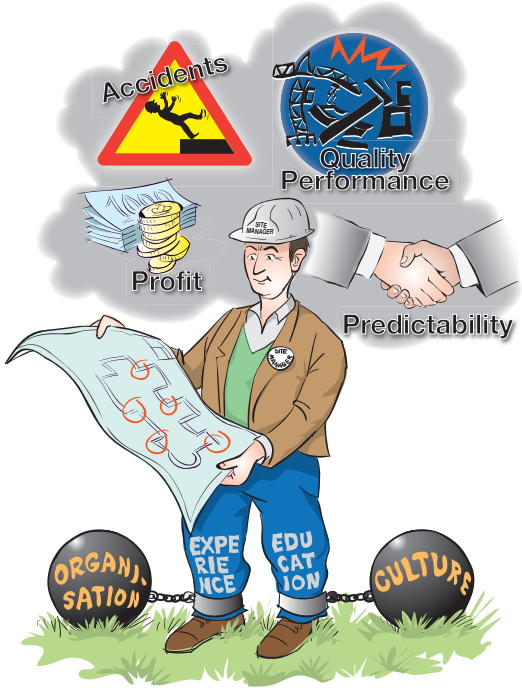
DOCTORAL THESIS

The Construction Site Manager's Impact on Risk Management Performance



Kajsa Simu

Luleå University of Technology

LULEÅ UNIVERSITY OF TECHNOLOGY

DOCTORAL THESIS

THE CONSTRUCTION SITE MANAGER'S IMPACT ON RISK MANAGEMENT PERFORMANCE

Kajsa Simu

Luleå, January 2009

Division of Architecture and Infrastructure
Department of Civil, Mining and Environmental Engineering
Luleå University of Technology
SE - 971 87 LULEÅ
www.ltu.se/shb

Tryck: Universitetstryckeriet, Luleå

ISSN: 1402-1544
ISBN 978-91-86233-00-6

Luleå 2009

www.ltu.se

It is what we think we know already
that often prevents us from learning

Claude Bernard 1813-1878

Abstract

Risk management in construction is traditionally based on the experience and individual judgements made by site managers, especially in smaller projects. The site managers in construction should also be regarded as key individuals, with a prevailing picture of being tough and possibly also risk prone in their behaviour.

This study follows up a previous study by the researcher which found that the management system itself does not have such a large influence on the way risks are managed at a construction site. The construction site manager, as an individual, is regarded as having a greater impact on the project performance related to risk. The question raised in this study is therefore what individual impact the site managers have on the effects of risk management. To be able to answer this question, it is also important to determine the extent to which it is possible to measure the effects of risk management at construction site level.

The results of this study present a model for measuring the effects of risk management on site and at individual level in a construction project, using specific indicators. These indicators are related to *profit, safety, quality performance* and *predictability*. Further, this model has been tested using authentic data from a construction company. These data do not reveal strong correlations between the chosen indicators and, as a result, reliance on profit is dominant. The individual impact on risk management performance focuses on two aspects of the character of an individual; personality and background information, such as education, age and experience. Personality traits measured by the PAPI test reveal three significant traits that correlate to economic performance on site. They are *need for change*, *need to be forceful* and *social harmoniser*. None of these traits was, however, found to be related to risk

management performance. Moreover, the characteristic personality of construction site managers is compared with that of managers from the general labour market to see whether there are any significant differences that could help to explain the prevailing picture of the character of construction site managers. The most powerful difference is the trait of *need for change*, indicating that construction site managers are more conservative than other managers. In this comparison, it is not possible to assign attributes to site managers as being more risk prone than other managers. Instead, a picture emerges of individuals who focus on details, are keen on following routines and also have a work pace indicating stress tolerance.

The conclusions from this study are that there are indicators that ought to work as indicators of risk management performance, but the amount of data required to find significant correlations needs to be vast. It is also concluded from this study that, due to the site managers' aversion to change, they remain at the less demanding rule-based level of problem solving instead of moving up to the more time-consuming, knowledge-based level of problem solving. It is also concluded that site managers from construction are not more risk prone than managers from the general labour market. The final conclusion is that the individual impact on the effects of risk management is fairly small. There are other issues, possibly related to organisational context, that have a greater impact.

