CHALMERS

Risk management in the tendering process

A survey of risk management practices within infrastructural construction

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

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Master's Thesis 2012:16

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Chalmers tekniska högskola 2012:16

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Chalmers Reproservice
Göteborg, Sweden 2012

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ABSTRACT

The construction and infrastructure sector is associated with complex projects with high risk exposure. The project related risks compel companies to a structured risk management process to enable successful projects. The project complexity generates a high amount of information which creates a demand for computer based tools. However, there is currently a lack of adequate risk management support tools. Previous studies show that the risk exposure is at its highest level during the tendering process and it is therefore vital to examine how risk management tasks are performed during this process.

The purpose of this thesis is to examine and evaluate how contractor experts manage risks during the tendering process for large scale infrastructural projects. The aim is to provide knowledge that will contribute to improvements of a risk management support tool in the studied company. The improvements should be based on an analysis of behavioural practices and attitudes in a project tendering team.

To enable a detailed risk management study, one major infrastructural contractor has been examined. The methodology is based on a broad literature review of risk management in construction and the company's internal documents and policies. Additionally, 11 semi structured qualitative interviews with key persons in the tendering process and one observation of a risk meeting have been carried out. Finally, the Monte Carlo simulation technique has been used to simulate risks in two completed infrastructural projects.

Findings indicate that the present risk management process is acceptable but can be improved by a better structure. Furthermore, result shows that the respondents have different risk definitions and that the risk management process will be enhanced if threats were separated from opportunities, both in the identification phase and in the analysis phase. Other findings reveal that there is a suitable risk management support tool within the company but it is not used in the tendering process. Findings indicate that the tool will contribute to a better structured risk management process. To enable a successful implementation, the software has to increase its usability. To improve the risk analysis, a function to perform Monte Carlo simulations and a possibility to create a suitable risk structure for tendering has to be integrated in the software.

Key words: risk management, tendering, construction, support tool, risk simulation

Riskhantering i anbudsprocessen
En studie av praktisk riskhantering för infrastrukturprojekt
Examensarbete inom Design and Construction Project Management

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SAMMANFATTNING

Många större anläggningsprojekt är komplexa och ger upphov till en hög riskexponering som tvingar företag att strukturera sin riskhantering. Komplexiteten medför ett större behov av informationshantering, vilket ökar kraven på datorbaserade hjälpmedel. Enligt studier är det idag dock en brist på tillgängliga adekvata riskhanteringsprogram. Då studier visar att riskexponeringen är som störst under anbudsfasen blir det under denna process viktigt att undersöka hur väl riskhanteringen fungerar.

Syftet med studien är att undersöka och utvärdera hur professionella entreprenörer hanterar risker under anbudsskedet i större infrastrukturprojekt. Målet är att ta fram ett kunskapsunderlag för att möjliggöra en vidareutveckling och förbättring av ett riskhanteringsverktyg för det studerade företaget. Förbättringarna ska vara baserade på uppfattningar och beteenden hos ett anbudsteam.

För att uppnå en detaljerad beskrivning av riskhanteringsprocessen studerades endast en utvald entreprenör. Den metod som använts i studien, är förutom en bred litteraturstudie inom framförallt riskhantering, även genomförandet av 11 semistrukturerade kvalitativa intervjuer, en observation av ett riskmöte och granskning av interna dokument. För att utföra en risksimulering användes en Monte Carlo-simulering på två av företagets redan genomförda projekt.

Studiens resultat visar att dagens riskhantering fungerar tillfredsställande men kan förbättras genom en tydligare struktur. Studien visar att respondenterna har olika definition av risk och att riskhanteringen skulle förbättras genom en tydligare distinktion när negativa och positiva risker ska identifieras och värderas. Andra resultat visar att företaget har tillgång till ett adekvat riskhanteringsprogram som inte används i anbudsskedet utan endast i utförandeskedet. Genom att implementera programmet i anbudsskedet skulle det bidra till en bättre struktur i det studerade företagets riskarbete. Resultat visar dock att programmet fordrar en vidareutveckling för att få det mer effektivt och användarvänligt innan det implementeras. Ytterligare förslag till förbättringar är en inbyggd Monte Carlo-simulering och en anpassad riskstruktur för anbudsarbete.

Nyckelord: riskhantering, anbud, infrastrukturprojekt, byggindustri, risksimulering

Contents

Preface

This master thesis was written during the spring of 2012 and it concludes five years in total and the last two years at the master program Design and Construction Project Management at Chalmers University of Technology.

We would like to thank our supervisor at Chalmers, Jan Bröchner. Your great experience is remarkable and we are thankful for your support throughout the process, with wise assistance and interesting thoughts.

Secondly, we would like to thank the people at Skanska, especially everyone working at the department where the study was carried out. Great thanks to Claes Svanström and Robert Sturk who have supported us with crucial information for the study. Also, we would like to show our appreciation and gratitude to Per-Anders Ericsson and Per-Ola Svahn, not only for guiding us into an interesting subject, but also for taking the time to discuss and advise us with important and intellectual thoughts.

Finally, we would like to thank every person participating in interviews, observation and other wise being involved. Without you, this master thesis would not have been possible.

Göteborg, June 2012

John-Niclas Agerberg & Johan Ågren

1 Introduction

The construction industry is associated with a high risk exposure and is therefore a field where risk management is crucial (Baker et al., 1998; Hastak and Shaked, 2000). During the last decade, the demand for risk management in civil engineering and construction has increased as a consequence of more complex projects. The development within the construction sector will continue and consequently, the complexity of projects will increase. Hence, the demand for increasingly sophisticated risk management will presumably also increase (Faber and Stewart, 2003).

1.1 Background

According to Smith et al. (2008), the level of risk increases in the beginning of a project and reaches its highest level during the tendering process where the project uncertainty is at its peak. When the production starts, risks are either actualised or expired and the level of risk will decrease as the project progresses. As a result, risk management becomes most vital in the tendering process. To confirm this statement, Elkington and Smallman (2002) claim that there is a strong relation between an early risk management and the success of a project. The volume of resources spent in risk management activities is a fundamental factor to project success. An early involvement of risk management will create better conditions for the contractor, in both the tendering process and in the execution phase. Also, Bajaj et al. (1997) state a relevant conclusion relating to the importance of identifying risks at an early stage in a project: if a risk cannot be identified it cannot be analysed or in any other way be managed.

Cost estimation is the phase of the tendering process where the contractor specifies a price on their commitment to the client. Kim et al. (2008) say that the cost estimate has to be low enough to win a project but high enough to get the required rate of return. Therefore the estimate is a consideration of the two extremes and it will become crucial to the existence of the company. A major part of the cost estimation is performed in the tendering process where risks are assessed and added to the tender price.

There are several studies (Kim et al., 2008; Potts, 2008) showing that risks have historically either not been managed at all or assessed as a stipulated percentage of the contract sum. However, this view has changed during the years and Fayek et al. (1998) show that more than 50% of the contractors still do not use any formal techniques to assess risks in the tendering process. Because of the importance of risk management in the tendering, contractors should use structured techniques to compile more correct estimations. While the construction industry is becoming more complex, structured risk management systems can be the difference between failure and success.

With more complex projects and an increased level of information structured and formal techniques have to be used in order to store and process the available data effectively. In order to manage these techniques, computer software tools should be used. The tools should encourage and assist the contractors to use structured risk management techniques and generate more knowledge about their estimations. However, Dikmen et al. (2004) show that there is a lack of available risk management support tools and the existing tools have several disadvantages. Therefore a possible solution is to customise a support tool perfectly suited for the organisation's demands regarding risk management in the tendering process.

The fact that risk management is important not only for a single project's success but for the entire company, makes it vital to investigate further. Surveys have previously been performed on risk management in construction, but few of them have investigated how risk management in tendering is practically used in projects (Lyons and Skitmore, 2004; Osipova and Eriksson, 2011). This study will both investigate how contractors practise risk management during tendering, and examine what the requirements are for an effective risk management support tool in the tendering process.

1.2 Purpose

The purpose of this thesis is to examine and evaluate how contractor experts manage risks during the tendering process for large scale infrastructural projects. The aim is to provide knowledge that will contribute to improvements of a risk management support tool in the studied company. The improvements should be based on an analysis of behavioural practices and attitudes in a project tendering team.

1.3 Delimitations

The study will focus on risk management in the tendering process from a contractor's perspective and will not cover the execution phase. Subjects outside the field will be discussed, due to the importance of the subject's connection to risk management in the tendering phase, but will not be covered completely. These delimitations have been set because the extent of this study does not allow examination of risk management over the entire construction process. To gain more knowledge on the subjects not covered here it is recommended to do further research. The study will focus on infrastructural construction projects. Examples from other sectors and other processes within the construction industry are used to highlight differences or similarities in the examined subject.

1.4 Report outline

The report consists of eight chapters plus references. The report starts with an introduction to present the background of the performed study, the purpose and a delimitation description is presented. Chapter 2 covers how the study was executed and which methods that were chosen. The main methods involved literature studies, interviews, examining internal documents, plus one observation. Except from the methods mentioned, two Monte Carlo simulations were performed. Chapter 3 contains the literatures view on the tendering process. Chapter 4 presents the theoretical view on risk definitions, risk attitudes and the risk management process. The chapter is concluded with information about a risk management standard and information about risk management support tools. In Chapter 5, the results from interviews, internal documents and observations are presented. There will be a presentation of how procedures are executed in practice and how it should be performed according to the internal documents. Moreover, investigation result regarding an in-house developed risk management support tool will be presented. Chapter 6 gives a theoretical view about simulations and presents results from the performed case study. In Chapter 7, an analysis and a discussion of the most essential results from chapter five and six are discussed. The results are connected to the theoretical views of the subjects. The last chapter presents the most important conclusions of the study and gives a proposal to further work.

2 Methodology

To investigate how risk management in the tendering is conducted, a method is required which in detail investigates the issues. Therefore one company has been studied and a qualitative method has been used which covers risk management in the tendering process. The research method covers three major parts. At first a literature review of the subjects has been conducted. The second phase involved data collecting from three sources: studied the company's internal documents and policies, conducted 11 semi structured interviews, and observed a tender risk meeting. The third part is a case study where two Monte Carlo simulations of the company's past projects were performed.

2.1 Terms describing research quality

There are some important terms which can be related to the quality of a study's result. These terms must be investigated to understand what the advantages and disadvantages are in relation to the study. Bryman (2008) mentions two important parameters; *reliability* and *validity*. Reliability refers to whether the results from a study would be the same if the study was performed again. Therefore reliability measures how big the influence from non-consistent factors has been and how they have affected the results of the study. Validity explains how well the method measures what it claims to measure.

When internal documents are evaluated other parameters should be discussed to evaluate the choice of method. Bryman (2008) lists four important components. The first is *authenticity*; to what extent the document is genuine. The second component, *credibility*; how reliable the documents are. The third category describes if the document can be represented in the situation; *representativeness*. The last component, *meaning*; how clear and how easy to understand the documents are.

2.2 Literature review

The literature review has mainly covered two parts: the tendering process and the risk management process. The purpose of the literature review is to gather important knowledge about the subjects covered in the theoretical framework. The tendering process will be covered to examine how construction and civil engineering companies act in tendering practices. The risk management section should give the reader a comprehensive view of the risk management process to be able to understand how an effective support tool should be designed. Beside these two categories other subjects have been investigated in a general perspective: risk management in the oil and gas industry, statistical information and Monte Carlo simulations. A broad literature review will generate higher reliability of the study because the collected data will be compared to the results from the review. The literature review will have insignificant effect on the validity.

Bryman (2008) mentions several advantages with literature reviews. One main advantage is the broad coverage of high quality data, when there is a limit of time and cost in the study. Even though the advantages of literature reviews outweigh the disadvantages, some shortcomings can be mentioned. One of them is the fact that the quality of the literature cannot be controlled and that the material is unknown. Another disadvantage is that it takes time to understand the material.

2.3 Documents and policies

Internal documents and policies were investigated to examine how tendering and risk management in the tendering process should be governed according to the company.

The results from the internal documents are compared with how the process is carried out in practice. By choosing this method, random influences from other sources are minimised and the reliability will increase. All internal documents and policies were collected from the studied company's intranet.

The internal documents can all be considered as highly significant in the two first categories explained in section 2.1, authenticity; it is no doubt that the company has created the documents and credibility; it is clear that the documents are reliable. The document's representativeness is more difficult to evaluate due to the fact that the study only concerns one company. However, there are no arguments why the representativeness can be evaluated as low. The fourth category, meaning; can be evaluated as high, but occasionally some documents are ambiguous due to the fact that they were written by company employees. In these cases assistance from employees was needed to reduce uncertainty.

2.4 Observation

To examine the company's risk management practices, one observation was performed. The observation included participating in one meeting concerning a medium-sized infrastructural project where the topic was risks in a specific tender. The purpose was to investigate how practice correlates with established routines and what has been said during performed interviews. One problem according to Bryman (2008) is the difficulty to decide which people, what time and which situations to observe. Due to the limited numbers of risk meetings under the period in which this study was conducted, there was no possibility to choose which risk meeting to observe. It is a weakness to only study one meeting, because other meetings can be different from the observed meeting. This makes the reliability uncertain, but along with other used methods the reliability becomes higher. The validity of the observations is high since other sources of information correspond well with the observed meeting.

2.5 Interviews

According to Bryman (2008) semi structured interviews are interviews which have specified themes, but where the respondents have a high degree of flexibility. In total, 11 semi structured interviews have been conducted and each interview was approximately one hour. Each interview was performed in person at the interviewee's office and all interviews were recorded and supported with notes. This was to determine any misunderstandings as well as highlight how things were expressed during the interviews. The recordings and notes enhance the quality of the study with a higher degree of reliability. The selection of interviewees was made because of their key roles and level of involvement during the tendering process. All interviewees have management positions in the studied department.

Ten interviews, divided into two groups, were conducted. Five of the interviews concerned the tendering process as a whole, and the other five covered risk management in the tendering process. The last interview was conducted to examine a risk management support tool in detail. All interviews were structured and performed from the sequence of themes in the interview guide. The interview guides can be found in the Appendix. Each category of interviews had the same themes and the same questions. According to Bryman (2008) validity increases if the respondent follows the planned structure of the interview.

2.6 Case study - Monte Carlo simulation

The case study involves performance of Monte Carlo simulations on two completed infrastructural projects. A Monte Carlo simulation is a quantitative analysis which simulates the outcome of uncertain costs. The simulation will generate both a probability and a range of the outcome. Except from information about the probability, the simulations are carried out to exemplify how a simulation can be performed and which data that is needed. Moreover, it is important to investigate how time consuming the simulation technique is and to compare the simulated results with the risk costs in a project. Lastly, it is most important to examine what the department will gain by using a Monte Carlo simulation. Two projects were selected to increase the reliability by minimising random errors, which correlates with Bryman (2008) who says that one way to enhance the reliability is to increase the investigated sample size. The input data used in the simulation was collected in two approaches. In one of the simulations, data was collected directly from the recorded risk budget. In the other, the available data from the risk budget was complemented by estimations by the two people involved in the specific project. To be able to conduct the risk simulations, the software @RISK was used.

3 Tendering processes within construction

The tendering process can be identified as one of the major activities in the construction process and competitive tendering is the most frequently used method to decide who is going to be responsible for a project's execution (Winch, 2010). The sequence of the process varies due to the chosen procurement method.

3.1 Procurement strategies

According to Potts (2008), the selection of procurement decides the level of risk in the construction project. The procurement involves four parts:

- Organisational method
- Payment system
- Tender procedure
- Conditions of contract

The organisational method illustrates how an organisation is designed. Payment system defines how the client is paid, examples are price based alternatives; lump sum and cost based alternatives; cost reimbursement. Tender procedures can be open or selective. According to Söderberg (2011), contract conditions in Sweden are regulated by two forms of standard agreements. According to Osipova and Eriksson (2011) there are two major types of procurement options in the Swedish construction industry, design-bid-build and design-build. The most significant difference is the responsibility of the design, illustrated in Figure 1. According to GNA (2008) each procurement method is in monetary terms used at the same amount in infrastructural projects.

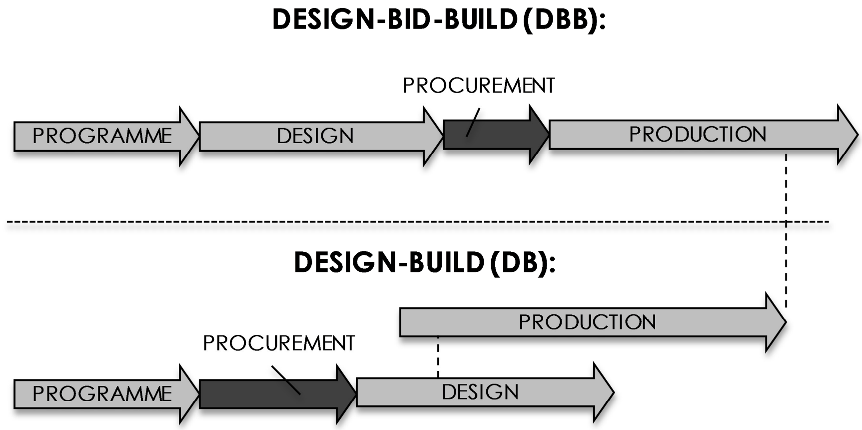

Figure 1. Sequence of DBB and DB contracts (based on Osipova, 2008)

3.1.1 Design-bid-build (DBB) procurement

In DBB contracts, the responsibility for construction design is in the hands of the client. When the design is completed, it becomes a part of the tendering documents. A contractor's procurement phase therefore only involves construction (Murdoch and Hughes, 2007). The process of a DBB contract can be visualised in Figure 1, which explains the procurement sequence and how the procurement phase relates to the design phase. DBB procurements can be arranged into two categories, where the essential difference is the involvement of a main contractor, called the general contractor (Osipova, 2008). In general contracting there is only one contract between the client and the contractor and it is the general contractor's responsibility to coordinate work between the involved subcontractors. General contracting is sometimes referred to as traditional contracting. This has to do with general contracting being the most used form of procurement method over the years (Murdoch and Hughes, 2007).

