed the fact that he himself makes mistakes. All other interviewed personnel though points out many flaws in the other actors material or work structures. All actors see this as problem that is traditionally inherited in the construction industry and in human beings. You do not want to be told that you are wrong; therefore no constructive improvements were suggested by any actor.

All actor´s geotechnical engineers have a common view that their involvement in projects is very dependent on the project managers at their companies. There are still many managers trying to manage the project with as little help from the geotechnical engineers as possible. It is not uncommon that people who need the help do not ask for it, this is however changing slowly. A contractor´s geotechnical engineer says that once he gets a chance to work with the site managers it often continues on forthcoming projects since they are pleased with the assistance. One of the designer´s geotechnical engineers have experience of projects where geotechnical engineers have not been involved at all, probably because the client has not seen a need and the contractor thinks it a relief with less control over the project. This will lead to more risks if the original risks are not communicated and discussed in a proper way. One other designer´s geotechnical engineers experienced a project where he did not get a single question about the designed material during the production phase. Two years after the project ended the project manager told him that the material was really bad, but he had solved all the problems by himself instead of asking. According to the designer´s geotechnical engineer this lead to many idiotic solutions that could have been avoided if communication existed.

A general opinion among designer´s and contractor´s geotechnical engineers is that it is very difficult to get an acknowledgement from the Swedish Transport Administration that you were right, even if they pay you for the extra work carried out. Different reasons for this are given such as tradition of skepticism against contractors and human instinct to be defensive if someone accuses your work to be wrong.

5.2.4 Attitudes and focus in the business

There is a common skepticism towards other actors in infrastructure projects. This skepticism influences the entire process and attitudes in a very negative way which leads to a negative work environment.

Who is Responsible for doing what?

There are different opinions on who is responsible for doing what and also what the purpose of the work in the different phases is.

"Since they have BAS-P responsibility, everything they design should be possible to produce. They don't always succeed in this which is why we have to do a lot of work preparations. These are sometimes similar to an investigation and take a lot of time " –Contractor* (*BAS-P is explained further down)

"We don't design a plan to build after; the main purpose of the design is to have a basis for the procurement." -Designer

Designer and contractor have different views on what the purpose of the designed documents is. The contractor's geotechnical engineers think that the designer does not take enough consideration to the production phase and that it therefore sometimes is impossible to implement the design. They see a problem in that the designer does not have time to be out in the field to see how the production works. According to them it should be possible to build directly from the designed documents in a conventional way otherwise it should be stated clearly in the tender documents. It should for instance be stated if reinforcement measures are necessary in an area so that the contractor do not need a geotechnical engineer in the procurement phase. However, according to a designer, the purpose of the design document is just to be able to calculate on it in the procurement phase, not to build from it. He also thinks that a problem might be that they have different focuses; the designer often have a long perspective in mind, while the contractor may think only of the warranty period, which means that communication does not always work between them. A geotechnical engineer from the client has a similar idea, and says that the designer's job is to produce the overall cheapest solution when looking at the entire project. He thinks the contractor rarely realizes this, because he only looks at his own costs in production.

New regulations governing the work environment have made it clearer who is responsible for what. Someone, usually the designer, shall be responsible for work environment coordination of the planning and design work (BAS-P). The contractor is usually then responsible for work environment during the execution of the work (BAS-U). A designer´s geotechnical engineer says that with the BAS-P and BAS-U responsibilities, the designer's responsibilities, especially for work environment risks, are much more distinct. He thinks this is difficult because the designers have very little control over what happens during production. He says that things will always happen on the construction site; therefore the contractor must be responsible for their own men and machines. During production the contractor must be responsible. Even though it is difficult sometimes, he believes that it works pretty good today; where designers make sure that the project is feasible, but the contractor is responsible for the production phase.

"It's a counterpart relationship, which makes it harder"-Designer

For different reasons the contractor sometimes has remarks on the designers material. The contractor and designer often have different ideas about what is right or wrong in the material. When these remarks are presented the designer often feels questioned by the contractor which results in bad dialogue and communication between the actors. From the client-side it is also believed that the designer during the production phase often is held to account by the contractor e.g. how did you think here? Why should it be like this? A designer’s geotechnical engineer does not see this as a major problem but believes that it will be like this as long as the relationships are counterpart. He says that the biggest problem is when the discussions are about small things, such as how a sentence is written, instead of trying to find a solution.