Potts (2008) argues that DBB contracts generate a distinct view on what the project cost is going to be before the construction starts. Murdoch and Hughes (2007) claim that projects with advanced design are more suitable for DBB contracts. This is determined by what the design team creates, and explains what should be built, and the contractor only focus on construction. Osipova (2008) says that DBB contracts are less risky for a contractor, due to the absence of construction design. However, Potts (2008) argues that a disadvantage with the contract is that they are more time consuming than DB contracts. Osipova and Eriksson (2011) claim that a DBB contract gives the contractor a lower profit margin than a DB contract and it is a less expensive alternative for the client.

3.1.2 Design-build (DB) procurement

In DB procurements the contractor has a wider role than in DBB procurements, due to the responsibility for the project's design. The design can be performed by an internal division within the contractor's company or by an external body selected by the contractor. How detailed the design is varies between projects and the client might have predetermined parts of the design in the tendering documents. In those situations, the contractor will design the remaining parts. Another alternative is that the contractor is obligated to perform the entire construction design (Murdoch and Hughes, 2007). One main advantage with DB procurements is that the construction phase can begin before the design phase is completed. However, the time for tendering is usually longer in a DB contract. The DB contractor composes a contract with each subcontractor. It is possible that each subcontractor can be in charge of the design within its actual theme (Murdoch and Hughes, 2007).

According to Osipova and Eriksson (2011), DB contracts have become more frequently used due to the greater range of responsibility for the contractor and less responsibility for the client. An advantage with DB contracts is that the client establishes one agreement with the party responsible for both design and construction (Potts, 2008). This facilitates the communication between the client and the contractor and there is only one party for the client to exchange information with. Ling et al. (2004) argue that DB contracts are more successful when it comes to construction and delivery speed. On the other hand they argue that DB contracts are more expensive to the client, due to less competiveness in the process and a wider range of responsibility for the DB contractor. The DB contractor takes a big risk by being both in charge and responsible for faults in design and construction.

3.2 Contractor's tendering

The planning for a tender can start before the tendering documents are announced and available for the contractor. The contractor observes potential projects by studying plans or announcements from public bodies, where an example of a client publishing upcoming infrastructural projects is the Swedish Transport Administration (Söderberg, 2011). He discusses that contractor's must have continuous contact with potential customers. This phase can be seen as stage A in the tendering process, see Figure 2.

The tendering documents are presented by the client, which is normally done electronically (Tindsley, 2008). According to Brandt and Franssen (2007) the tendering documents can be divided into two parts; where the first part is technical specification and the second part is the administrative conditions. Technical specifications can include general drawings, bill of quantities and descriptions. The administrative part contains contractual issues and other construction details concerning the project.

Preparation for tendering can be related to high costs as well as time consumption (Wilson and Kusomo, 2004; Hassel and Långström, 2004). The cost for tendering varies between 5-15% of the contract sum, depending on size and complexity of a project. Results indicate that one of six tenders turns out to be a winning tender. Thus it is important to decide whether to tender or not (Wilson and Kusomo, 2004).

Two studies investigate factors to determine the decision whether to tender. Fayek et al. (1998) lists 15 factors which decide whether to tender or not. The results from the study aligns with Bajaj et al. (1997), who rank the most important factor to what project type it concerns. The type of project answers how well the project is suited to the business plan, number of competitors and time for tender. The second most important factor whether to tender or not, relies on the availability of personnel. Additionally, a contractor can have several intentions to tender on a project. Fayek et al. (1998) identify the most usual intention to win the contract, but also to enhance reputation.

3.2.1 Cost estimation in tendering

Cost estimation is the event where the tender price is calculated. According to Akintoye and Fitzgerald (2000) the most popular methods of estimation techniques is the traditional cost estimating, which is often supported with computer based software. Brandt and Franssen (2007) separate the traditional cost estimating technique into six activities. The first activity includes two phases, investigation of what is going to be constructed by a careful study of the tendering documents and to visit the construction site; it also involves the choice of construction method. The second phase consists of producing bill of quantities, which lists all quantities of the chosen construction method. The third activity is to perform schedule of execution. The fourth activity is to estimate the direct costs for material and labour. The fifth activity is to select overhead costs that include costs of machines and salaries for the production management. The last activity is to combine all documents and transform it to a tender. The six estimation stages are illustrated in Figure 2.

Another cost estimating technique that is frequently used is experienced based techniques (Akintoye and Fitzgerald, 2000). It is mainly a comparison of information or experience from past similar projects. The traditional method and the experienced based method are deterministic methods which only include the most likely value of the estimation (Ali, 2005). Also, he claims that a deterministic technique is inadequate due to the fact that the estimator misses the likelihood of the estimation. Thus, Ali (2005) argues for probabilistic methods which include the probability and a range of the estimation. Akintoye and MacLeod (1997) claim that absence of experience of the technique and that many projects are too small to invest in the time it takes to perform probabilistic simulations, are the two main reasons why probabilities simulations are rare.

Akintoye and Fitzgerald (2000) investigate which people are the most frequently participants in the estimating process. Except from the estimator, other participants are subcontractors and contract managers. Moreover they point out that site managers do not participate in the estimation process. Most of the tendering time is used to perform accurate estimates on material and labour, choice of construction method, setting the design and to assessing risks (Fayek et al., 1998). A vital activity, according to Potts

(2008) is when the contractor turns the estimation to a tender. Additionally to the estimations, risks must be assessed to investigate how it affects the tender price. The last stage involves the senior management making final comprehensive decisions on the estimations before the tender is submitted. This phase can be seen as stage C in the tendering process, see Figure 2.

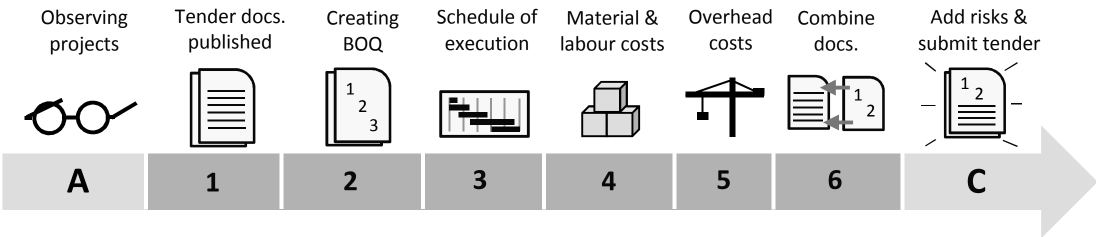

Figure 2. Sequence of a typical tendering process (based on Söderberg, 2011; Brandt and Franssen, 2007; Potts, 2008)

3.2.2 Calculation of a tendering price

There are usually two options on how to calculate costs in a tendering price. Nemuth (2008) separates the tendering price into three categories, direct costs, indirect costs and the company's profit and risks. Direct costs include wages, materials and subcontractors. Indirect costs include management etc. Profit is the mark-up decided by the company and risk includes positive and negative risks. Olsson et al. (2006) separate the tendering price into three categories: the estimated cost, profit and risks. The risks can then be divided into two categories, cost for contingencies and risks relating to uncertainties in a project. Fayek et al. (1998) say that approximately 60% of the companies include a risk percentage in the mark-up. All mark-ups in the study were in the range of 4-16% of the tender price.

According to Nemuth (2008):
+ Direct costs
+ Indirect costs
+ Profit including risks

= TENDER PRICE

According to Olsson et al. (2006):
+ Estimated costs
+ Profit
+ Risk (contingencies)
+ Risk (uncertainties)

= TENDER PRICE

3.3 Public procurement

According to Eriksson (2008) public bodies are a major part of a country's construction clients. In Sweden, The Public Procurement Act (LOU) explains how public bodies must act in construction procurements and what regulations the contractor must comply with. A public body can be a municipality or a public authority, but it also includes companies and authorities acting under a public interest. The regulation affects several aspects in the tendering process. For instance, it regulates what the tender documents should contain and when a tender must be disproved. Larger construction projects must be announced to the public (Söderberg, 2011).

LOU is regulated by two principles; equal treatment and transparency. Equal treatment claims that all involved parties in the tender should access information at the same time. Transparency defines that all parties should access exact the same information. The two principles can be exemplified in a tender process where there is ambiguity in the tender documents and an answer from the public client must be available to all competitors at the same time (Söderberg, 2011).

4 Risk management

This chapter will present a comprehensive view of the risk management process, which will be based on the established risk management standard ISO 31000. Initially, the text will illustrate how risk and uncertainty can be defined and why some people rate a specific risk as significant, while others find it less important. Also, this chapter will compare risk management practice within construction with other project based industries and finally explain how a risk management support tool can be developed.

4.1 Definitions

Most people have a good notion about how the terms risk, uncertainty and opportunity are related in their daily life. However, most people would have a problem when it comes to state a definition that clarify its whole content. It becomes clear that it exists a wide range of definitions when studying engineering and finance based publications. In this section some of the most often used definitions will be presented and an explanation why it will become important to know about the existing differences will be given.

4.1.1 Risk

Most available risk management literature explains risk as an event that occurs with a certain probability in combination with a consequence in the case of occurrence. Risk can in a simplistic approach be defined as:

Risk = probability of risk occurring x impact of risk occurring (McNeil et al., 2005).

Samson et al. (2008) say that it does not exist any general risk definition. They argue that a new definition will be established every time an organisation faces a new decision problem. Their statement is in accordance with the research of Grimvall et al. (2003) on the same subject. They claim that most people's risk definition will to a high extent be dependent on the situation in which the risks may occur. Also, they argue that this state of knowledge will have some impractical consequences in projects where risks often occur in a number of different situations and with a lot of different actors involved. Grimvall et al. (2003) discuss that the most important aspect is that the whole organisation agrees with a definition that everyone is comfortable with. Today, most of the big organisations that frequently are exposed to risks have identified this problem and as a result agreed with a common definition. According to Samson et al. (2008), organisations usually adopt some of the already established definitions, but employees would rather come up with their own specific definition. Table 1 illustrates some of existing risk definitions established by well-known institutes and researchers.

Winch (2010) discusses that most risk definitions include the whole range of both positive and negative outcomes, which corresponds to the definitions presented in Table 1. Furthermore, studies have indicated that project managers tend to use the term risk almost solely for the negative consequences of an event. Winch (2010) is criticising this approach and says that this attitude can lead to a lack of determination when it comes to managing the opportunities in a project. Therefore he argues against the use of risk as a term for both positive and negative outcomes and calls it highly inappropriate. Instead he suggests an implementation of a more suitable framework that separates the risk definition into threats and opportunities. When adopting this approach, organisations can design more effective strategies that manage threats and opportunities separately. Finally he claims that the management of threats and the management opportunities will in many aspects be different, and therefore necessary to separate.

Table 1. Summary of risk definitions

Reference	Definition
PMI (2004)	*"Risk is an uncertain event or condition that if it occurs, has a positive or negative effect on a project's objective"*
ISO 31000:2009	*"Effect of uncertainty on objectives* - *An effect is a deviation from the expected, positive or negative.* - *Objectives can have different aspects and can apply at different levels"*
Jaafari (2001)	*"Risk is defined as the exposure to loss/gain, or the probability of occurrence of loss/gain multiplied by its respective magnitude"*
Alessandri et al. (2004)	*"Risk represents the probability distribution of the consequences for each alternative"*
Holton (2004)	*"Risk is exposure to a proposition of which one is uncertain"*

In this report we will use the definition which is established by PMI (2004), "*risk is an uncertain event or condition that if it occurs, has a positive or negative effect on a project's objective"*.

4.1.2 Uncertainty

Samson et al. (2008) argue that there does not exist any general accepted definition of either risk or uncertainty. Alessandri et al. (2004) say that strategic managers and finance academics for decades have argued about the terminological differences between risk and uncertainty. Today there are in general two different approaches of the question, see Figure 3. The first opinion claims that uncertainty is equivalent with risk and the others argue for a point of view where risk and uncertainty are two different concepts. In the second approach, there are those who consider uncertainty and risk as two independent concepts, while others have the belief that they are dependent on each other. Although the differences in opinion, a majority of the concerned parties do agree that risk and uncertainty are two different concepts that somehow are related. Additionally, most parties do agree that projects are associated with both uncertainty and risk, and therefore need a management system that can handle both simultaneously (Samson et al., 2008).

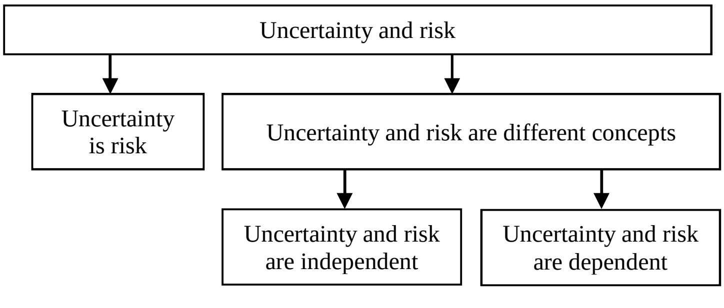

Figure 3. Relationship between risk and uncertainty (based on Samson et al., 2008)

Jaafari (2001) defines uncertainty as: "the probability that the objective function will not reach its planned target value". He claims that an uncertainty creates risk and that the extent of the risk will depend on the level of uncertainty and its consequence for the project. Furthermore, when the probability for an event is 100%, the uncertainty becomes certain.

In this thesis, uncertainty and risk will be used as two different concepts that are related to each other, which correspond with the most accepted view (Alessandri et al., 2004).

4.2 Risk classification

Several studies have been made in order to identify various risk categories to enable a design of an effective risk classification system for construction projects. Today, a number of allocation approaches exist, separating risks into categories. Some literature gives the recommendation to allocate the risks based on its consequences on a project, while others suggest a categorisation based on the risk source (Hastak and Shaked, 2000). Furthermore, a risk allocation approach based on the level of knowledge can be performed by using the following four categories (Winch, 2010):

- *Known knowns,* is the condition of a risk where its source can be identified and a specific probability and consequence in the case of occurrence can be calculated.

- *Known unknowns*, is the condition of uncertainty where the risk source can be identified but the probability will remain unknown.

- *Unknown known*, is the condition of an uncertainty where someone has knowledge of both the risk source and its estimated probability but the information will be unknown for most concerned parties.

- *Unknown unknowns*, is the condition of uncertainty where the risk source cannot be identified, therefore there is no possibilities to calculate its probability or consequence.

A key for an effective risk management strategy is how an organisation can manage these concepts. When an organisation accepts a project they realise that risks will arise that will require extra spending of resources, this is the known part. If the organisation has the ability to determine the risks probability and its consequences it will be classified as a known known. If the organisation neither can estimate its probability nor its consequences, they will face a known unknown. Furthermore, unknown known are those uncertainties where knowledge about the uncertainty exists, but not among the people who manage it. Finally, unknown unknowns, also called black swans, are unrecognised until they actually materialises. They will always occur without warnings, with a substantial impact, and the possibilities to prepare the organisation for its consequences are small (Winch, 2010).

4.3 Risk perception

Risk perception is according to Grimvall et al. (2003), the joint concept that discusses why some people rate a specific risk as significant, while others find it less important. The concept will be a key for the understanding of how risk should be managed in projects and how effective risk strategies should be designed.

Grimvall et al. (2003) discuss risk management in technical systems and say that there are a large number of factors that will affect in which way humans experience risk. R*isk* *accessibility* is presented as one of the most significant factors, which is risks that one can easily imagine and have one's own experience of. This type of risk will be seen as more probable and therefore judged as a bigger threat. Another factor that will affect the way one experience risk is *risk voluntariness*. Grimvall et al. (2003) explain that humans are willing to take on up to ten times more risks if the decision to carry out the event is based on their own free will than if someone else would make the decision. The third risk perception factor is based on the moment when the risk was discovered. Recently discovered risks can be seen as a larger threat than risks that have been around for a longer time. Grimvall et al. (2003) discuss that much of our risk perceptions can be explained by the irrational nature of the human being. Alessandri et al. (2004), say that decision makers will often act irrationally when it comes to decisions which include substantial risks. This is an effect of the limitation of the human ability to process various types of information simultaneously.

An additional approach is the one that explain how people experience risk differently as a consequence of human and social factors, such as gender, age, educational level and social belonging. As an example, females rate general risks higher than men. However, when it comes to personal risks, female rate risks in just about the same way as men. Moreover, people's educational level will affect their risk perception. Research indicates that highly educated people rate risk lower than people with less education. To minimise the effect of the differences in humans risk perception, an organisation should assemble a heterogeneous decision-team (Grimvall et al., 2003).

Grimvall et al. (2003) argue that most studies in the area of risk perception are done by psychologists which are specialised in human behaviour. However, some researchers address criticism against their point of view and claim that it assumes a far too homogeneous picture of a group. The critics agree with the statement that there are differences between groups, but favours a view focusing on individual risk perception. The individual risk perception is a product of the genes that one gets from one's parents, the environment in which one is raised and one's collected experiences. The critics claim that the social factors are far more dominant than the human factors. This statement carries the discussion to whether humans are able to make objective evaluations of risks or not. Studies have concluded that humans tend to overestimate risks with small probability and underestimate risks with high probability. This behaviour can cause numerous failures in risk calculations, especially when it is based on a high proportion of small risks (Lidskog et al., 1997).

Another condition that will affect the limitation of an objective risk evaluation is the level of individual risk acceptance. Winch (2010) uses the term *risk propensity* to explain that every individual has a specific risk acceptance function. These functions illustrate what people are willing to pay to avoid risks. He presents a frequently used approach which separates the human risk propensity into three different behaviours, see Figure 4. *Risk averse*, are people who have a negative slope of the risk-reward function, which illustrate a person who avoid risks when the reward is smaller than the risk exposure. Flanagan et al. (2007), say that the risk averse behaviour can results in a condition where a number of projects are not accepted, even though it would be profitable. The second behaviour is the *risk taker* (Winch, 2010). Risk takers are willing to accept a high numbers of risks under uncertain provision of reward. The behaviour can let organisations accept projects with an opportunity to generate a big return but with the possibility of big losses (Flanagan, 2007). The risk taking behaviour can be illustrated by a positive slope of the risk-reward function. Finally, *risk neutral* are those who are indifferent between a specific risk's profitability and its risk premium if they are equally big. The risk neutral behaviour can be explained by a linear risk-reward function.