Actors' interaction and response

All actors' geotechnical engineers points out that the success of a project is very dependent on different personnel's collaboration skills. They also have the common opinion that the collaboration is not working well in the construction industry and blame it on inherited structures and the history of procurement with counterpart relationships.

From designer's geotechnical engineers it is highlighted that if there has been a constructive dialogue to find solutions with the contractor to begin with, not only focusing on money, there will be a much better communication continuously.

"Clients probably often just wonder: what will this cost? when the contractor identifies errors" -Designer

According to designer’s geotechnical engineers, the response a contractor gets depends largely on how he presents his remarks. He thinks this differs greatly between different contractors. If there is an error it should of course be questioned, but usually the error is not clearly right or wrong but something in between. If the contractor presents his remark in a way that shows that they just want to make money, they probably do not get a friendly response. A contractor’s geotechnical engineer says he usually tries to ask things in a kind way, especially if he is not certain of the error. In his opinion, however, the contractor often receives very bad responses from the client and designer. He says that he often do not get any response at all unless he asks a couple of times. If he identifies and remarks on a “real” error, he will just get a short answer back.

"Some new people enter the industry and work with the intention of improving procedures and collaboration but after being deceived a couple of times they go back to old routines." –Designer

A contractor's geotechnical engineer feels that the client often unites with the designer against the contractor and also state that they have different confidence in different contractor firms. A designer´s geotechnical engineer also believes that different contractor firms are treated differently by the client and designer. He thinks that the contractor firms with a proficient geotechnical engineering department in general are treated better and get better response from the client on the issues they emphasize.

6 Analysis and Discussion

The analysis and discussion is structured to answer the different research questions raised in the introductory chapter and to evaluate the validity of the thesis.

How does the different procurement options design-bid-build and design-build, used in infrastructure projects, affect how information about geotechnical risks is communicated between client, designer and contractor?

Design-build project is a procurement option that is quite unexamined in infrastructure projects in general. Peab has currently two large design-build projects where the Swedish Transport Administration is client. However, both of these projects are in such an early state of production and design that it has been impossible for involved actors to see any clear changes in how risk communication and work structures related to this problem have worked. According to Osipova (2008, pp. 33-38), design-build projects are preferable from a risk management point of view since the contractor is involved earlier and the open communication about risk is higher. The interviewees opinions does not contradict this, however are both client´s and designer´s geotechnical engineer afraid that the contractor will use lower safety margins if not properly reviewed. Carlsson (2005, p. 71) also raises the question about change of risk responsibilities as a difference between design-build and design-bid-build projects, which the interviewees have different opinions about. Experiences are however too limited to be certain. Due to the Swedish Public Procurement Act that the Swedish Transport Administration have to obey, both Carlsson & Josephson (2001, pp. 66-72) and the interviewees raise the issue concerning if the firm who calculates the lowest bid often have calculated with too low safety and risk margins which may lead to a more expensive project in the end. Conclusions whether this phenomenon decreases with design-build projects can unfortunately not be clarified due to the lack of experience of design-build projects among the interviewees in this study.

From the studied projects no specific differences in demand of risk management or supervision can be seen. There is however differences in the documents due to the different procurement options, but any obvious change in risk communication because of the differences in the documentation cannot be concluded.

One distinguished reason to choose design-build procurement is the possibility to shorten the project time. Shortage of time can however increase the risk which is an issue mentioned by the interviewees as well. A common point of view from all actor´s geotechnical engineers are that warranty time and the formulations in the tender documents are crucial for the quality of the product, which can be a risk to the project. Experiences are also here insufficient to be certain. Since contractor and especially client are inexperienced with design-build procurement in infrastructure projects these projects might have increased risk and cost. This must however be seen as a temporary problem.

How can improved risk communication between actors and decreased risk in infrastructure projects be achieved?