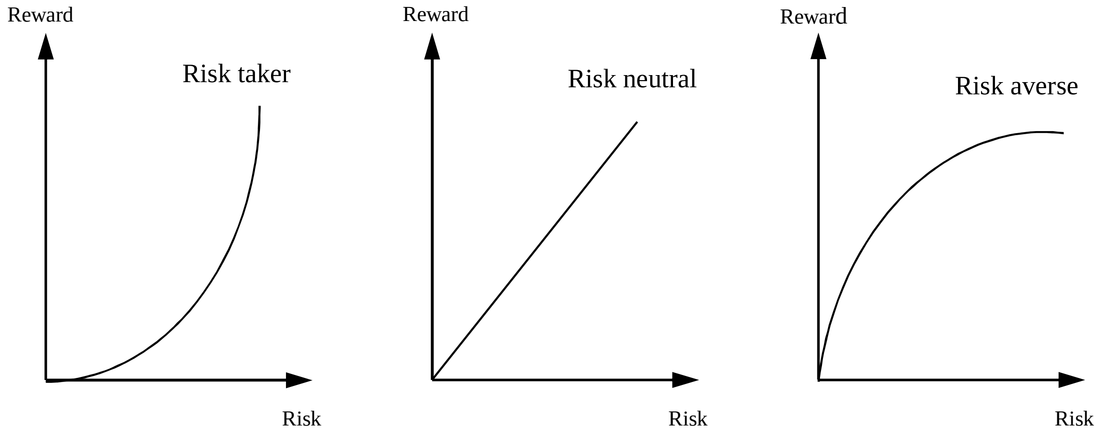

Figure 4. Risk propensity (based on Winch, 2010)

Lyons and Skitmore (2004) investigated how risk acceptance may differ in the Australian construction sector. The result indicated significant differences in risk tolerance among construction actors. The result confirmed that construction contractors were more willing to take risks than the selection of consultants and project clients. They classified project clients as risk averse, contractors as risk takers and consultants as risk neutral. Lyons and Skitmore (2004) claim that research performed within the UK construction industry indicates an overall risk taking behaviour in the construction industry. Paradoxically, a study with respondents from several segments within the construction industry confirms that a majority classifies themselves as risk averse or neutral to risk.

4.4 The risk management process

The risk management process has during the last decades become an important event in most project based organisations (Flanagan et al., 2007). Potts (2008) says that the risk management within the construction industry has historically been either ignored or dealt with in an arbitrary way. Today, risk management techniques are best developed within industries with heavy engineering events or in organisations where there are high levels of technical risk involved (Maylor, 2003). However, Flanagan et al. (2007) claim that it is important for most organisations to implement an effective risk management system that enables minimum loss from occurred risks. By the risk management system, risks can be transferred into opportunities which can generate gain for the company.

To be competitive and able to make correct decisions in the project processes it becomes crucial to take advantage of the knowledge and experience within the organisation. The risk management principles describe how knowledge should be managed in a systematic manner. Most organisations adopt an informal risk management approach, without realising its content. The informal approach will often give the outlook of risk management as something subjective and uncontrolled. Subject related literature argues for a more formal attitude to the risk management process. The attitude should include a more systematic approach, with established routines, which should give involved parties guidelines and structure on how to manage risk in their daily business (Flanagan et al., 2007).

In reality, even small incidents can have significant impact associated with big losses. These incidents can start a chain reaction that can threaten the whole project's existence and in the long run, even be a threat for the survival of the company. Therefore, it will be essential to provide a risk management system that enables identification of those risks and a comprehensive analysis of its triggers (Flangan et al., 2007).

4.4.1 The risk management model

The risk management model can in a simplistic approach be divided into activities that identify risks, activities that analyse its probability and impact and finally activities where the handling plan is evaluated and established. Maylor (2003) separates these activities into three event categories: identification, quantification and response.

Risk management literature explains this process differently, but as a whole, much of the described principles are the same. A majority of the literature illustrates the process as a circular model in order to emphasise risk management as an on-going and learning process throughout time (Winch, 2010; Baker et al., 1998). In contrast, some literature explains the model as a line of processes where the start and end activities are disconnected from each other (Simu, 2006). Criticism has been addressed against this models and claim that its lack of interrelation is why the construction industry often faces the same incidents in projects time after time (Winch, 2010).

The risk management process consists of three prime phases, which correspond with Pott's (2003) and Maylor's (2003) established models. The phases are risk identification, risk analysis and risk evaluation. The model is based on ISO 31000 and can be seen in Figure 5. The risk management strategy has to be tailored for the specific organisation and its processes. It is impossible to design a risk management strategy that is suited for all organisations (Flanagan et al., 2007).

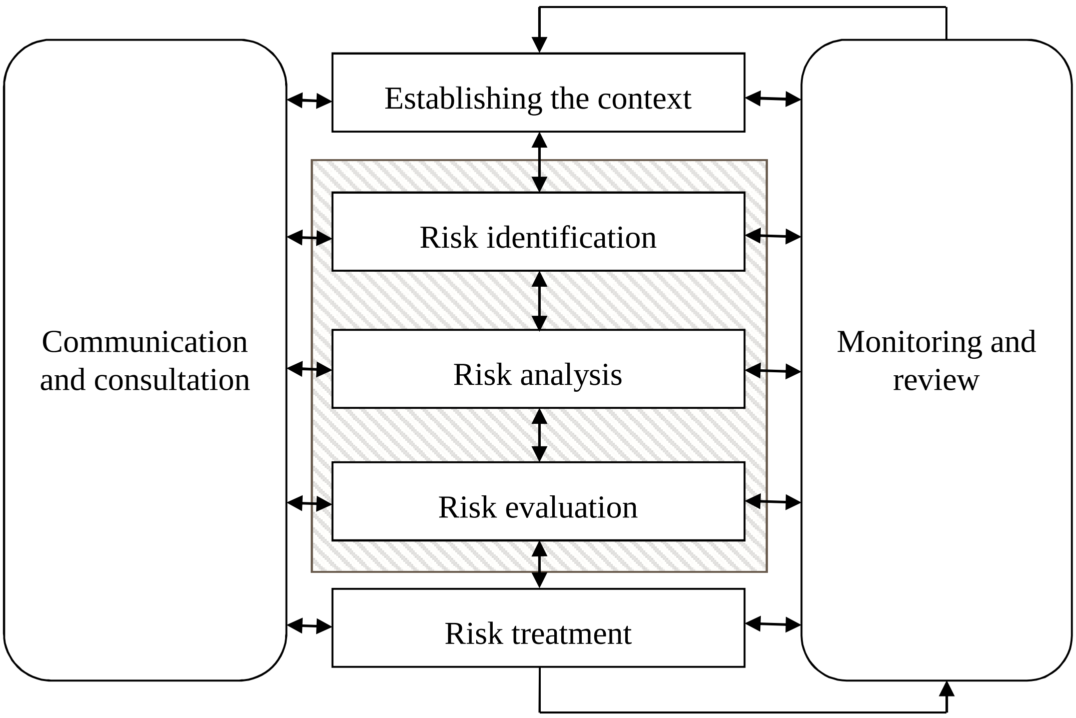

Figure 5. The risk management model (based on ISO 31000:2009)

Eskesen (2009) claims that it is of great importance that the risk management processes begin early to enable a successful project outcome. The process should be started during a project's feasibility study and in the early planning phase. Reilly and Brown (2004) say that an early implementation will reduce the number of risks that affect the project objectives. Also, it should be done to assure the project team and shareholders that the planned events are rationally evaluated. They claim that an execution of the early risk management process will give the contractor useful information about specific threats, which makes it possible to calculate a budget and a schedule. Finally, the process enables the parties to construct a mitigation plan to effectively manage the identified risks, and subsequently define the project strategy.

4.4.2 Risk identification

The risk identification process should be a set of on-going activities during the whole lifetime of a project. As a construction project makes progress, it will be harder to make changes as these will be associated with high costs. Therefore it will be crucial to identify project risks in an early stage while it still can be governed (Smith et al., 2006). The risk identification activities can be separated into events where the project team identifies risks and events where the identified risks are separated into an appropriate structure (Chapman and Ward, 1997).

Establish the context
According to ISO 31000:2009, the first phase, before risks can be identified, is to establish an organisation's risk management context, see Figure 5. This is the process where the company's objectives are expressed and defined in external and internal parameters. When establishing the external parameters, aspects of the company culture, rules, laws, financial condition, stakeholder relationship and key drivers are evaluated. When defining the internal parameters aspects of the organisational structure, policies, strategies, information systems and internal stakeholders have to be evaluated. Eskesen (2009) advises a high involvement by the project team when establishing the context. It will be important that all parties have a good knowledge about the context and have the chance to contribute in the process. The invested time and effort by the project team will result in a more effective process and a reduction of disputes. When the contextual phase has been completed, the risk identification process can start.

The importance of risk identification
The primary aim with the risk identification process is to generate a list of risks with both negative and positive consequences, which is called risk register (PMI, 2004). The risk register should be as comprehensive as possible and include risks whether or not its consequences are under control of the organisation (ISO 3100:2009). Bajaj et al. (1997) claim that if a risk is not identified it cannot be controlled, transferred or in any other aspects managed. However, Potts (2008) claims that it is impossible to identify all project related risks. He says that it will be counterproductive if a company think that they can, and base the tender price on that assumption. Projects within the construction industry are unique projects, which results in a demand of an individual identification phase for each project. Winch (2010) claims that the risk identification process is an important key to the whole risk management practices. This statement concurs with Bajaj et al. (1997), who claim that the main benefits of risk management arise from the identification phase rather than the risk analysis. Paradoxically they argue that the identification phase is one of the less formalised elements in the risk management process.

Trial and error
Winch (2010) states that risk identification performance is mainly based on experiences from skilled personnel within an organisation. The experiences of a risk are often based on a specific incident that has occurred in a previous project. People tend to remember

risks that have a negative impact on a project, rather than events with a better outcome than expected. This statement corresponds with the information that Bajaj et al. (1997) provide, where they claim that the primary basis for risk identification is internal and external experience and historical data. To increase experience within a project team, ISO 31000 advices organisations to involve people with appropriate knowledge and experience in the identification phase. Flanagan et al. (2007) make an attempt to explain in more detail how risks can be identified and what resources they will demand. Experience, knowledge and advice from a third party seem to be the most important elements in the process. They argue that the best result will be achieved when organisations combine several of these alternatives and not rely on one source alone.

Identification techniques

Flanagan et al. (2007) say that much of the resources for risk identification should be spent in an early project phase, during the tendering process. The frequently limitation of time during tendering generates a demand for effective identification methods. The risk identification process can be performed with a number of techniques. Brainstorming, interviews and risk source identification are some of the most used methods within construction projects. Other important activities are contract studies, site visits and further project research. Bajaj et al. (1997) asked 19 contractors how risks were identified in their organisations. The conclusion highlights that the most used risk identification activity is the risk review, which was performed by 70% of the respondents. Although it is important to realise that it is impossible to design a risk identification technique which is suitable for all organisations and projects. The brainstorming technique enables people from different departments and with different knowledge to share their point of view regarding risks. To obtain the best possible outcome, it will be crucial to engage the right mix of people with different background, gender and age (Smith et al., 2006). Another used method to identify risks is to perform a set of interviews with people from relevant areas within the project. The respondents should have experiences from similar projects or other knowledge that will contribute to the risk identification process. The risk interview itself gives the respondents a feeling of both involvement and responsibility in the risk identification process (Smith et al., 2006).

The next phase after the identification period is to assemble a risk register based on the respondent's answers. This can be done by one single person from the project team or during a meeting where all respondents discuss together the identified risks. In some situations it can be challenging to compare and summarise the identified risks, as it is difficult to determine whether some of them regard the same risks potential (Smith et al., 2006).

The risk register

As previously stated, the primary aim with the risk identification phase is to generate a risk register of project specific risks. Bajaj et al. (1997) claim that it is possible to contain a list of more or less standard risks that will be present in all construction projects. To confirm this statement, Potts (2008) says that Perry and Hayes (1985) constructed a comprehensive list of construction risks, where they identified over 100 potential risky project events. Today, many organisations adopt some of these risk lists, but some prefer to construct their own, which is suited for their organisation's projects. The risk register should give an extensive focus to the identification of critical risks. Bajaj et al. (1997) say that the risk identification process will be a waste of resources if critical risks are missed in the process. If noncritical risks are identified and some of the most critical risks are missed, a risk analysis will give the decision makers a misleading result about the total risk exposure. As a consequence, the organisation will be exposed for risks without realising it.

The risk register can be designed in a number of ways (Potts, 2008). The design will depend on the organisational size, project characteristics and the personnel using the risk register in practice. For smaller organisations which mainly manage small projects, the demand of a sophisticated risk register is minor. In contrast, the risk register used by larger organisations with large projects can be a range of complex documents which have been prepared in a software program. ISO 31000:2009 claims that it will be important to design the risk register based on an organisation's projects. The individual design will be crucial in order to get an effective and useful support tool and not been seen as a burden.

When it comes to the content of a risk register Flanagan et al. (2007) claim that a basic register should include information about the identified risk, and its expected impact on the project. The impact is usually measured in a monetary unit but can also be measured in time or quality. For a more detailed risk register, information about the following should be administrated: risk type, risk status, risk identification date, identification number, mitigation plan, date for mitigation activity, risk owner and probability of occurrence. An example of a quite detailed risk register is presented in Figure 6. If the risk register should be used as a reference for future similar projects it should include information concerning whether each risk occurred, the observed impact and how the mitigation activities succeed (Flanagan et al., 2007).

			Impact on project		Probability				
Nr	Risk	Identification date	Money	Time	Low	High	Mitigation plan	Result	Risk owner
1 2 3 4 5									

Figure 6. Risk register (based on Flanagan et al., 2007)

The need of structure

A construction project consists of a large number of risks, which should be visualised during the identification process. The risks may vary rather widely from one project to another. However, the variety of project related risks, the key risk sources will basically be the same (Smith et al., 2006). In the identification process the project team can use the risk sources as a checklist, to ensure comprehensive risk identification. The below presents list consists of frequently used risk sources in construction related projects (Smith et al., 2006).

- Financial risks
- Political risks
- Environmental risks
- Geographical risks
- Construction risks
- Supply risks
- Commissioning risks
- Injury and safety risks
- Legal risks
- Social risks
- Communications risks
- Geotechnical risks
- Technological risks
- Force majeure risks
- Completion risks
- Design risks
- Weather related risks
- Third party risks
- Client related risks
- Subcontractor risks
- Contract risks

The presented list of construction risk sources can be too detailed to successfully build a base for risk categorisation in all projects. Therefore, a frequently used approach is to select a number of risk sources that characterises the specific project and then separate them into more detailed risk elements. The risk source allocation technique can often be difficult to realise and is often associated with a high degree of personal subjectivity. Additionally, the method can generate a risk register where some of the risks are counted twice as a consequence of attributing a specific risk to more than one risk source (Smith et al., 2006).

Risk breakdown structure (RBS)

Hillson (2003) claims that one of the most effective methods to structure and organise risks is by using a RBS, which is based on similar principles as the more frequently used work breakdown structure. The method is based on a hierarchical allocation of project related risks. In fact, all procedures which are dealing with a great amount of information, structuring is an essential part to ensure that all data is understood. A risk RBS can be defined as "A source-oriented grouping of risks that organises and defines the total risk exposure of the project or business" (Hillson, 2003). The method adopts a full hierarchical structure, where each level increasingly shows more details about the risk source. Much of the available risk management software programs retain a pre-constructed structure where organisations have the opportunity to select risk sources. Once the structure design is selected, it can be used for a number of purposes. Hillson (2003) says that the structure can be used in a specific project, while it likewise can be used across a range of projects or for an entire business. The structure's upper level can be used as a *risk identification aid,* which can generate a prompt list of all risks. Moreover, the lower level can be used as a risk checklist which can assist the project team to identify the upper level. Hillson (2003) claims that a generic RBS can be produced based on experiences from previous projects with similar characteristics. The structure can be reused in other projects, after consideration whether each risk should be valid or not.

The RBS can be used in the *risk assessment*. The identified risks should be allocated to its source in the structure which highlights significant risk sources. It will provide a comprehensive view of the risk exposure for each of the project's risk sources. The total risk exposure can be compared with the impact of each individual risk. Additionally, the analysis will give decision makers knowledge about the critical and most important risks in a project. In contrast of analysing the risk exposure in an unstructured risk list, the RBS provides a comparable measurement of the risk exposure for the project portfolio (Hillson, 2003).

Hillson (2003) claims that a RBS can easily be used as a *risk reporting tool*. By selecting information from the structure, it can be communicated to the organisation and the project team. A risk report addressed to the organisation's senior management may include a presentation of the total exposure and the most relevant risks. The organisation can use the structure to inform the construction workers about the risks they are exposed to in their specific part of the project. The RBS will provide a common used language to report and discuss risks in a project which generate a more efficient risk management.

4.4.3 Risk analysis/quantification

The overall purpose with the risk analysis is to quantify the effects of the identified risks. The risk analysis techniques can be separated into three categories: qualitative, semi quantitative and quantitative methods (ISO 31000:2009). At the most fundamental level, each recorded risk should be analysed and quantified independently from the other identified risks with regards to both its consequence and probability. In a more detailed analysis, decision makers should consider the interdependences of the present risks. Although this will require more resources and the analysis can in practice be rather complex (Potts, 2008). Some of the techniques can be performed by hand while other requires a computer based software program that assists the calculations (Flanagan et al, 2007).

The choice of risk analysis technique will depend on the identified risk's characteristics, the analysis purpose, the project size and finally the available resources (ISO 31000:2009). Furthermore, Flanagan et al. (2007) say that the choice of technique should be based on the analysts' experiences and knowledge in risk analysis. In some projects, the used technique will be too detailed which makes the analysis a waste of resources and in some projects it will be too superficial to generate useful results. When decision makers choose a technique there are three aspects that have to be considered. The first aspect is *usability,* the provided result has to be accessible and expressed in an understandable language. Moreover, the decision makers have to consider the *practical aspects* of the analysis technique. The gain from the analysis has to be larger than the spending of resources. Finally, decision makers have to consider the analysis *reliability*. The result's confidence level has to be acceptable so decisions can be based up on the result (Flanagan et al, 2007).