It is very evident that infrastructure projects have the same inherited collaboration problems as the rest of the construction industry. There is a very obvious "us versus them thinking" that leads to an attitude that other actors have less knowledge, are very tedious and greedy. Carlsson & Josephson (2001, pp. 66-72) state in their research that counterpart relations, such as in design-bid-build projects, create barriers between actors and therefore focus communication on the wrong things. Since the infrastructure industry mainly work with design-bid-build projects this attitude against other actors is common. Furthermore, Carlsson & Josephson (2001, pp. 66-72) state that the client´s efforts are crucial for the success of the communication. The Swedish Transport Administration makes efforts to enhance the collaboration and communication between actors by e.g. extended collaboration meetings and a forced number of design-build projects. These efforts are of course very important to develop the infrastructure industry but when personnel at the Swedish Transport Administration at the same time have old prejudices, these efforts may not result in as big changes as they were hoped for. This inherited attitude can only be changed by the people involved and it might be easy to be naive from the outside but if people in the industry want to make it more attractive again, so that the deficiency of competent personnel decreases, there has to be a change! All actors involved must realize that there are problems that the other actors are facing, and that they might have better knowledge of these than you. All actors must realize that both they and other actors can make mistakes, everyone should correct their own mistakes before commenting on others'. Without these two insights; the communication, continuous feedback or knowledge dissemination between actors will never improve substantially. It is the companies' responsibility that these attitudes are obeyed by the companies' employees.

Carlsson & Josephson (2001, pp. 66-72) conclude that in order to improve the construction industry, "Actors should be chosen by competence and not by money". This is not possible for the Swedish Transport Administration since they have to obey the Public Procurement Act and therefore need to choose the lowest bid. This gives no incentive for neither contractor nor designer to collaborate in order to get the project to run smoother or to make any efforts that are not required. Without this incentive for a longer and increased collaboration, that could benefit all involved actors, all actors instead only see benefits from the specific project. Another problem is that it is often the contractor who has calculated with the lowest safety measures, least cost of geotechnical expertise or even calculated something wrong that is successful in the procurement. This could cause increased risk and cost and are a problem inherited with the Public Procurement Act that is not further analyzed in this thesis.

There is risk management performed in all different phases of a project by different actors, it is performed with both a formal and an informal approach, however there is no structure that is uniform and successful in all the projects. Since there are different approaches and different engagement in the risk management between the different projects it is difficult to analyze the structures that are used or should be used today. However it is evident that the extent of the risk management today are dependent on the interest of the project´s management this is also discussed by Staveren (2007, pp. 9-10). Contingency funds and involvement of experts are common informal approaches as also mentioned by Smith, Mena & Jobling (2006, p. 38). Today risks in different areas are handled by different areas of personnel and the collaboration and knowledge about each other's risk management is not satisfactory. Even if risks are in different areas, they are very often connected to each other and a collective systematic approach would therefore be favorable. A suggestion would be that all actors make a collective effort to make the Swedish Transport Administration´s new risk management system work. This system apply a collective approach but also divide risks into different areas and phases of the project to easier erase risks that are not current, hopefully would this increase continuous feedback and knowledge dissemination. It is also very important that risks are assigned to personnel that are most appropriate to be in charge of risk treatment which Carlsson M. (2005, p. 43) also points out. Today too many systems are not integrated with each other, which prevent a successful continuous feedback and knowledge dissemination.

ISO 31000 (2009, p. 19) states that risk treatment measures are important since failure or ineffectiveness can introduce risk itself. This fact is very clearly stated in interviews as well. Work preparations are often made as a risk treatment against geotechnical risks, but the work preparations are useless if they are not followed. All actors are concerned about the fact that work preparations are not followed or even not made in some projects. Even if most actors see this as a decreasing problem it is still one of the largest sources for geotechnical failure. The problem is related to the fact that security measures are an expense until something goes wrong, and therefore difficult to solve. In one project, the Swedish Transport Administration had education of all involved personnel about the difficult geotechnical conditions which maybe would be possible to implement in all projects by the contractor also. This education would lead to better continuous feedback and knowledge dissemination between machine operators and geotechnical engineers. The report “Extending to Geotechnical Risk Management” states that motivation, tools and training are the three barriers for successful geotechnical risk management (Staveren, 2007, pp. 9-10). This must be implemented everywhere in the process and motivation must be implemented from higher levels and down. Branch managers should actively try to motivate, provide tools and training in order to get a more successful risk management, and also inform people who do not actively search for this information. Even if it is widely accepted that it is more beneficial to do changes in projects early in the project, the conditions in infrastructure projects can never be totally certain in the planning phase. Therefore, situations will always occur where work preparations or designed material do not correspond with reality, and might therefore spread skepticism towards these, but closer collaboration will hopefully heighten the understanding when these situations appear. Closer collaboration would hopefully also ease the decision about who should decide about which actions should be taken in these situations. In the situations mentioned above the Swedish Transport Administration´s construction management are very important, according to the interviewees. In best practice they are both sufficiently experienced to survey if work preparations are obeyed on-site and to request further assistance if conditions are deviating from design. Another opinion stated by all actors in the interviews are that work preparations are followed much better after an accident, and that geotechnical issues get more focus after incidents. In the light of these statements Peab´s work structure with mandatory reports of incidents are very important.