Qualitative analysis

Qualitative risk analysis techniques can be used to evaluate identified risks in a simple and rapid assessment. Therefore, the available methods have become popular in organisations where there is a limitation of time for the risk analysis (Baker et al., 1998). Lyons and Skitmore (2004) claim that qualitative techniques are frequently used by contractors and consultants while clients tend to use the quantitative approach more regularly. The primary aim with a qualitative risk assessment is to generate a prioritised list of risks in order to identify those with the most negative impact, and require further treatment. The qualitative analysis is often used in small to medium-sized projects where the complexity is rather low (Smith et al., 2006). Radu (2009) claims that qualitative analysis should be used when an organisation's numerical risk data is inadequate or unavailable, which it tends to be in the early project phase. As a consequence, an organisation's risk analysis has to be started in a qualitative approach before it can be carried on in a quantitative (Smith et al, 2006). PMI (2004) claim that a small number of qualitative methods exists, where the most frequently used technique is the risk matrix analysis. Additionally, Potts (2008) presents two qualitative methods; expected monetary value and the risk tree approach.

How likely the risks are can be evaluated through a method where a specific probability for each risk is assessed. The likelihood can also be estimated in a probabilistic approach by designing a probability interval and then picking a number on the scale. The quantitative technique adopts the second approach while quantitative techniques adopt the first. A risk's probability is often rated in per cent of the likelihood of occurrence. The designed interval may include events that are most improbable to events that are highly likely to occur during a project. The risks impact can be estimated in a similar approach. The impact is usually measured in a monetary or a time unit. The impact interval may stretch from events with critical consequences to events with minor consequences (Maylor, 2003).

Quantitative analysis

The outcome of the qualitative risk analysis should be a priority list of a project's potential risks. In contrast, the quantitative risk analysis will provide the decision makers with numerical knowledge about a project's risks characteristics and its consequences. The result can be compared with the established risk acceptance criteria, which give the decision makers guidance for risk acceptance (Baker et al., 1998). The needed data to perform a quantitative calculation should be obtained from historical databases or from specialist's estimates. The estimates will contain a level of uncertainty as a consequence of subjective estimations. The quantitative techniques are rather time consuming and require a high level of knowledge by the analyser. As a consequence, the quantitative techniques are more suited for large and medium-sized projects (Smith et al., 2006). The quantitative analyses are often based on mathematical probability theories, which can be complex and difficult to manage by hand. Therefore, most available techniques utilise computer based software to manage the calculations. Finally Radu (2009) claims that the Monte Carlo simulation, decision trees and the sensitivity analysis are the most used quantitative analysis techniques.

Risk matrix

The risk matrix technique is one of the most used qualitative methods and is often used in organisations which exclusively perform a risk analysis based on negative risks, sometimes called static risks. However, some organisations will perform a parallel risk matrix analysis based on the identified risk with positive outcome (Flanagan et al., 2007). A risk matrix analysis is often the initial step to a more comprehensive risk analysis and used as a basis for a quantitative risk analysis. The analysis is performed by plotting the identified risk's estimated value for probability and consequence in a matrix which have predetermined scales (PMI, 2004). The risk matrix will thereafter indicate the level of risk exposure by an indication in different colours. In general, risks with a high risk exposure will be displayed in a red colour, which indicates that it will need a response to reduce either its probability or consequence. Moreover, risks which demand further analysis will be displayed in a yellow colour. Finally, events in green colour are risks that can be accepted without further investigation or response. These are risks with a low probability of occurrence and with minor consequences for the project objectives.

Figure 7 illustrates a risk matrix constructed by PMI (2004). This particular model categorises risks into five colours, which can be seen in a grayscale. The risk consequence interval is divided in five fractions and stretches from events with severe impact to events which are negligible. The probability interval is also divided into five fractions, and cover risks which are very likely to very unlikely. Flanagan et al. (2007) say that each organisation should decide on the translation of the matrix's colours and establish criteria that decide which risks are accepted and which cannot. Most of the used risk matrix analyses are designed in a qualitative manner. However, a risk matrix analysis can be designed in a semi quantitative approach with numerical values. The method will then be more detailed and provide more information to the decision makers about a project's risks (Radu, 2009).

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

Figure 7. Probability and impact matrix (based on PMI, 2004)

Expected monetary value

Potts (2008) presents a qualitative risk analysis technique which aims to estimate the total risk exposure for a range of risks. He claims that the risk exposure is the generated product of a risk's estimated consequence and its probability of occurrence. The total risk exposure can be calculated by summarising the risk exposure for all individual risk (Maylor, 2003). Potts (2008) claims that risk exposure can be estimated in three scenarios, an optimistic, most probable and in a pessimistic manner. The sum of the scenarios calculated probabilities should be 100%. Also, Potts (2008) discusses that the estimation should be carried out for both the probability and the possible impact, which generate three risk exposure values. The cost which should be added to the cost plan or to the tender is the sum of the three calculated values of the risk exposure.

Decision tree method

The decision tree method is frequently used when a decision maker can affect the probability of an event occurring (Flanagan et al., 2007). Smith et al. (2006) claim that the method is based on a graphical model which basic design consist of a decision node and a chance node. The decision node represents a decision which has to be made and the chance node represents a possible risk. The concerned events are connected with arrows which illustrate how the events interrelate with each other.

Smith et al. (2006) say that the decision tree method can be handled as a qualitative risk analysis technique or as a quantitative risk analysis. If the decision maker estimates the event's probability of occurring as a complement to the consequence, the method is used as a quantitative analysis method. Moreover, the decision maker can choose to exclude probabilities in the network, the method will then be classified as a qualitative analyse. When using a decision tree in a qualitative approach it is up to the organisation to choose what the model should measure in the project. The model may include information about the cost of taking a series of decisions or the total risk exposure for a set of events. When the model is used in a quantitative approach, it has to include information about the possible alternative decisions and their probability. The main advantage is to ensure that decision makers have concerned all available options in a project's early phases. Additionally, the model can be used to communicate potential scenarios in a project, which will give the project team a deeper understanding about the project. Also, it is rather cheap to perform and its result is easy to understand. If the decision tree is used in more complex projects, it can be a time consuming method and complicated to analyse. As a consequence, the method is appropriate in small and medium-sized projects or if decision makers should analyse a specific event in a major project (Smith et al., 2006).

Sensitivity analysis
Grimvall et al. (2003) state that risk analysis is primarily based on good and less good subjective estimates about how events will turn out in the future. For that reason it becomes important to highlight the level of uncertainty in the estimations. Organisations might be superstitious of quantitative risk analysis techniques without critically reviewing the provided result. Obviously numerical results will have many advantages for decision makers but not without knowing the results uncertainties. The sensitivity analysis is a frequently used quantitative method which aims to evaluate the performed calculation's uncertainties. Smith et al. (2006) claim that the basic purpose with the analysis is to answer the "what if" question. In practice, the method isolates key variables in the calculations and evaluate the effect of an increasingly change in one of the other key variables. The analysis will pinpoint events which will be critical and more important for the project. A sensitivity analysis is an effective tool and should be performed by all project based organisations (ISO 31000:2009).

The sensitivity analysis outcome is often visualised in a diagram and shows the variables in which the project will be sensitive to change (Smith et al., 2006). Although many advantages, the analysis have a number of limitations which has to be considered. Most important is the knowledge about the calculation assumption that all other variables will remain fixed when changing one of the analysed parameters. In reality events within a project will be interrelated to each other and affect the outcome simultaneously when changing one of them. If the sensitivity analysis is performed in an early project phase it will provide decision makers with information about were the attention should be focused. Smith et al. (2006) claim that the method is appropriate for projects where an organisation does not have any or minor experiences from similar project.

4.4.4 Evaluation/treatment

The purpose with the treatment process is to decide which risks that should be treated and what priority they should have. The evaluation aims to compare the results provided by the risk analysis with the established risk acceptance criteria, in the present context (Smith et al., 2006). If the identified risks cannot be accepted it has to be treated in one way or another (ISO 31000:2009). The treatment process involves methods which modify risks until it can be accepted or controlled. In general, risks can be modified in two approaches where the first decreases the risk's probability of occurrence and the second decreases its consequence on the project. Four basic types of risk responses exist, for a company to treat a risk, according to Smith et al. (2006). They claim that the basic methods are to avoid or reduce a risk, to transfer a risk to another party or to retain a risk. The treatment options can be used individually but should preferably be applied in combination with other treatment techniques to obtain the best possible outcome. When decision makers are selecting the treatment option, they have to balance the cost and effort for the risk treatment activity against the benefits it provides (ISO 31000:2009).

4.4.5 Monitoring and review

The final phase in the risk management process is the monitoring and review. It is important to highlight that this phase is not the end of the risk management process, rather an end of a performed cycle, see Figure 5. The phase is claimed to be one of the most important phases in the whole risk management process (Tah and Carr, 2000).

After performed risk treatment activities, there might be a number of residual risks which could not be treated as the established plan. The remaining risks should be documented and transferred to the next phase in the risk management process, the monitoring and review (ISO 31000:2009). The phase should be executed as a routine in the risk management process with established checklists to guide the work. The process will review the treatment activities to ensure that it has turned out effective and cost efficient. Project decision makers should evaluate if the treatment activities have turned out particularly effective for a certain risk type or if the chosen method should be changed for future projects. The risk status should be documented and transferred to the risk register for further analysis and evaluation (Tah and Carr, 2000).

4.4.6 Risk communication

It is important to have a good communication with internal and external shareholders throughout the whole risk management process. The organisation should therefore establish a risk communication plan, which should be developed during a project's contextual phase. The communication plan should clarify how risk related information should be transferred between involved parties and from one phase to another. The plan should clarify a common risk language that minimises the misunderstandings in the process. Moreover, the plan is needed to ensure effective implementation of the risk management process in an organisation. Due to the differences in risk perception, the communication plan should highlight the subject and ensure that all relevant views are appropriately considered when the risk criteria are defined (ISO 31000:2009).

4.5 The risk management standard

ISO 31000 is a standard for risk management practices and is published by the International Organization for Standardization, which are the world's largest developer and publisher of international standards. The complete version was finished in 2009 and is approved by 25 countries as the official standard of risk management. The standard's purpose is to create a common view of risk definition and risk management practices. It is developed to be suitable for all industries and all types of risks. In contrary to other standards, ISO 31000 is not aimed to be an object for certification (Leitch, 2010).

Purdy (2010) says that ISO 31000 has four objectives. Firstly it should create a common used risk terminology and secondly it should establish performance criteria, which companies have to adopt. The third objective is to create a framework on how risk management should be performed in practice from the identification process to the treatment process. Finally, it should provide guidelines on how the risk management process should be implemented in an organisation.

The standard is rather new and it has been criticised since it was published. Leitch (2010) mentions four arguments why ISO 31000 is a disappointment. He claims that the standard is unclear; it leads to illogical decisions; there are problems of complying with the standard and it does not cover mathematically issues as probability and data handling. There are both positive arguments and negative arguments to adopt a new standard. Moatazed-Keivani et al. (1999) exemplify this statement and claim that an adoption can generate higher costs, more bureaucracy and can be time consuming. However, they discuss that an implementation's advantages clearly outweigh the downsides.

4.6 Risk management in the oil and gas sector

A sector with high risk exposure is the oil and gas industry (Baker et al., 1998; Skogdalen and Vinnem, 2012). Baker et al. (1999) say that the oil and gas industry is known for advanced quality risk management and claimed to be more successful compared to the construction industry.

Baker et al. (1998) investigated how risk management was executed in the oil and gas industry compared with the construction industry. The study involved the 100 largest construction companies in UK and 27 companies within the UK oil and gas industry. The study classified available risk management methods into two categories, qualitative and quantitative techniques. The result indicated that qualitative methods are more frequently used in the construction sector, while quantitative methods are more used in the oil and gas sector. However, 80% of the studied firms used a combination of both methods and it was rare that a company solely relied on one of these methods. The overall most frequently used quantitative methods were the breakeven analysis and the scenario analysis, where the latter is a type of sensitivity analysis (Flanagan et al., (2007). These two were observed as the most successful quantitative methods. Furthermore, the most often used qualitative methods were the risk matrix and the decision tree analysis, which also were the most successful qualitative methods. When studying the two industries separately, the oil and gas industry's mostly used quantitative methods were the expected monetary value analysis and risk simulations. The result indicated that the construction industry used considerably less risk simulation analysis than the oil and gas sector. When it comes to the most used qualitative risk analysis methods within construction, the result corresponded with the overall most used qualitative methods.

4.7 Risk management support tools

According to Dikmen et al. (2004), there is a lack of risk management support tools for all sequences in the risk management process and there is no tool that provides a comprehensive support for all construction phases. They list 22 commercial software programs where only five of those could be described as comprehensive risk management tools that cover the whole risk management process. A majority of these five tools was inadequate concerning the risk correlations and too trivial for most risk processes in practice. Most of the available software is claimed to be risk analysis support programs, which manage the quantitative calculations during risk management activities. There is a clear difference between these programs and risk management support tools, which are able to manage all procedures during the risk management process.

Dikmen et al. (2004) studied a set of commercial risk analysis programs, which was based on quantitative risk analysis techniques. A majority of these programs were adopting simulation functions, normally the Monte Carlo simulation method. Examples of the studied programs are: Risk Solver, DFSS Master, RiskAMP and Risk Analyzer. Two of the most frequently used programs are @RISK and Crystal Ball (Loizou and French, 2012). However, these programs cannot be used as standalone products and must therefore be used with a base of another spreadsheet program. All risk analysis programs have technical functions to configure the Monte Carlo simulation. Four of these functions decide the characteristics of the simulation and can be highlighted as practically important. The operator can decide what sampling method to use in the simulation, where the sampling method is the function that selects a random value from available data. Furthermore, the user should be able to choose from several probability distributions, where a distribution describes how probable a value of a variable is. It is often that risk analysis software has functions to decide how variables relate to each other. Finally, a sensitivity analysis function is often provided, which aims to show how changes of a variable changes the calculated result (Sugiyama, 2008).

4.7.1 Customised support tools

An alternative to use already developed commercial software, is to use a custom made software solution that directly corresponds to the specific company's business process. Langer (2012) asserts that customised software programs generate a better solution of special requirements. The biggest obstacle for companies that decide to develop a customised program is high cost. More than 70% of the costs derive from maintenance and improvements of developing the software. However, more organisations decide to develop their own risk management software as a consequence of an increased need of unique specifications and new technologies in the organisation.

5 Findings

In this chapter, findings from interviews, observations and internal document studies will be presented. The text will focus on how a department within the studied company manage risks practically in the tendering process.

The studied company is one of Sweden's top three construction companies and has long time experiences of infrastructural construction. The study was performed at one of the company's departments that mainly manage and construct large scale infrastructural projects. Usually, the department cooperate with another department within the company when contracting substantial projects. Moreover, the interviewed personnel were frequently active in the tendering process and employed by the studied department in geographical region 1. To get a broader picture of the department's risk management practices, the study includes findings from interviews performed in one other geographical region where the department is active, region 2. Region 1 and region 2 have a close connection to each other and often work together in projects.

The performed study analyses how the selected department manage risk practically in their tendering process. To assist their tendering activities, the department uses an in-house developed support tool, which will be called *Software X*. Furthermore, the company has developed a risk management support tool for substantial infrastructural projects which will further on be called *Software Y*. In the following chapters, there will be abbreviations for the interviewed personnel. Following abbreviations will be used:

DM1=District manager, region 1

DM2=District manager, region 2

DPM1=Deputy project manager, region 1

DR1=Design responsible, region 1

ER1=Estimation responsible, region 1

PM1=Project manager, region 1

RE2=Risk expert, region 2

RMB2=Risk management board, region 2

TR1=Tender responsible, region 1

5.1 The tendering process

In this section we will present findings regarding the company's established policies and practices in the tendering process. The findings are mainly based on the company's internal documentation and answers from interviews, see Appendix.

5.1.1 Policies and routines

The available internal documents clarify what the main objectives should be during the tendering process. A basic principle is the 80/20 rule, which refers to the guideline that 80% of the time should be spent on 20% of the most important activities. There is a directive to focus on project opportunities and to perform neutral calculations without subjective judgments which cannot be verified. Finally, the studied company is required to perform threat and opportunity management which should cover all types of uncertainties in the tendering process.

It is not specified when the tendering process should be started. Nevertheless, it is claimed that the process should be started as soon as possible after an executing department spots a potential project. The attention can arise during market research and sometimes before tendering documents are published by a client. There are several reasons why it is important to spot a major potential project in an early phase. The department has to reserve resources to the project so it does not conflict with other needs. Moreover, the time in which the company has to perform the tender is often short and associated with a high level of stress. By preparing the department for the tendering process the stress will decrease and the quality increase.

According to established routines, the management of an executing department should select a tender responsible for every tender. Another important function in the process is the estimation responsible. It will be the department for support functions that selects an appropriate candidate for that position. Thereafter, the tender and the calculation responsible select the needed resources, which will make the tendering team. It will be crucial to gather the right experience and knowledge among the involved parties that can contribute in all tendering parts. The estimated tendering size will frame the composition of the team. The company has established routines that regulate which functions should be involved in the tendering process dependent of the contract sum. When the contract is substantial, the executing department has to involve functions from other specialised departments, such as purchase and technical specialists.

When the tendering team is selected, the tender responsible will call for a start up meeting. Its purpose is to confirm a tendering schedule which gives information about the defined deadlines and a responsibility clarification. Additionally, it should include a brief description of all required activities, where the construction designs are one of the most important activities. The schedule will be updated and communicated to involved parties while the process proceeds to clarify possible deviations.

When the client publishes the tendering documents, the tendering team will be provided with specific information about project features. After the involved parties have got themselves the necessary knowledge about the project they have to consider the possible risks which can be present in the project. This will initially be done by completing a pre-established risk table which indicates if the project is associated with any extensive risks. If the project is expected to be large and complex, a further risk analysis has to be performed and communicated to an external risk support department. Without any remarks, the tendering process can be carried on.