Both Carlsson & Josephson (2001, pp. 66-72) and Carlsson B. (206, pp. 57-60) state that a start-up meeting always should take place when a project change phase in order to transfer as much information as possible. Start-up meetings are standard procedure in infrastructure projects today and are an important part of a successful project. According to the interviews, these meetings cover very diverse areas and therefore tend to be too general to cover all geotechnical issues even if the broad understanding of other areas is important. In many projects geotechnical meetings are also occurring with different intervals and in the tender document for all of the examined projects geotechnical meetings are a demand. These meetings are, according to both the interviews in this thesis and Carlsson B. (2006, pp. 57-60), important to keep a good communication, in this case between geotechnical engineers, before errors and defects appear which can avoid time consuming communication about economic regulation. In order to decrease the amount of the knowledge loss in the handover phase, it is important that these geotechnical meetings are attended by the personnel who have designed the project. Of course it would be preferable if the personnel who designed were attending these geotechnical meetings throughout the entire project but for smaller project this is maybe not economically viable. This is also supported by Carlsson B. (2006, pp. 57-60) who also points out that meetings after completion of a project are important for continuous feedback and knowledge dissemination. In the projects studied in this thesis have e.g. contractor not been prepared enough, in projects where the client has a building support geotechnical engineer they have not hired the company who designed, if the designing company was hired they still have not sent the personnel that made the design. These are all reasons to why the communication has not worked satisfactory. In best practice would the meetings be an excellent forum for all actors to analyze risks, transfer information from designer and in the first meetings discuss the conditions in the area and then later have continuous communication. The right personnel must however attend and be sufficiently prepared. The question raised by the geotechnical engineers on who should call for the meeting would be easily solved with one line in the tender documents to avoid further issues regarding this.

The geotechnical calculation memo has been discussed in the interviews and even if the opinions have differed among different personnel, the collective opinion is that the structure today is working satisfactory. Problems related to the discussion about the geotechnical calculation memo can be very much related to the barriers of counterpart relations in design-bid-build projects according to Carlsson & Josephson (2001, p. 9). A work structure were the geotechnical calculation memo would be handed over before the first geotechnical meeting would be preferable in order to increase the possibility for a successful first geotechnical meeting

Discussion about the thesis

Whether this thesis is written a couple of years to early or to late can be discussed. Work structures to decrease the geotechnical risks in infrastructure projects have been implemented in all projects the last couple of years and many of the problems today are seen as temporary until the structures have been properly worked through. This would be a reason to say that the thesis is a bit too late. However, design-build projects are not common enough to be properly examined today, which would be a reason for the thesis to be carried out in a couple of years instead.

When the thesis was initiated the primary research questions were how the different procurement options design-build and design-bid-build affect risk communication in infrastructure projects and how the quality of risk management could be increased. The question of differences between the procurement options has been very difficult to examine due to the low experience of design build projects in the industry and therefore a failure from a research point of view. Our initial thoughts about heightening the quality of risk management were to implement a specific risk management structure and e.g. a hazard identification method that focused on the difficult technical problems with geotechnical issues. This however, as mentioned in the research by Tengborg (1998) is often not the largest risk related to geotechnics, instead it is often risks that are not as obvious e.g. organizational. Finding relevant theory about structural problems related to a specific actor and even a specific company has been very difficult, and therefore have our interviews been focused on how the structure at the companies actually is today. This has lead to the finding that our starting point for the research question was to narrow and specific, since the problem was a broader structural problem. Procedures like advanced quantitative risk management or advanced hazard identification methods cannot be implemented until the basic structures are working properly. Some problems that affect the risk communication are common for the entire construction industry e.g. lack of trust for other actors, shortage of time in the design phase and deficit of competent personnel in the industry. These problems are examined thoroughly in old studies, without any obvious improvements in the industry the last years, and are therefore hard for us to give improvement recommendations about. Other problems were of a more specific nature, often related to choices made by personnel, for which it is possible to give some recommendations of important operations that should not be forgotten in infrastructure projects.