The content of the tendering activities depends on circumstances and a project's features. The construction design process will be crucial for the outcome of the tender and it is a rather large percentage of the total tendering cost. The design process should focus on the choice of the execution method and material decisions. To obtain a high efficiency in the calculation process, the studied company uses an in-house developed software program, Software X, which assists the calculations and enables a good structure. The software should be present in all activities during the whole tendering process. Moreover, it should be used as a communication tool to provide involved parties with project information.

When the tendering process reaches its end, a close up meeting should be held. The meeting should be performed in good time before the tender should be submitted to the client. The team should get the opportunity to value the identified risks and discuss the final tendering price. If the project is substantial it can become necessary to divide the close up meeting into three. The meetings should then be separated into discussions regarding the use of methods, performed calculations and the finally meeting focusing on the tendering price. It is important that the whole tendering team is present during the discussions and if the project is large, the department's management should be involved in the discussions.

After adjustments of highlighted changes from the close up meeting, the responsible will submit the final tender to the client. If a tender exceeds a certain level, the tender has to be reviewed and accepted by the risk support department. If the client represents a municipality or the state, the tender should be submitted in accordance to the Swedish public procurement act.

5.1.2 Tendering in practice

Here we shall present the findings from performed interviews. The purpose is to describe how the tendering process is carried out in practice. A typical tender process of the studied department is illustrated in Figure 8.

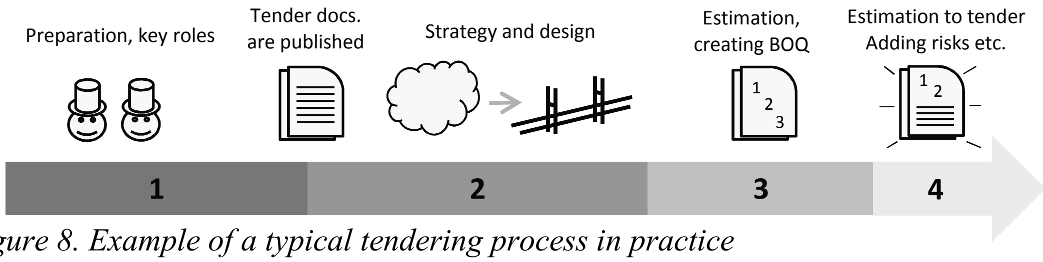

Figure 8. Example of a typical tendering process in practice

All respondents highlight the importance of starting the plan for a tender a long time before the tender documents are available. This as a consequence of the shortage of time from the tender announcement to the tender should be submitted. TR1 claims that it is expensive to put resources in a tender, therefore it is essential to evaluate how valuable a project is in an early phase. If a project appears to be profitable, a project plan can be established, where human resources are essential. Key persons in the project can be selected and the need for external competence has to be investigated. If external consultants are needed, these persons have to be allocated at an early stage. In addition to resources, focus areas and construction methods should be evaluated. TR1 says that the design responsible and the tendering responsible are the persons who manage this process. Respondents think that project preparations can be started up to one year before the tender is announced.

"*During the years, every successful project has been prepared a long time before the tender documents were available*" (DM1)

TR1 mentions that the Swedish Transport Administration is a client to the majority of the substantial infrastructure projects. Moreover, Swedish regulations imply that the client has to inform the public about all upcoming projects. DM1 says that if the procurement has not started, it is possible to discuss with the clients about upcoming projects. DM2 thinks that tunnel projects are performed as DBB contracts because of the high risk exposure which is associated with tunnel projects. The price in tunnel DBB contracts is then calculated from provided bills of quantities. TR1 thinks that if it is not a tunnel project, the department should only be involved in DB contracts because it is where the department has its competitive strengths. DM2 claims that there is more to gain from DB contracts since it can be profitable to come up with smart and distinctive design solutions.

DR1 explains that when the tender documents are available, one should carefully read the documents to search for ambiguities or inaccuracies. Moreover, a study should give an understanding of what the customer wants and which strategy the contractor should use to meet their demands. The assembly of a tendering team has to adapt to the actual project and usually a tender involves 20 persons. The respondents think that frequent roles in the tendering team are: tender responsible, design responsible, planning responsible, estimation responsible and the potential project manager. Sometimes there are other roles, for example: specific consultants, purchasers or environmental specialists. DM1 says that all information during a tender is shared in a common folder on the internal server. Regular meetings are conducted for specific groups and with key persons for general matters.

TR1 says that if the project is purchased as a DB contract the first half of the tendering phase mainly covers design work. DR1 explains that the objective is to create a bill of quantities so the estimators can start performing their work. If the design is complex, the department has the option to involve external consultants. Meanwhile, if the project is less complex, external consultants are often selling bills of quantities that contractors can purchase to base their estimates on. Other important activities are to compose the schedule for execution and to prepare descriptions of how the construction will be formed. TR1 claims that design and estimations is an overlapping process, but the majority of the second half is allocated to estimating costs. ER1 says that estimations are executed more in detail for the parts where the majority of the costs are located.

"*80% of the estimations are done on the 20% of the project*" (ER1)

PM1 says that all estimates are performed in Software X. Both PM1 and ER1 say that approximately one third of the tendering team are actively using the tool to assist their estimations and to record identified risks during a tendering process. Software X is moreover used in the execution phase and the estimates can be transferred from the tendering phase to the execution phase. PM1 says that the program is easily used but demands frequent use to make the process efficient. They explain that the management function therefore does not use the tool.

TR1 says that approximately one month before the tender should be submitted, the estimations are finished and the third main process can be started, which is to secure the quality of the tender. The process will ensure that the tendering methods and estimates are controlled and possible mistakes are corrected. Another important part is to schedule the production organisation. DR1 says that they always leave a tender on what the customer asks for, but sometimes they complement the tender with an alternative if there is another advantageous solution.

"One of the most difficult decisions during tendering is to pick the most favourable alternative" (DR1)

5.2 Risk attitude

We will present findings in the following section concerning the department's overall risk attitude in construction projects. The risk attitude concept will include staff answers regarding risk acceptance and their risk and uncertainty definitions.

5.2.1 Risk and uncertainty

According to studied internal documentation, the company's established risk definition is as follows:

"*Uncertainty that matters. Risk is an uncertain event with likelihood to have an impact on the project objectives. Risk can have a downside (threat) or an upside (opportunity)*".

When the respondents were asked how they would define the term risk and uncertainty there was a wide range of different definitions. RE2 and RMB2 answered the question by telling that risk is uncertainty that matters. RMB2 says that uncertainty has to have an impact on the project objectives, either positive or negative to be defined as a risk. Moreover he thinks that people will have a problem when it comes to refer risk to an opportunity, since risk often is associated with a negative impact. To confirm this statement, TR1, DM2 and DPM1 refer risk to the negative impact and opportunity to the positive outcome of a certain event. Moreover DPM1 claims that risks are something that might happen but is not valued in the construction calculations. TR1 claims that risk has a probability of occurring that is more than zero per cent and less than hundred per cent. DM1 discusses the difficulties to state a risk definition. In a simplistic approach, risk can be defined as the product of an event's probability of occurrence and its consequence. However, he says that a risk definition is more complex than a mathematical formula. When DM2 defines risk, he claims that it is something that one cannot forecast and that one cannot calculate with completely certainty.

When it comes to the respondents' definitions for uncertainty, DPM1 and RMB2 claim that uncertainty is a lack of experience and knowledge which gives rise to risks. Moreover, TR1 says that an uncertainty is present when one has a notion about the outcome of an event but one is not completely sure about the outcome's extent. DM1 answers the question by telling that uncertainty is a component in risk. In general, the respondents found it harder to define uncertainty than risk.

5.2.2 Risk acceptance

RMB2 thinks it is a huge difference in people's private risk attitude and their professional. He claims that he is neither risk averse nor a risk taker, rather neutral to risks. He discusses that a contractor has to take risks to attain profits and he would like to see that their department took more risks than they do to be more competitive. TR1 says that he is risk averse as a consequence of experiences from his career. When managing a huge infrastructural project and some unexpected event occurs, it can have enormous consequences which might ruin the whole project. Similar answer is given by DM2 who says that he is fairly risk averse. He explains that a possible consequence of a risk averse behaviour is that a project they win is connected with a high level of profit. The negative effects are claimed to be that they lose some projects to their competitors. However, he says that the company has during the last five years become more willing to take risks and better to take advantages of a project's opportunities. DM1 takes the risk discussion further and says that his acceptance will depend on the circumstances and the risk type. He thinks that humans are risk averse by nature and have a limitation when it comes to estimate risks with a very low probability of occurring. Moreover he says that it is almost impossible to forecast the future and if he cannot estimate the magnitude of the identified risk he rather avoids it. When it comes to the company's risk acceptance, he claims that the established policies sometimes tolerate a higher risk exposure than what he is willing to take. In summary, most respondents claimed that they acted in accordance to a risk averse behaviour. Moreover they would like to take more risks and improve their ability to take advantage of project opportunities.

5.3 Risk management during tendering

We shall in the following section present the findings regarding the company's risk management process throughout a tender. The findings will concern both internal documentation of established routines and risk management practices based on interviews, see Appendix.

5.3.1 Policies and routines

According to the studied company's policies, risk management should be an ongoing and essential part of the whole tendering process. The overall purpose is to increase the rate of return on an investment by avoiding projects associated with losses and increase the transparency in the process. The risk management activities should be based on risk awareness rather than risk aversity, which recommend an open minded approach and systems for sharing experiences and knowledge.

Risk management system

The company has developed a risk management system which consists of policies and guidelines how to manage uncertainties in the tendering process, during negotiations and in the execution phase. The system's purpose is to minimise risks with negative consequences, maximise risks with a positive outcome, ensuring a proactive risk management throughout the whole project and finally securing the delivery of a successful project to the client.

Risk management and tendering board

The risk management and tendering board is a part of the risk management system. Each executing department should send their initial risk assessments to the board for further analysis. The risk management board's purpose is to prepare the incoming risk assessments for a later decision by the tendering board. In some projects, the tender responsible is required to present the content of a project's risk management preparation for the board. Moreover, the board supports the executing departments in their risk management activities and constantly improve the company's risk management processes. After consideration, the risk management board will present the result for the tendering board who will decide whether the project should be accepted or not.

Before the tendering process can be started

Before resources can be spent in the tendering process, an established risk document has to be completed. The assessment will give the company a brief overlook of the project's risk exposure. Its aim is to create knowledge to prioritise the most profitable projects in an early phase. The assessment consists of a risk matrix which indicates a project's characteristics and its critical risk triggers. The risk matrix is unique for each of the company's executing departments and based on a department's strength, weakness and core competence. A project is reviewed based on its characteristics, contract form, client, geographical location and the available competences. Furthermore, the assessment will consider construction design's with substantially high risks. The matrix will indicate the risk exposure in three colours, green, yellow and red. If there is a green indication, the project did fulfil the risk criteria and the tendering process can proceed. A yellow indication is a result of failure in one of the established criteria and therefore needs a further analysis. If the matrix has a red indication, the tendering process should generally not be carried out. However, if the tender responsible wants to proceed a project with a yellow or red indication, the risk management and the tendering board has to analyse the project and decide if it can be accepted.

If a project is associated with a critical risk indicated by the risk matrix or if a contract is estimated to exceed a certain price level, an initial risk assessment has to be performed and communicated to the risk management board, see Figure 9. The assessment should clarify the information which the tender responsible recorded in the risk matrix. In addition, the responsible has to give information about the tender reasons, the relationship to the client, a treatment plan for the most critical risks and finally a presentation of the project's key staff. After completion, the risk assessment should be submitted to the risk management and tendering board for further analysis and consideration.

During tendering process

According to the risk management system, the tendering risk assessment should be managed in Software X to ensure an effective and comprehensive process. The software is not mainly developed to manage risks, rather to manage a project's overall estimates. Nevertheless, Software X provides a 'risk management add' which can be reached under a separate tab in the program. The risk management add is developed to handle a project's related risks during all project phases.

During the tendering process, Software X's risk register can easily be reached by all team members and it provides a rapid risk record whenever a risk might be discovered. A risk register can be created by reusing a register from a previously performed project with similar features. This should preferably be done in an initial tendering process when the amount of information is limited. High levels of the identified risks are not project specific, which enables a reuse of an already produced risk register. The recorded risks can be seen by all members and its information can be changed, clarified or removed throughout the whole process. The risk identification should be performed on a general level and not too detailed. The identified risks have to be defined and categorised based on characteristics in accordance with a pre-determined structure. A risk has to be categorised based on its risk type. There is a set of risk type alternatives which the member can choose from. Examples of risk categories are: financial, production, construction design, purchase and risks related to the client. Moreover, the member can choose to specify the risk's probability of occurrence and its impact. The probability is recorded on a three degree scale with the following content: 1, occurs rarely; 2, occurs a few times; and 3 occurs frequently in a project. The impact can be recorded with the same approach but with the following consequential content: 1, not substantially; 2, substantially; and 3 refer to a more massive consequence on the project.

The identified risks should be evaluated during a separate meeting, where the team members decide how it should be managed. The meeting should end up with decisions regarding if the recorded risks should be treated right away, clarified, priced, or if they should be removed from the risk register. The recorded data regarding probability and impact provide a risk matrix analysis. If a risk should be priced, there are basically two alternative approaches. In the most basic approach, one estimates a single value for each risk and decides whether it is an opportunity or a threat. On the other hand, one can use Software X's valuation add. By estimating values for the most probable outcome, maximal and minimal, Software X would provide a weighted mean value. The software uses a triangular distribution which weights the most probable value three times higher than the maximal and the minimal values. Furthermore, if the risk should be treated, the team discuss and record an appropriate treatment plan attached to the risk in the register. The treatment cost for a specific risk should be valued and recorded. All relevant data regarding each risk can be seen at a separate sheet in Software X, which gives the involved parties a comprehensive view of a project's risks. The sum of the priced risks should be added to the calculated prime cost for construction, central administrative costs and the required profit margin, which should end up in the final tender.

Before the tender can be submitted

If an executing department was required to perform an initial risk assessment, they have to make a similar assessment before the tender can be submitted to the client, see Figure 9. The tendering responsible has to add information about the most critical risks and establish a treatment plan for each of them. Moreover, additional information about the financial exposure and possible regulatory risks should be clarified. The assessment will be submitted to the risk management board for further consideration. If the board accepts the assessment, the responsible can thereafter submit the tender to the client. Under special conditions, the board will request complimentary risk information before the project can be accepted.

5.3.2 In practice

The following findings regarding risk management practice will be presented in accordance to a structure which corresponds with the risk management model established by ISO 31000.

Figure 9. The studied department's risk management process

Risk identification

According to all respondents, risk identification is a responsibility shared by all members within a tendering team. Although when it comes to how the process is executed, the answers slightly differ. DM2 says that it is the estimation responsible who frequently will perform the initial risk identification. The responsible should study the tendering documents and list all potential project risks. He claims that all team members should thereafter add risks to a risk list when they arise during their work in the tender. In contrast, TR1, DPM1 and DM1 explain that risks will be collectively identified by all team members from the very beginning. Moreover, DM1 clarifies the statement and says that it should be the division manager or the tendering responsible who should delegate the identification activities to the right people in the team. The basic principle is that the responsible for a certain tendering part identifies its related risks. However, TR1 gives his picture of the process as rather unstructured and its proceeding is highly dependent on the involved parties. PM1 and EM1 say that the risk identification process should be managed in Software X. All team members should have access to the software and should record risks when they come across, although this is not the fact in reality. They claim that it is just a few that continuously use the software in a substantial project, usually the estimation and tendering responsible.

TR1 says that they often use a pre-established risk register and modifies it to the specific project, which contradicts EM1, who claims that this is not the case. The identified risk will cover risk with minor impact to risks which have the potential to ruin the entire project. DPM1 and PM1 mention that risks are initially recorded in an excel sheet and then transferred to Software X's risk register. Moreover DPM1 says that it is solely risks with a substantial impact that are transferred to the register. The less important risks will be valued in the construction calculations. Furthermore, DPM1, DM1 and TR1 say that repetitive risks are in general easy to identify, while unique risks are difficult to identify.

"*A high number of a project's risks are repetitive and easy to identify. It is much harder to identify those who are specific for a project."* (DPM1)

When the respondents answered the question about how the identified risks was sorted and categorised they gave a similar picture of the process. The team follow the structure in the risk assessment, which they have to complete before the tender is submitted. However, they did not sort negative and positive risks separately, instead these were mixed in the register.

DPM1 and DM2 agree and say that a majority of the risks which occur in a project were identified during the tendering process. In contrast, DM1 and TR1 say that their ability to identify risks is relatively low. To illustrate this statement DM1 claims that about 50% of a project's occurred risks were not identified during the tendering process. However, all respondents claim that it is hard to estimate their ability, due to the fact that they do not perform any risk review after a project is completed. Moreover, all respondents say that their ability to identify risks with negative impact is much higher than the ability to identify risks with a positive outcome. They say that this is probably a consequence of a clear focus on the negative risks. DM1 and DM2 suggest an operation mode where the team uses two risk registers that identify negative and positive risks separately. Finally, all respondents expressed that the risk identification process can be improved, especially when it comes to identifying risks with a positive outcome.

Risk analysis/quantification

All respondents agree and say that much of the risk quantification and analysis is performed during a separate risk meeting in the end of the tendering process. ER1 says that his responsibility is to prepare the risk estimations before the meeting is carried through. This corresponds with DM2's answer, who says that he has one responsible who performs a majority of the risk quantifications. Moreover, recorded risks which have not been quantified will be analysed during the meeting. The remaining risks are usually risks which are difficult to quantify and associated with a substantial impact. This statement corresponds with the answer which was given by TR1, who says that the meeting's purpose is to quantify the substantial risks and not those with minor impact.

PM1 says that the team members should estimate a value of each risk's probability and its impact, which altogether will make a risk cost that is added to the tender. In reality, most of the interviewed gave a more simplified picture, where the estimated probability and consequence was not registered separately. Instead the risk impact was registered as a monetary sum without any deeper analysis or calculations. DPM1 mention that risk costs usually are based on gut feelings without any deeper analysis or calculations.

PM1 says that the tendering team can use Software X's triangular distribution add to estimate a risk cost. He continues and says that the risk characteristics will influence if the add will be used or not. However, most of the respondents did not use the add to assist their estimations. When it comes to the difficulty to quantify risks, DM1 says that risks with a substantial impact will generally be more difficult to value than risks with less impact. According to DM2, DPM1 and TR1, the less challenging risks to quantify are those that are based on uncertainties in quantity. Moreover, DM1 and DM2 claim that external expertise can be involved in the risk analysis if there is a lack of knowledge in a specific part of the tendering.

All respondents claimed that a contingency cost was used as an effect of the limitation of ability to identify all project related risks. The contingency cost which should cover the unidentifiable risks is a percentage amount of the contract sum. The value of the cost is often based on a project's complexity, contract form, project type and the limitation of time in tendering.

"*If the process has been associated with a high amount of stress we know that we have missed risks in the identification and therefore increase the contingency cost"* (DM2)

DM1 discusses the chain reaction phenomenon which is present in construction projects and illustrates it by saying that profitable projects tend to be more profitable as time passes by. In contrast, projects associated with losses tend to have increasing losses as a function of time.

DM1 and DM2 suggest that the risk analysis process should be separated in the same approach as their suggestion about a separated risk register. Furthermore, DM2 and DPM1 express a need to improve the structure of how to return knowledge regarding risk analysis from one project to one other. However, DM1 thinks that the gain would not exceed the cost of needed resources to execute the analysis. Finally, all respondents say that the organisation should leave the deterministic approach and develop a more probabilistic way of identifying and analysing risks.

Risk evaluation/treatment

All respondents agree and claim that the treatment of risks depends on a specific risk's characteristics. Moreover they say that the public procurement act governs how risks can be treated in a major project with a public client. To exemplify this statement DPM1 says that if there is an uncertainty in the tendering documents, the contractor has in general two alternatives. The contractor can ask the client for a clarification, which according to the act has to be communicated to all contractors. He discusses that this approach will be used when the department is not willing to accept the risk but realises that there are other contractors who will. In contrast, if the department identifies a possible gain which is connected to an uncertainty in the documents, they can decide to not ask the client for additional information.

When it comes to transferring risks to subcontractors, their answers slightly differ. DM2 says that they usually do not contract any subcontractors, due to the contract form that he usually adopts. DM1, TR1 and DPM1 explain that they transfer risks to their subcontractors if it is possible. However, the transaction is usually performed under the *back to back* condition, which refers to an approach where all risks attached to a specific work will be transferred. DM1 complements the statement and says that risks should not be transferred to a subcontractor if the company has a better capacity to manage it. Additionally, the department should avoid transferring risks with low probabilities if they expect the subcontractor to add an indefensible supplement charge. Another frequently used treatment method according to TR1 is to purchase insurances that cover some types of risks. He continues and says that this is a rather expensive approach and therefore not always cost effective. Finally, the respondents claim that risks with a low impact will be retained by the company and added to the tender.

5.3.3 Risk management development

The respondents were asked about how the company's risk management process has changed during the last five to ten years. They gave a basically similar answer and claimed that the most significant change are a more seriously view of the process and the attitude where risk management is seen as a separate profession. DM1 gave a more detailed answer and claimed that risk management activities until 2003 were generally managed in an arbitrary approach, which was shown by varying results. Thereafter the company's management changed their attitude to risk management and started to imply a more structured way to manage risks. DPM1 mentions a consequence of the more systematic system was the realisation of a language in which the organisation discussed risks. Furthermore, he says that the company became more aware of their risk exposure, which resulted in a more restrictive attitude to risk. A contradictive answer was given by RE2, who says that the process itself has not changed it is rather about business related changes. He says that the company has to highlight the importance of risk management activates and make them more prioritised in a future. Moreover he would like to see more involved parties in the process. Today there are few persons who identify and analyse risks in a project, the process has to be more transparent. Finally he discusses that the company and the construction industry as a whole has historically been rather good at identifying risks. He says that the construction industry has to develop their risk management practices and implement structured systems where contractors use their experiences and knowledge in a more effective manner.

The respondents were asked what they knew about ISO 31000. All responds answered that they got a notion that it concerned a new risk management standard, but they did not know anything about its content. RE2 was the only person who claimed that he knew the standard's details. He told that when the standard first appeared in 2009, the content was no surprise. It confirmed that the company's risk management policies did correspond with ISO's view of risk management practices. He thinks that the standard is established on a basic level and it is easy to claim that their policies are in line with it. He says that there is no reason to fully comply with the standard until the clients demand it. However, RE2 believes that the clients will probably demand that contractors use the standard in the future.

5.4 Software Y

Back in 2003, the company initiated a project to develop a risk support tool which should assist the organisation to manage risks in substantial infrastructural projects. The decision was based on a client's demand for an effective risk management tool in a certain project. Initially, the company performed a study where they tried to find an already existing support tool which suited the organisation's and the client's demand, but did not find any appropriate alternative.

"We could not find any transparent support tool which had the needed risk management structure; we wanted to develop something better than the already existing" (RE2)

Software Y was originally developed to fit the risk management processes in the execution phase. RE2 claims that the tool is today mainly used as a hub for stringent risk management in the execution phase but can easily be adapted to all project phases. RE2 says that he wants to see a wider use of Software Y and especially as a support during tendering. In present, the tool is used in two major infrastructural projects with several active users.

The user can adjust Software Y's functions and make it suitable for all project sizes. In smaller projects, the user can decide to exclusively use the basic functions but it has the potential to manage larger projects with more advanced functions. RE2 says that the tool is suited for the whole organisation and the responsible can select different types of project operators. The users who should govern the tool will be given an introduction course for about an hour. RE2 says that the process is much about learning by doing. Moreover he explains that people lack time to attend in to lengthy training and think that the process runs smoothly as it is designed.

RE2 says that the decision whether a project should adopt Software Y or not lies in the hand of a project owner. Today, the studied department does not use the tool in any of their running projects but has previously considered the alternative. None of the interviewed from the studied department has worked with the support tool but has a brief notion about its function and its purpose. Further their general opinion is that Software Y is too complex and too time consuming. However, RE2 claims that the persons who have used the tool find it relatively user-friendly. Moreover he says that if the department would adopt the tool in their upcoming projects, they would probably get a better risk management structure in their processes. Finally he explains that he does not think that the department have studied the tool deeply enough to get insights about its benefits.

"Adopting a new system is always associated with a degree of scepticism among the employees" (RE2)

Software Y is in much based on a risk management structure which accords with the model which is provided by ISO 31000. RE2 says that there are still some smaller differences in the terminology. The identification phase will be performed by mapping new risks or by copying an existing risk register from a previously performed project. The user should describe the risk characteristics comprehensively by specifying the following main features: risk name, start and end date, degree of confidentiality, risk owner, risk source, warning bells and chain events. The risk identification phase will be similar to the previous way of working with Software X but with an increased awareness about the risks.

The identified risks will be evaluated and analysed in a separate summary page. The risks have to be assessed regarding how probable they are and what their consequences might be on the project. The risk consequences should be selected from a five degree scale stretches from risks which are negligible to risks that are associated with a catastrophic impact. The user will in a similar approach estimate the probability of occurrence by using a five degree scale. The scale will cover risks that are improbable to risks which are very probable. Software Y provides a translation table where the user can use a probability interval instead. The assessment will be illustrated in a risk matrix, where the user gets a notion about each risks exposure. The assessment can be made for up to five consequence categories which provide a deep understanding about the risk's impact on a project's objectives. In advanced settings, the user can select a probability distribution for each risk from three alternatives: triangular, rectangular and a fixed value.

After the risks have been assessed, the next step is to evaluate if the risk can be accepted or not. If the risk cannot be accepted it has to go through a further analysis or connected to a mitigation plan. By selecting the last alternative a mitigator has to be selected.

By applying the advanced settings, the user will get access to Software Y's risk breakdown structure, RBS. According to RE2, this is one of the features that make the tool effective as it provides the user with an appropriate risk structure which gives an overview of all risks and a measure of the risk exposure. He says that the RBS might be the biggest difference between Software Y and Software X. The RBS is a hierarchical structure of a project's related risks, see section 4.4.2. The user can choose to design the RBS as it provides information about a specific project's total risk exposure, a set of projects or for a whole department. Software Y does not provide any generic RBS. Therefore the users have to compile the structure by themselves or reuse an already produced one. Negative and positive risks should be separated in the RBS structure. The calculated total risk exposure can be presented in a graphical view as a function of time. The graph shows historic development of a project's risk exposure, the present risk exposure and a prognosis of the future. To summarise, the positive effects will be reached first when the advanced settings is adopted. In the basic settings, Software Y is similar to the company's previous way of managing risks with Software X.

6 Case study – Monte Carlo simulations

In this chapter, general information about Monte Carlo simulations are described and their advantages and disadvantages are discussed. To explain how a simulation can be performed, information about probability distributions and correlations is provided. The results from the two performed Monte Carlo simulations are presented.

6.1 Risk simulation

Pidd (2010) defines a simulation as a model that is used to explore and experiment a future outcome. The reason why simulations are often used is that they are cheaper, safer and faster than to perform a test in the reality. Smith et al. (2006) say that Monte Carlo simulations are relatively simple to perform and it is the most used simulation technique. Several studies advocate simulations to be used in risk assessment and tender cost estimation (Ali, 2005; Nemuth, 2008). An obstacle is to get a representative sample which would provide a good result. The solution is to execute the simulations repeated numerous times. As a consequence of the high number of iterations, a simulation is often supported by computer based software (Smith et al., 2006). Beside the Monte Carlo simulation, there are other simulation techniques that do not require the same computer capacity. One frequently used technique is Latin hypercube. Latin hypercube uses a more advanced sampling method and creates more accurate values with a lower sample size. If the sample sizes are relatively high, the accuracy is similar for Monte Carlo and Latin Hypercube (Olsson et al., 2002).

6.1.1 Monte Carlo simulation

Firestone et al. (1997) indicate that a Monte Carlo simulation aim is to quantify uncertainties and to investigate the variability of risks. Moreover it is used to investigate how variability of one single risk affects the total risk exposure. Furthermore, Akkoyun (2012) presents when a Monte Carlo simulation can be profitable to use. One example is when the risk treatment costs are high or when treatments are too many. Loizou and French (2012) explain benefits with Monte Carlo simulations and claim that they generate comprehensiveness, clarity and rigidity to a decision. Another benefit is that the simulation guides the decision maker to be more rational and consistent, due to a lower degree of subjectivity. However, Loizou and French (2012) present some disadvantages with Monte Carlo simulations. It can often be a problem to find a correct probability distribution to each variable and the fact that the input data come from historical information or subjective estimates which could be incorrect. They also point out that if a Monte Carlo simulation should be effective, it should be a complement to other decision techniques.

Matstoms and Björketun (2003) say that Monte Carlo simulations can be divided into four sequenced steps. The first step is to decide what type of probability distributions to use in the simulation. The second step is to generate random data within the specific range. Random sampling for each variable creates a set of data and a large number of sets to get a wide spectrum of data. To improve the spread, there is a possibility to divide data into ranges. Step two also involves the set of variable correlations. In the third phase, every set of data must be evaluated to test if the set manages the given criteria. The last step is to create a sensitivity analysis from the generated data. Smith et al. (2006) advocate 1,000 or more iterations in a Monte Carlo simulation to get a representative sample.

6.1.2 Probability distributions

Probability distribution is a function which describes how values are distributed. An important distinction is the difference between a discrete distribution and a continuous distribution. A discrete value is a value with fixed outcomes where an example can be the throwing of a die that has six possible outcomes. A continuous variable has endless possible outcomes within a given range (Devore and Farnum, 2005). The selection of probability distributions is normally generated from historical data or from gathered experience in an organisation (Smith et al., 2006). Normal, lognormal, triangular and uniform distributions can be seen as the most used, see Figure 10 (Smith et al., 2006; Palisade, 2012; Akkoyun, 2012).

Devore and Farnum (2005) say that normal distributions are the most important distributions in statistics and the distributions with the widest range of use. Some examples where normal distribution can be used are for human characteristics, errors in measurement of scientific experiments or economic indicators. The standard normal distribution function has a symmetric bell curve shape.

Lognormal distributions are only valid for positive numbers, but have no upper limit. The lognormal value is a normal distributed curve that is positively skewed (Devore and Farnum, 2005). The distribution is applicable on oil prices and financial indications such as stock prices (Akkoyun, 2012).

According to Smith et al. (2006), the triangular distribution is one of the most used distributions. There is often a lack of how a variable is distributed, while information about the most likely, best case and worst case outcome often are available. Triangular distribution is created by setting a minimum, a maximum and a most likely value and it takes the form of a triangle. The triangular can be skewed if the most likely value is closer to one of the two extreme values. Palisade (2012) claims that triangular distributions can be utilised for sales history and inventory levels.

The uniform distribution describes an interval where all values have equal probability to occur. The range of the values is selected with a minimum and a maximum value, but all values in between have the same probability of occurrence. Uniform distributions can be utilised for sales revenue from a new product (Palisade, 2012).

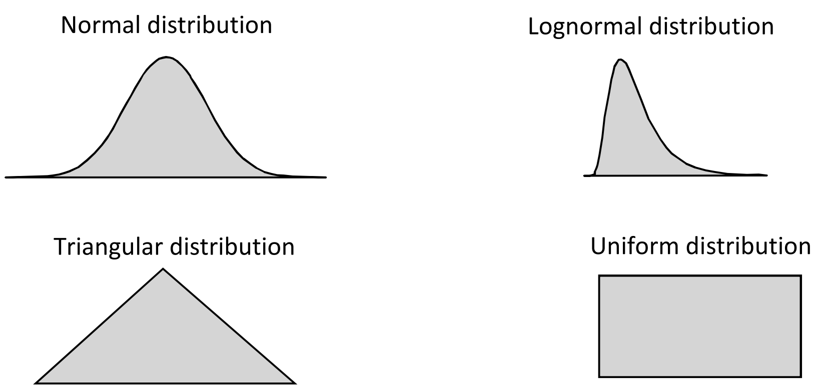

Figure 10. Four often used continuous probability distributions

6.1.3 Correlations

According to Dikmen et al. (2004), a Monte Carlo simulation can give an incorrect result if the correlations are misjudged or not defined. Vrijland (2005) explains correlation as the interdependency between two variables and it is often illustrated by using a correlation coefficient. The value the coefficient can vary between -1 and +1. When it is equals +1, there is a full positive correlation between the two variables. Moreover, when the coefficient equals zero, there is no correlation at all, this means that the studied variables are completely independent to each other. The third alternative is when the coefficient equals -1, which indicates a full negative correlation. This can be illustrated by two dependent variables where one of them is high and the other will thus be low (Vrijland, 2005). Correlation coefficients are often difficult to get from the data and they change according to unique situations and as a consequence, the correlation is often based on subjective estimations (Loizou and French, 2012). However, if there are data, there are methods to estimate correlations (Vrijland, 2005).

6.2 Case study results

In this section, the performed simulations and the results are presented. The Monte Carlo simulations are executed to evaluate how a probabilistic risk analysis can be performed.

The requirements for the simulated infrastructure projects were a relatively large contract sum and an adequate number of identified risks in the project. Furthermore, the projects must be completed to be able to compare the results with the actual outcome. The contract sum of project 1 is in the range of 1,000 million SEK to 2,000 million SEK, while project 2 is in the range of 100 million SEK to 500 million SEK. Project 1 is a DB contract, while project 2 is purchased as a DBB contract. The studied projects are situated in two regions in Sweden and concern two different types of projects. The studied projects were selected as a consequence of the stated differences. To understand the simulations, the calculation of the tender price is as follows:

+ Prime costs (including overhead costs for production)
+ Central overhead costs
+ Threats and opportunities (including contingency costs)
+ Profit
= TENDER PRICE

Prime costs are the calculated costs to perform a specific construction, where costs for production overheads are included. Central overheads are the cost for central administration. Threats and opportunities are costs for uncertainties that have been identified as a negative or positive to the prime cost. In this post, costs for unidentified risks and risks with minor impact are included as contingencies. Profit is the department’s required rate of return from the investment. The summation of these costs generates the total tender price. However, the only cost that will be simulated in this study is the cost for threats and opportunities including contingencies. The logical explanation to this is the fact that central overheads and profit are fixed percentages that are not variable. The variables of the prime costs are covered by threats and opportunities. Therefore these costs are the only values which are simulated. Threats and opportunities are classified in 12 categories, as they were originally structured in the risk register: finance, legal, construction design, organisation, purchase, quality, environment, working environment, production, third party, customer and others.

An important decision is to select a distribution for all variables in the risk register. Since there are no historical data available, the distributions are estimated by key persons in the projects. To define a variable’s distribution, an easy method is to use the triangular distribution. When adopting this distribution, values for the investigated risks have to be estimated in a scenario approach, where a best case, a worse case and the most likely situation should be estimated. This corresponds to the selection of distribution which is mentioned by Smith et al. (2006). The most likely values were extracted from the original risk register and values for worst case and best case were jointly estimated by DR1 and DPM1 for project 1. In project 2, values of the three scenarios were already defined in the risk register.

The matrix (Table 2) shows how correlation between each threat and opportunity category was estimated. The same correlations were used in both simulations.

Table 2. Correlations of the categories in the risk register

	Finance	Legal	Customer	Design	Organisation	Purchase	Production	Third party	Contingency
Finance	1								
Legal	0.5	1							
Customer	0.5	0.5	1						
Design	0.5	0.5	0.5	1					
Organisation	0.6	0.6	0.6	0.6	1				
Purchase	0.5	0.5	0.5	0.5	0.5	1			
Production	0.7	0.7	0.7	0.7	0.7	0.7	1		
Third party	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1	
Contingency	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1

The results from the executed simulation study are presented in an accumulated ascending curve diagram, where the y-axis shows the probability of the simulated result. The values on the x-axis are normalised, where each number represents one part of a thousand of the entire prime cost, implying that a value of 1,000 represents the entire prime cost. Both projects were simulated with 100,000 iterations.

Project 1 consists of 75 identified risks plus contingency and the result is illustrated in Figure 11. The diagram will help the tendering team to investigate how probable the estimated costs for risks are. In project 1, the mean value is approximately 106‰ of the prime cost and if this would be added to the tender, the company can be approximately 53% certain to have a cost lower than this value. Maximum is the highest value that has been sampled in the simulation and minimum is the lowest sampled value.