The Swedish Transport Administration is almost always the client in Swedish infrastructure projects related to roads and railways, therefore are there no other clients to examine further. There are however many different contractors and designers and this thesis only examines one contractor and two designer companies which is definitely questionable if it is enough in order to ensure a scientifically certain result, especially since the interviewees have highlighted that the success of the communication are very different between different companies. In addition to this, two of our supervisors are employed at the same contractor at which we have been situated during the work with this thesis. This might have influenced the work even though objectivity has been strived after. The possibility for us to be stationed at the contractor´s office has of course given us a perfect opportunity to discuss with personnel that do not have geotechnical occupation. Since the structures of risk management are both complex and extremely dependent on personnel in the specific project, new information has been received with every new conversation. Because of the complexity it is though reasonable to think that we have not been able to locate all different structures of risk management, related to geotechnics in this thesis. Some of the questions raised that were not possible to examine in this thesis are suggested for further studies. Räisänen & Gunnarson (2007) question that results from master theses written at technical universities often are taken as scientifically certain, which is a question that has to be raised for this thesis as well (Räisänen & Gunnarson, 2007, pp. 6-7).

7 Conclusion and Recommendations

There is a common opinion that the infrastructure industry the last few years has put a lot of effort in improving the risk management and ensuring that geotechnical risks are handled better. This also leads to the conclusion that geotechnical risk management and risk communication work much better today than five years ago. Many problems today are seen as temporary before new work structures are properly established. However, just as in the rest of the construction industry, there are collaboration problems which can be related to the history of only counterpart relationships between actors in design-bid-build procurement. Experience from other procurement options such as design-build in infrastructure projects cannot be ensured but the expectations are diverse. Inherited scepticism towards other actors are a big problem in infrastructure projects which limits the risk communication and will take time to change. The lack of a common structure is also a barrier to enhanced risk communication. Listed below are important steps and recommendations to different actors to enhance the risk communication and thereby also risk management over time:

- Realize that other actors have competence that you do not
- Ensure that geotechnical meetings take place
- Ensure that geotechnical start meetings with collaboration between actors about risk management is performed and site conditions are examined
- Ensure that all actors have the possibility to be well prepared at the geotechnical meeting
- Involve the designer more in the production phase, especially in the early phase, both in order to prevent knowledge loss and to ensure continuous feedback
- Realize that work preparations are made for a reason, make sure they fulfill that purpose instead of becoming "shelf warmers"
- Try to unite on one risk management procedure to decrease knowledge loss in the handover phases, and ensure continuous feedback and knowledge dissemination
- Inform about the benefits of both work preparations and risk management in order to ensure continuous feedback and knowledge dissemination
- Ensure that the project time is sufficient for a well elaborated design and a secure production

Recommendations for further research

- Are work preparations made for the right people, and is the extent reasonable?
- Who are responsible for failure in work carried out according to the work preparations if the client has reviewed and signed them?
- How can contractor motivate personnel to ensure that work preparations are obeyed?
- Is a more specific quantitative risk assessment possible to implement through utilization of continuous feedback?
- Does the Public Procurement Act affect how communication, continuous feedback and knowledge dissemination in infrastructure industry works?

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Appendix 1, Interview checklist

- How are you involved in the project and what is your background
- Was this a successful project? If not, was it due to geotechnics?
- How was the collaboration between actors? Is the success of the collaboration dependent on which company or personnel is involved in the project?
- How is your company working with risk management? How has this project/projects in general worked with risk management?
- Was there any collaboration in the risk management? How was the risk identification process? (Where/when/who)
- Did you have any incidents with identified/unidentified risks in this project?
- How are identified risks transferred in the tender documents? When contractor identify new risks, how does the communication of them work?
- How does the hand-over meeting proceed? Dialogue or presentation?
- Who decides about Geotechnical meetings? How do they work?
- How is the transfer of the geotechnical calculation memo working in different projects?
- How has the communication between actors been working in the project? What is positive/negative with different communication methods?
- How does the risk communication differ between actors in projects with the different procurement options design-build or design-bid-build?
- What are the general benefits/concerns with new procurement options like design-build?
- What are your experiences regarding how work preparations are followed by contractor on-site?
- How is the designer´s competence of the production phase?
- Research points out the obvious that the client has a big impact on how the communication works. Is the Swedish Transport Administration encouraging open communication?
- Which risks and conditions imply the biggest risks?
- Suggestions for improvements of the risk communication? A specific risk chapter in the geotechnical calculations memo?