Project 2 contains 46 risks plus contingency, the result is illustrated in Figure 12. The simulated mean value for the project risks are approximately 16‰ of the prime cost and the company can be approximately 52% certain to have a risk cost lower than this value.

To conclude, by performing a simulation the tender team will, besides the probability information, also get a measurement on how big the risk spread is by examining the shape of the curve. This will give the tendering team information on how accurate the risk estimations are. From our perspective the result from the simulations gives more information about the risk costs variation compared to one single risk cost. Different scenarios show how the outcomes of the risk affect the total risk exposure.

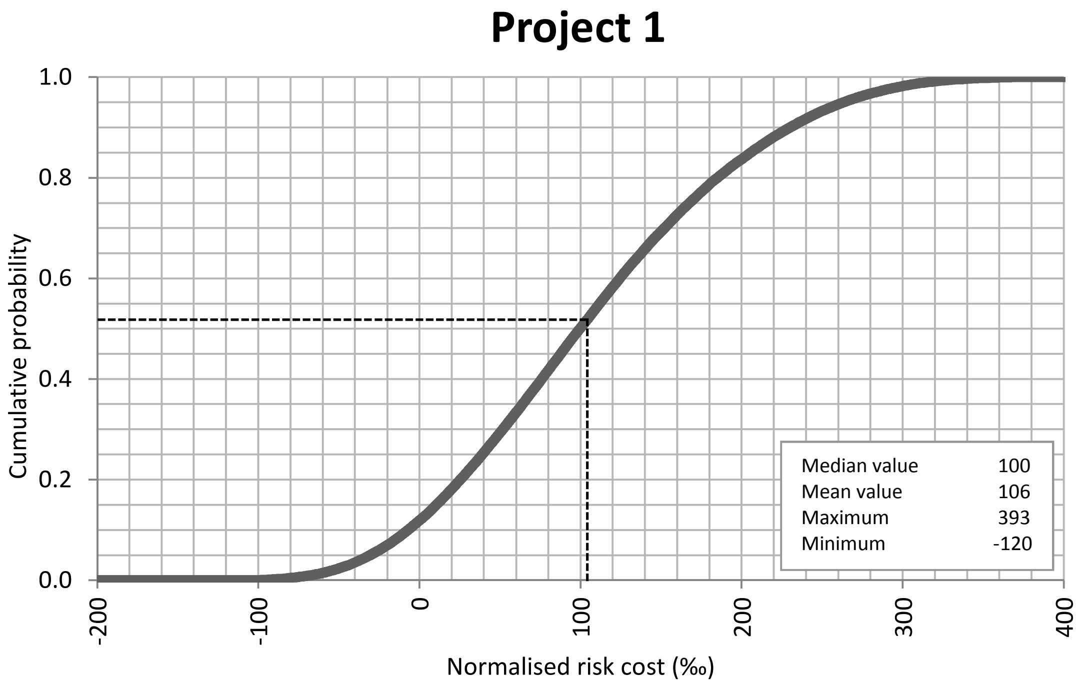

Figure 11. Simulation of project 1 [risk cost as ‰ of prime cost]

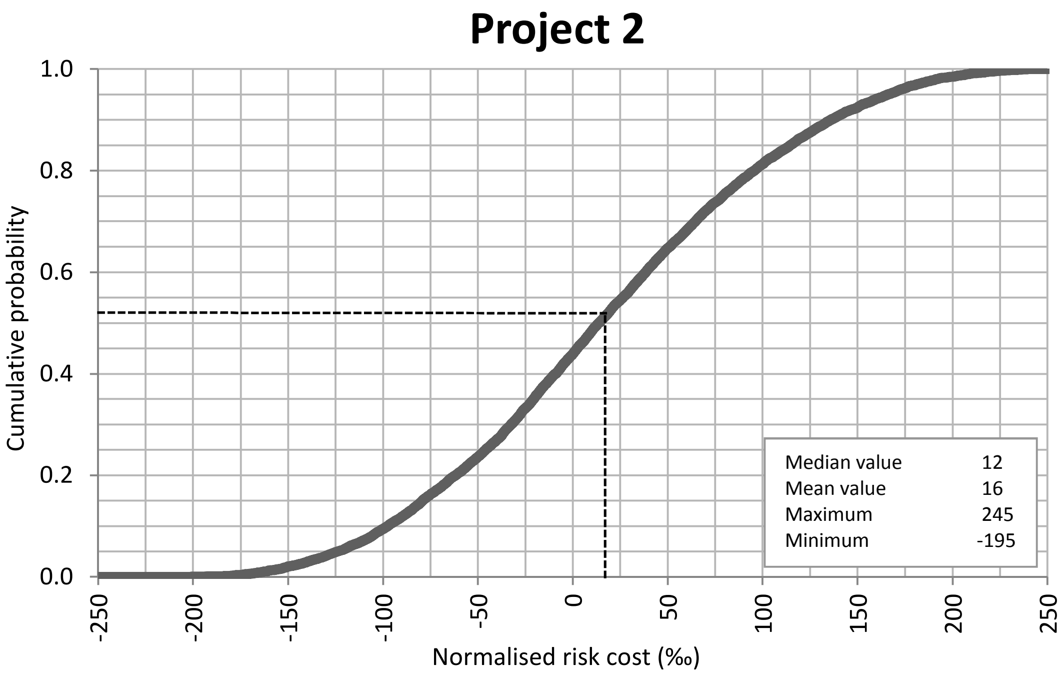

Figure 12. Simulation of project 2 [risk as ‰ of prime cost]

7 Analysis and discussion

This chapter will present an analysis of the performed study's findings, which will be discussed and compared with the theories presented in Chapter 4.

7.1 Tendering process compliance with company routines

Results indicate that there are just small differences between how the tendering process should be performed according to prescribed documentation and how it is performed in practice. One possible explanation is the high quality documents. The established routines assist the tendering team throughout the process and make it more effective. However, the routines are not in detail describing how the process should be carried out, which makes the respondents to claim that they do more than they are demand to. Their ambitious perpetrations before the tender documents are published are an example of this. The studied department put more effort in the preparations than what the directives compel them to.

One identified difference is that the internal guidelines describe that the tendering responsible and the estimate responsible are accountable for selecting the tendering team. In practice it is done by the tendering responsible and the design responsible. The minor differences can be explained by the fact that the design responsible has a more prominent role in the studied department, while it perhaps is less prominent in company's other units. Furthermore, the department's tendering process corresponds well with the traditional tendering model, which is described by Brandt and Franssen (2007). There are similarities between how Söderberg (2011) argues how important it is to monitor an upcoming project. The studied department monitor upcoming projects to a higher extent than mentioned by Söderberg (2011) and even prepare for resources at an early time. However, this might not be possible in all countries, on account of that public clients in Sweden must announce upcoming projects.

7.2 Risk attitude

The performed study indicates that most of the interviewed refer risk solely to the negative consequence of an event. The finding corresponds with other studies in the same subject (Winch, 2010). However, the company has established a risk definition which states that risk should be referred to both the negative and the positive consequences of an event. RE2 explains that he sees theoretical difficulties to convince the organisation to refer risk to a positive impact. Furthermore in the identification process, the company record risks in their risk register which they call "risk and opportunity list". To comply with established definition, opportunities should be included in the risk term. If the company should be consistent, they should rename the risk register as it corresponds with their risk definition. Winch (2010) promotes a more suitable framework where risk is separated into threats and opportunities. To enable a common language about risk management and not contribute to confusion, they should rename the risk register "threat and opportunity list" or simply "risk list". Samson et al. (2008) claim that an organisation should consider risk and uncertainty as two different concepts that somehow are related to each other. A majority of the interviewed had an opinion that uncertainty gives rise to risks and claimed that uncertainty can be seen as a risk. The view might cause problems when it comes to design strategies how to manage the present uncertainty and risks in a project.

Lyons and Skitmore (2004) claim that construction contractors are generally open minded to risks and act in accordance to a risk taking behaviour. However, the respondent's claimed themselves to be rather risk averse and restrictive to negative risks. It could be discussed if the company in fact is more risk averse than other contractors or if the interviewed are misjudging their risk acceptance. The second alternative might lead to an unfavourable situation where the company are accepting risks without realising it. Findings indicate that the studied company is more risk averse than other contractors, but the finding is probably a result of a combination of both.

7.3 Risk management practices in accordance to ISO 31000

The studied company presents a risk management process during their tendering process which to a high extent corresponds with the model presented by ISO 31000.

7.3.1 An effective risk identification process

ISO 31000:2009 claims that the risk identification process should be a set of ongoing activities throughout the whole tendering process. Findings indicate that the studied department identifies risks actively from a phase before the tendering documents are published, to a phase where the tender is submitted to the client. Bajaj et al. (1997) say that a frequently used identification technique is to circulate the tendering documents between involved parties. In practice, there are just few persons who regularly identify risks in the tendering process. Risk is identified through risk reviews, where some of the most experienced parties list risks on a separate sheet and throughout brainstorm sessions. One can argue to involve more people in the department's risk identification process. It would doubtless decrease the effect of differences in risk perception in a rather homogeneous group. Moreover it would probably lead to a more comprehensive process, where more risks are identified in an early project phase. The interviewed said that the department are in general good at identifying risk with a negative outcome but less effective to identify opportunities. The finding corresponds with Winch (2010), who says that people seem to better remember negative incidents in comparison to positive and as a consequence focus on a project's threats. Therefore it will be important to challenge the team to direct a clear focus on project opportunities in a future. The identification process should according to PMI (2004) end up with a risk register which will be analysed later on. The department produces a risk register that accords with advise in ISO 31000 but is less informative than the register that Flanagan et al. (2007) present.

Potts (2008) says that it is impossible to identify all project risks and that it can be counterproductive to have the belief that it is possible. He claims that it is the critical risks that should be recorded in the risk register. The company confirms to this statement and manages the unidentified risks by adding a contingency cost to the final tender while they focus on critical risks. The identification process should be executed as comprehensively as possible to enable an identification of all critical risks. Moreover, an organisation should use a risk identification support tool which should be suited for the objectives of the identification process (ISO 31000:2009). Today, there is a lack of consistency in the use of Software X, especially the uses of its risk management add. There is no clear structure of which persons should use Software X's risk management add, to record identified risks and it seems to differ from one project to another. The inconsistency can be a result of an unprioritised context phase and a lack of detailed guidelines in the internal documentations. The process would probably be more effective if a larger number of people actively did contribute to record risks in the risk register during a tendering process.

When it comes to structuring the identified risks, the studied department uses the established structure, which is provided in the initial risk assessment. Their approach corresponds with the structure which is suggested by Smith et al. (2006). However, findings indicate that there is no systematic routine to structure the risks under each category and negative and positive risks are mixed. Some of the interviewed suggested a separation of negative and positive risks into two separate risk registers. A separation will enable the department to focus on a project's opportunities to a higher extent, which should lead to more identified opportunities. A possible problem might be to manage risks with an unclear outcome. The department should therefore establish routines how to record risks which can have both a negative and a positive outcome.

Today, the studied department does not use any structured technique to connect risks to each other. Software Y provides a RBS, which can be seen as a way of connecting risks to other risks. However, it is important to realise that it will be time consuming to produce a RBS and demand necessary knowledge from the user. In return, it will bring insights into a project's risk exposure which can be communicated to the tendering team. To make the process more effective, a solution might be to import a semi-generic RBS to Software Y. It will provide the user with frequently used risk sources and some of the most important related risks. The user can then modify the structure and add project specific risks. Findings indicate that the available RBS in Software Y is quite difficult to operate and it is rather time consuming to make changes in it. RE2 says that he has recognised the problem and presents an idea to introduce a drag and drop function. The function would make the tool more user-friendly, which should be prioritised in all future improvements. When transferring identified risks from the register to the RBS, only the most relevant risks should be transferred. It might be problematic to decide which risks that are relevant and which are not. Therefore routines have to be established to assist the tendering team in their decisions. It would be difficult to structure all identified risks in the RBS and the gain will not exceed the cost to produce the structure.

In summary, the studied department's risk identification process is well developed and effective in several aspects. However, the process can be improved by directing a stronger focus on project opportunities and establishing routines of how risks should be identified and by whom. Bajaj et al. (1997) say that the identification process is often the less formalised process, which does not accord with our findings. Instead, the department's identification process is one of the most formalised processes in their risk management practices. This is probably one of the explanations why the department is rather successful in their risk management practices during tendering. This is confirmed by Winch (2010) and Bajaj et al. (1997) who say that it is during the identification process where the main benefits of risk management activities arise. An implementation of Software Y in the department's business will not dramatically contribute in their risk identification process. The benefits will rather be seen when the identified are structured as a consequence of the provided RBS structure.

7.3.2 A deterministic risk quantification and analysis

Findings indicate that the studied department are quantifying and analysing identified risks in accordance to a set of qualitative techniques in a deterministic approach. Lyons and Skitmore (2004) say that qualitative techniques are often used by construction contractors as they provide easy and rapid analysis of project related risks. The respondents explained the tendering process as a set of activities which were often associated with high levels of stress, due to the limited time schedule. Therefore the choice of quantification and analysis techniques have to be evaluated with regards to the time needed from the user, as well as the gain compared to its cost.

To evaluate critical negative risks in an early project phase, the department use a risk matrix analysis, where risks are quantified based on their probability and impact on a relative scale. Flanagan et al. (2007) say that it can be useful to produce a parallel risk matrix to evaluate the project's positive risks as a complement to the static risk analysis. The initial risk matrix analysis is performed in accordance with established routines, and its aim is to identify critical risks which have to be further evaluated if the project should proceed. It is reasonable to focus on negative risks in an initial phase and a complementary risk matrix analysis would not be relevant. Smith et al. (2006) say that the aim with a qualitative risk analysis is to generate a priority list of risks which will demand further treatment. This statement corresponds with the purpose of the department's performed initial risk assessment. Software Y will provide the user with a more detailed risk matrix in comparison to Software X, as it is based on more detailed estimations of probability and impact. For example, the user should classify the impact based on several consequence categories, which will contribute to a wider understanding of a project's risk situation in an early phase.

In practice, the recorded risks in the register will generally be assessed in two ways. The most trivial risks will be quantified by the estimation responsible. The estimates along with the remaining risks, which were not unquantifiable, will be discussed and assessed in a separate risk meeting in the end of the tendering. Both opportunities and threats are quantified during the meeting, but with a clear focus on the threats. Their working process is favourable as it enables people to contribute with their knowledge and experiences when it is needed. Moreover, all team members can give their point of view about the already quantified risks but do not have to spend time on less essential estimations. Winch (2010) claims that more effective risk management strategies can be designed if threats and opportunities are separated. An improvement would be to separate their risk meeting into two, where threats and opportunities are discussed separately. The separation will be a logical reform in accordance with the suggested risk register separation. Furthermore, it would enable the tendering team to focus on project opportunities, which was requested from some of the respondents.

The identified risks are quantified in accordance with the expected monetary value approach, which is presented by Potts (2008). He claims that risks should be quantified as a product of estimated probability and its consequence. The net sum of all assessed risks should then be added to the final tender. He says that the impact can preferably be estimated based on three scenarios, which will give the organisation an interval of possible outcomes. Moreover, the estimated interval can be used to calculate a weighted mean value, which can be used as the expected monetary value. To assist the tendering team in their risk quantification, both Software X and Software Y provide functions that generate a weighted mean value based on these three estimated values. In reality, the department does not systematically assess these estimates, but calculate the most probable value which is not weighted. The risk quantification is performed on a basic level, where probability and consequence are not recorded separately in the risk register.

Smith et al. (2006) propose that quantitative analysis techniques are often based on a qualitative analysis. To be able to change the department's analysis strategy toward a more quantitative one, they have to record more information about each risk. To initiate the process, the department should systematically record the identified risk probabilities and consequences in the register and then calculate a monetary value based on those estimations. Undoubtedly, this would be the first step towards enabling implementation of new quantitative techniques in the department's risk management process during tendering. Findings indicated a clear desire to improve the department's analysis techniques toward a more probabilistic approach, where an adoption of new quantitative analysis techniques would be a solution. Baker et al. (1998) claim that there is significant difference in risk management practices between the oil and gas industry and the construction industry. One of these differences is the more frequent use of quantitative analysis techniques in the oil and gas industry. They discuss that this might be one reason why the industry is claimed to be more successful in risk management practices compared to the construction industry. The industries are in many aspects similar and it seems reasonable that they would have developed in the same direction.

Negative risks which are unidentifiable are managed by adding a contingency cost to the tender. Findings indicate inconsistency in the department's specification of the contingency cost and there are no established routines to guide this process. The value is often based on a project's complexity and the available time to perform the identification process during tendering. The process seems to be quite irrational, where the decision is based on gut feelings from the tender responsible and to some extent experience from previous projects. When comparing the value of the contingency cost in one of the department's completed projects with the sum of the negative risks in the risk register, the result show that the contingency cost is approximately 1.5 times higher. Paradoxically, the department has a belief that they are able to identify a majority of the project's risks. This finding suggests a need to question if the contingency cost is over estimated or if the identified risks are valued too low. DM2 and DPM1 support the last answer by claiming that the department should assess the identified risks more aggressively than they actually do. The study shows that the department are active when it comes to raising the tender for an identified threat but less active in decreasing the tender for an identified opportunity. If the department should increase their competitiveness, they might have to change their attitude to project opportunities and manage it in the same manner as their threats.

To summarise, the department's analysis practices can be seen as one of the less formalised in their risk management process. The process is based on a deterministic approach, which provides the tendering team with inadequate knowledge about their risk estimations. To enable a focus on project opportunities, the department should separate the risk meeting into two, where threats and opportunities are assessed separately. Furthermore, they should consistently estimate and record each risk's probability and consequence in a scenario approach. This will be an important step to enable an implementation of new quantitative techniques in their risk management practices. After studying Software X and Software Y, one can make the assumption that an implementation of Software Y will develop the department's risk analysis process toward a more probabilistic direction. The support tool will provide the department with quantitative techniques, which will contribute to the tendering team's risk awareness. However, findings indicate that some important analysis techniques are not available in Software Y. Nemuth (2012) claims that risk simulations are cheap, safe and fast quantitative analysis techniques and therefore recommended in risk assessment during tendering. RE2 says that a Monte Carlo risk simulation can be performed based on data provided by Software Y, but it cannot be executed inside the software. A distinct improvement would be to add a Monte Carlo simulation function to Software Y, which would make it a more comprehensive risk management support tool. In general, Software Y's risk analysis has to be more user-friendly and efficient.

7.3.3 Four alternatives for risk treatment

Winch (2010) says that risks can be allocated into four categories based on an organisation's level of risk knowledge. Also, a project's success seems to depend on how well an organisation manages these risk categories. Findings indicate that the studied department unconsciously treats these risks differently. How the risk categories are managed can be explained by the treatment methods presented by Smith et al. (2006), avoidance, reduction, transaction or retention.

Known knowns, i.e. risks with recognised probability and consequence are primarily managed by two methods. Firstly, the department retains some risks by estimating the risk's value and then adds it to the tender without any further mitigation. Moreover, they often transfer risks to their subcontractors in accordance with the back to back method. *Known unknowns,* i.e. risks where the risk source can be identified but without the ability to estimate its probability or consequence, are often managed by adding a contingency cost to the tender. These risks are unknown for the organisation and it can be seen that they are retained by the department. *Unknown knowns,* i.e. risks which are unknown for the department but known for someone else, are to a large extent treated as the known unknowns. If there is an uncertainty in the tendering document which can be seen as a negative risk, the department might contact the client for additional information which eliminates or reduces the risk's impact. *Unknown unknowns,* which are not possible to predict and therefore not possible to treat, are always covered in the contingency cost which is added to the tender. Winch (2010) claims that these risks are always unpredicted and materialise with a massive impact. This might be one reason why the department adds a relatively high contingency cost to a tender. In summary, much of the department's risk exposure will be covered in a contingency cost.

Software Y would contribute to the department's treatment activities and make the process more efficient. When a risk is identified in Software Y, it has to be accepted or connected to a mitigation plan. This forces the user to come up with an early plan of how the risk should be treated.

7.3.4 Lack of risk monitoring and review

The performed study confirms that there is a lack of structured methods to monitor and review risks after project completion. According to ISO 31000:2009, monitoring and review is one of the most important activities in the risk management process. This statement is confirmed by other studies, where Flanagan et al. (2007) claim that it is crucial to take advantage of an organisation's risk experiences during a tendering process. Findings indicate that risks are monitored and reviewed, but not in a formal approach. Knowledge regarding project risks stays with the employee and is not documented in a structured system. Respondents claimed that they would like to see a more structured process that allows them to record and transfer knowledge from one project to another. Flanagan et al. (2007) say that an organisation can use the risk register as a tool to review project related risks. This is assumed to be an appropriate solution for the department, which allows the tendering team to record the observed impact and how mitigation activities succeed. Although to get the process successful, the department has to make the process more prioritised. The performed study indicate that Software Y should be improved with a monitor and review function to make it more comprehensive.

7.3.5 Improvements to a common risk communication

Grimvall et al. (2003) and ISO 31000:2009 discuss that it is crucial to establish a common risk definition in an organisation which is accepted by all employees. RE2 claims that there are some differences in risk terminology between ISO 31000 and Software Y. These terminological differences have to be adjusted so that the software corresponds to the standard. Firstly it would minimise confusion and misunderstandings in risk discussions. Moreover, if the company should be able to promote that they adopt ISO 31000, their risk management support tool has to correspond with the prescribed criteria. RE2 explains that clients will probably increase their demand that contractors use the standard in the future. It would be wise to prepare the organisation and adjust their risk management process, so that it fulfils the performance criteria. Findings indicate that the departments are inadequate when they record risks in the risk register. The process might lead to misunderstandings and that risks are neglected when there is no accepted method. By establishing clear routines and adapt them to the department, it would improve the process as a whole.

7.4 Implementation of Software Y

According to Dikmen (2004), there is a lack of adequate risk support tools that can support the entire risk management process. This is one of the explanations why the studied company decided to develop Software Y. Findings indicate that Software Y's functions accord with the features which would be profitable to implement in the department's risk management practices. Moreover it corresponds with staff demand of a more probabilistic process to manage risks during their tendering process. Therefore, Software Y seems to be an appropriate base which needs to be further developed to suit the studied department.

Software Y was developed to be used in the execution phase, but can according to RE2 likewise be used during tendering. It would be profitable to implement a support tool which can be used for a project's entire risk management. However, the study indicates that the software needs further improvements to fit the department's tendering process. Today, there is a pessimistic attitude to the software within the department, which they have to overcome to successfully implement the software. There is a belief that the software is complex and hard to managed, which is based on a lack of knowledge due to the fact that none of the interviewed personnel from the departments had operated the software. However, the department's opinion corresponds with findings, which indicate that Software Y should be developed to become more user-friendly. To convince the department's personnel about its benefits it is necessary to review a project where the software has contributed to a successful project outcome.

It is important to realise that an implementation of Software Y to the studied department, would be associated with rather big changes in their risk management practices. To accomplish this with the department's needed improvements, they have to adopt Software Y's advanced settings. Undoubtedly an implementation would require additional knowledge from the operator, due to the new analysis techniques and system. It would probably be an unrealistic challenge to import Software Y to all members in a project's tendering team. This statement could be confirmed by studying the department's challenge to teach their personnel Software X, which is assumed to be easier to govern than Software Y. As a consequence, an appropriate solution might be to select a couple of people from the department that accept the mission to learn the software in detail. Preferably the selected people should frequently undertake an important role in their tenders, people who frequently are responsible for tendering or responsible for estimates. The responsible employees should be trained on how Software Y is managed and be given a short educational course in risk management practices, where they learn to efficiently evaluate and analyse risks. The presented responsibility allocation would require an explanation on how to involve the whole tendering team in the process as ISO 31000 advises. Firstly, the identification process should be able to proceed as in present but with the exception that the project risk register would be connected with Software Y's risk register. The responsible employee should in the next phase categorise the identified risks according to a RBS and execute a set of risk analysis in Software Y. It will be the responsible employee that communicates the analysis results to the tendering team and delegates the team their risk activities. Risk meetings and discussions will be performed as they are now, with the exception that one single person is responsible that the risks will be evaluated and analysed in the right manner. It will still be crucial that all members contribute in the process and share their experiences. The responsible person would be the key to the whole process and it will be important that the selected people have an interest in project risk management and are willing to be ambassadors for the tool.

Finally, there is no doubt that implementing Software Y in the department's business will present challenges. The implementation process would likely be more successful if the stated improvements would be introduced before the support tool was adopted by the department. Furthermore, the suggested improvements would motivate the selected employees to actively use the tool as it would be important in their work during tendering.

7.5 An analysis of the Monte Carlo simulations

One reason why a Monte Carlo simulation was executed in this study was to evaluate its efficiency as a probabilistic risk analysis tool in the department's tendering process. Loizou and French (2012) say that a Monte Carlo simulation is the most effective when it is used as an addition to other decision tools. Another benefit is that simulations reduce subjectivity in decisions, which the respondents desire. According to Baker et al. (1998) the oil and gas industry has better risk management techniques than the construction industry. The most obvious difference is the more frequent use of quantitative risk analysis techniques, where Monte Carlo simulations are often used. This confirms why the studied department should use a quantitative Monte Carlo simulation in addition to other methods.

The biggest obstacle with a Monte Carlo simulation is that it is rather time consuming (Akintoye and MacLeod, 1997). This statement is not proven wrong by the simulations performed. A majority of the time was consumed collecting risk information that was not available. When the data was collected the simulations were easily operated. If the department establishes routines that ensure the needed risk information is collected consistently in their risk management process, it should only take a few hours for an employee to perform a Monte Carlo simulation. The simulations were executed in the risk analysis tool @RISK and did not take a lot of time to perform. A key to a successful implementation of a risk simulation tool is easy execution, which the method @RISK offers. A recommendation is that the developers study this method before implementing simulation functions in the future. Another obstacle with Monte Carlo simulations is that there is often a lack of experience in the technique (Akintoye and MacLeod, 1997). This studied department is fairly familiar with the method, but does not have the knowledge to use it. If the simulations would be adopted in Software Y, it would neither be time consuming or perceived as complex, as the software provides the needed information.

The distributions in the performed simulations are estimations from DPM1 and DR1 or from the risk register, where the best and worst case and the most likely values were already valued. Using this data might be associated with limitations, one of them being that the provided result is based on more or less subjective estimates. Moreover it is hard to assess whether an appropriate distribution was selected in the simulation. Loizou and French (2012) say that this is one of the most obvious disadvantages with a Monte Carlo simulation and claim that it is hard to find the best suitable distribution. The triangle distributions were chosen because estimating these three scenarios is relatively easy, and that this was already done in project 2. Additionally, Smith et al. (2006) say that the triangle distribution is an appropriate choice when there is no historical data available. It is difficult to investigate if the selected distributions reflect reality regarding the analysed risks, but one method to give an indication, can be to examine previous studies on how categories of risks are distributed. To exemplify, it would be profitable to find an appropriate probability distribution for all financial risks related to a project. However, this method may be associated with some limitations. It might be difficult to classify one risk to the right category and it would probably be difficult to determine how a specific risk category is distributed. A solution can be to monitor and review risks after project completion to enable an investigation and study of risk distributions. However, an adoption of the triangle distributions is a good starting point.

It is problematic to investigate whether the appropriate risk correlations were used during the simulations. The risk category's correlation was chosen to an appropriate level and these estimations were assisted by DPM1 and DR1. Findings indicate that the choice of correlations does not have any major impact on the results. If the department implement a risk simulation technique to their risk management analysis, the risk correlation should be based on experiences from previous projects. Once again, the monitor and review process would be a key for successful risk analysis. In summary, it is important to realise that the results always are limited by the quality of the data and the model that is used.

The risk register, including contingency from project 1, shows that 43‰ of the prime costs should be added to the tender. If the department adds 43‰, they can only be 27% confident to get a lower cost than what was simulated. Likewise, for project 2 the risk register indicated that the department should add another 25‰ to the prime costs, and with this, they can be 55% confident to achieve a lower cost.

It is difficult to decide what an appropriate confidence level should be and the value should probably be based on a project's characteristics. To match the department's risk acceptance level, they should demand a higher confidence level than 50%. If the company would have executed a risk simulation before they submitted the tender they would probably have added more than what they actually did. If the worst case numbers for all variables in the risk register are compared to the best cases, the worst cases are in absolute terms four times higher than the best case values. This affects the simulations, which indicate that the price should be higher than if the decision was based solely on a summing up of the risks in the register. A possible explanation might be that threats are generally estimated higher than opportunities, and if the values for best and worst cases are higher, threats become more dominant. If simulations should be used, the opportunities have to be estimated more generously. Finally, a larger number of simulations need to be carried out to evaluate the methods effectiveness.

8 Conclusions

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

- Most of the studied department's risk management and tendering practices are formalised and effectively performed. Their practices comply with the established internal documentation and routines.

The company has a structured method to identify risks, where the tendering team actively identifies risks throughout the whole tendering process. The department's risk analysis is carried out in a deterministic approach, where the identified risks are assessed by the estimation responsible or jointly by the tendering team in a risk meeting. During the meeting, both threats and opportunities are assessed, but with a clear focus on the threats. The valued risks with substantial impact are recorded in a risk register, where threats and opportunities are mixed. The unidentifiable risks as well as the risks with minor impact are covered with a contingency cost, which complements the risk register. The contingency cost is assessed in an informal manner based on experiences and gut feeling. Findings indicate that the contingency cost is a big part of the overall risk cost that is added to the final tender. During the study an in-house developed risk management support tool, Software Y, was investigated. Software Y is currently not used in the tendering process, and findings indicate that it would be profitable for the department's business if it is enhanced before it is implemented.

- The company should use a common risk definition.

The interviewees have divergent risk definitions. ISO 31000 highlights that it is vital to have a common risk definition to eliminate misunderstandings and confusion during the risk management process. Their established definition should be better communicated in the organisation.

- The department's risk management process is associated with risk aversity.

The respondents claimed themselves to be restrictive to risks as a consequence of project failure in the past. Nevertheless, Lyons and Skitmore (2004) state that construction contractors often act in accordance to a risk taking behaviour.

- A project's recorded risks should be more effectively structured.

Software Y will assist the tendering team in structuring the identified risks in a risk breakdown structure, which will provide insights of a project's risk exposure. The structure separates threats from opportunities by using two risk registers. By connecting their present risk register with the register in Software Y, most team members will be able to carry on in working like before.

- Risk analysis/quantification improvements and implementation of a risk simulation tool.

Opportunities need to have higher priorities and be assessed as more profitable. To enable a focus on project opportunities, both the risk meeting and the risk register should be separated into two, where threats and opportunities are managed separately. Respondents and literature (Baker et al. 1998; Ali, 2005; Nemuth, 2008) indicate that more quantitative and probabilistic tools should be used in the analysis/quantification process. Software Y would provide the tendering team with quantitative risk analysis techniques, which would direct their risk management process toward a more probabilistic one. Findings show that a Monte Carlo simulation analysis is an appropriate quantitative technique that should be added to the software, because a simulation will provide the tendering team with information about the risk spectrum and how scenarios will affect the result. The Monte Carlo simulations were easy to carry out and did not consume much time to do. The risk probability distributions are a good starting point, but can be developed further.

- Software Y has a mitigation plan which will provide the tendering team with an early treatment plan.

When a risk is recorded in Software Y, the risk can be retained or otherwise a mitigation plan needs to be prepared. It enables the tendering team to both create a plan for treatment at an early stage and make an early structured recording of the treatment plan.

- Implementation of Software Y in the studied department's business should be separated into logical phases.

All the proposed improvements are probably not possible or effective to implement simultaneously, however, some proposed improvements can be adopted immediately while others should be implemented in the future. Two enhancements which can be adopted in the near future, is the separation of their risk register and risk meeting into two. To enable an implementation of Software Y, the department has to overcome their negative attitude toward it. This might be possible by demonstration projects where Software Y did contribute to the project's success. Simultaneously, the department should unify with a common risk definition to prevent misunderstandings in the process. In a second phase, the department should fully adjust their risk management process with ISO 31000, to be prepared for clients demanding this standard in the future. The second phase should also involve enhancements of functions to Software Y. The aim is both to increase the software's usability and to add new functions, so that Software Y will improve the process and make it more effective when it is implemented. Functions that increase the usability are an easier graphical interface and a drag and drop function to the risk breakdown structure. Functions in Software Y which need to be further integrated are the possibility to create a suitable risk structure for tendering, and the possibility to perform a risk simulation. Step three concerns implementation of Software Y in the studied department's tendering process. An appropriate start would be to select an employee to be responsible for the software, who will receive risk management education and learn how to operate the software in an effective manner. The responsible employee should operate the software in a close cooperation with the tendering team and communicate the analysis results to concerned parties.

Recommendations for further research:

- Investigate how risk management practices and techniques are used in various industries. Findings from this study indicate that the oil and gas industry use other risk management techniques than the construction sector. Other industries, risk management will give new inputs and ideas to the construction sector.

- Investigate how a comprehensive risk management support tool should be designed to enable an effective connection between the tendering process and the execution phase.

- Examine how risk management practice in tendering is performed in other construction companies. In this study one company has been examined, it would be useful to investigate if the risk management practices differ between companies.

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Appendix: Interview questions

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A. Interview questions, first phase
B. Interview questions, second phase

A. INTERVIEW QUESTIONS, FIRST PHASE

The aim with this interview phase is to create a general understanding how the tendering process is executed in practice. The questions are divided into two themes, where each theme is represented by questions relating to each theme. Questions about the role are asked to understand the respondent's role in a tender and in the department. The tendering process will describe the entire process and explain the responsibilities in the tendering team.

Role of the interviewee

- What is your current role in the company?
- What is your role in a tendering process?
  - Is your role affected by a project's characteristics? (size, contract form and type of project)

The tendering process

- Can you describe a general tendering process? From the announcement of the tender until the tender is submitted to the client?
- Is the tendering process affected by a project's characteristics? (size, contract form and type of project)
- Can you describe how the tendering team is assembled?
- Do you perform a market analysis to investigate the competitors? (Analysing their available resources etc)
- Is there any audit which checks if the internal documents and policies are complied with?
- Do you use Software X in the tendering process?
  - If so, how do you use it?

B. INTERVIEW QUESTIONS, SECOND PHASE

The purpose with this interview phase is to examine how the studied department follows risk management practices during their tender process.

General question about risks

- How do you define risk?
- How do you define uncertainty?
- How risk averse are you?
    - To what extent does the company enable you to take risks?

Risk management in the tendering process

Risk management in an early project phase

- How and who identifies risks in the initial risk assessment?

Risk management and tendering board

- What do you think the main purpose is of having a risk management and tendering board in the company?
- Does the board have competences that your department lacks?
- Do you think that the board contributes to an overall better risk management?
- Can you come up with suggestions that improve of the board's function?

Identifying risks

- How do you identify threats and opportunities (t&o) during the tendering process?
- Are there any t&o that are easier/more difficult to identify?
- How big share of risks that actualises in the project are identified in the tender?
- Do you have any proposal on how your department can be better at identifying t&o?
- How do you categorise risks? Does this change between projects?
- How do you analyse the relationship between two risks?
    - How is this documented in the systems?
    - Are you satisfied with the way you structure risk today?

Risk quantification

- How do you quantify the risks you have identified?
- How do you quantify the risks you have not identified?
    - What t&o are included in the contingency cost?
    - How do you quantify the contingency cost?
- Are there t&o that are easier/ more difficult to quantify?
- Is it possible to compare the value of t&o with the actual value when the project is completed?
    - Are there any differences? If so, how big?
- Is there something in the risk analysis/quantification that you can do better?

Treatment of risks

- How do you treat the identified risks? (insurances, transfer to subcontractors)

Other questions about risk and risk management

- Is there any difference in the risk management process between DB contracts and DBB contracts?
- How familiar are you with ISO 31000?
- Has the risk management process within the department changed during the last five to ten years?
- Would it be desirable to know the spread (range of variation) of your risk estimations in the tender?
- Do you know any functions that you would like to include in a risk management support tool?