Sammanfattning

Riskhantering i byggprojekt förlitar sig av tradition på individers erfarenhet och personliga bedömningar gjorda i första hand av platschefer, särskilt i mindre projekt. Platschefer innehar en nyckelroll i byggföretagen och det är en förhärskande bild att de är tuffa killar som gärna agerar, ibland kanske väl riskfyllt.

Den här studien utgår från de resultat och slutsatser som kom fram i den tidigare presenterade licentiatavhandlingen ”Riskhantering i små byggprojekt”, som visade att tilltron till verksamhetssystemen är begränsad när det gäller hur risker hanteras på projekt. Tilltron är desto större till den enskilde platschefens förmåga att använda sin erfarenhet och kompetens för att sköta riskhantering i projekt. Fokus för den här studien är därför att belysa den individuella påverkan som platschefen har på effekterna av riskhantering. För att kunna svara på den frågeställningen ingår även i studien att definiera hur man kan mäta effekter av riskhantering på arbetsplatsnivå.

Ett av resultaten från den här studien är en modell, bestående av fyra olika grupper av indikatorer, som har tagits fram och testats med syfte att mäta effekter av riskhantering på individ- och arbetsplatsnivå. Dessa indikatorer är relaterade till *ekonomiskt resultat, säkerhet, kvalitet och förutsägbarhet*. Modellen har testats med verkliga data från ett byggföretag men det har inte varit möjligt att visa på tillräckligt signifikanta korrelationer mellan de indikatorer som modellen baseras på. Som en konsekvens har ekonomiskt resultat blivit den indikator som fått representera modellen och därmed även måttet på effekter av genomförd riskhantering.

Individernas påverkan på riskhantering har delats upp i två olika delar, den ena är relaterad till personlighet och den andra till erfarenhet, ålder och utbildning. Personligheten har mätts genom personlighetstestet PAPI som beskriver individers personlighet i 20 olika skalor. För tre skalor identifierades signifikanta korrelationer med ekonomiskt resultat; *behov av förändring, behov av att vara frispråkig och rollen att vara social och vänlig*. Ingen av dessa skalor kan dock relateras till effekter av riskhantering. Vid jämförelsen mellan cheferna i normgruppen från övriga arbetsmarknaden och platschefsgruppen från det aktuella byggföretaget konstateras att den största skillnaden uppträder i behovet av förändring där platschefer från byggsektorn har ett mindre behov av omväxling och förändring. Detta kan tolkas som att de är mer konservativa än chefer från andra branscher. Vidare konstateras att det inte heller finns något som pekar på att platschefer från byggsektorn är mer riskbenägna än chefer från andra branscher, snarare motsatsen. Studien av platschefer från byggföretaget visar på individer som är mer uppmärksamma på detaljer, har behov av regler och riktlinjer och har ett arbetstempo som indikerar att de är mer stresståliga än chefer från övriga arbetsmarknaden.

En av slutsatserna i den här studien är att det finns indikatorer som skulle kunna användas för att mäta effekter av riskhantering. För att hitta signifikanta korrelationer så krävs det däremot mer omfattande data än vad som varit tillgängligt i den här studien. En annan slutsats är platschefernas obenägenhet till förändring som innebär att stannar problemlösningen på arbetsplatserna till stor del kvar i det som kallas regelbaserad problemlösning istället för att nyttja den mer tidskrävande kunskapsbaserade nivån av problemlösning när så krävs. Det kan även konstateras att platschefer från byggföretag inte skiljer sig från chefer från övriga arbetsmarknaden när det gäller riskbenägenhet. Den sista slutsatsen är att i motsats till vad som antagits är påverkan från individerna på resultaten från riskhantering relativt liten. Det är andra aspekter, troligen relaterade till organisation och kultur, som tycks ha en större påverkan.

Contents

Acknowledgements

With mixed emotions I realise that a most pleasant but also one of the most challenging periods in my working life so far has finally or has already come to an end. It is with joy and gratitude that I now acknowledge the people who have supported me during this intense period and also made it possible.

Firstly, I would like to thank the people who have given me financial support to conduct this PhD study: Formas (the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning), SBUF (Development Fund of the Swedish Construction Industry) and NCC AB.

I am also grateful for the endless, great support given by my supervisors Professor Emeritus Jan Borgbrant, Adjunct Professor Lennart Apleberger and Professor Håkan Alm. Thank you, Jan, for your creative ideas and innovative solutions for proceeding with the work and for your endless attempts to arrive at the *"real research"*. Thank you, Lennart, for your loyal, strengthening support when large steps needed to be taken. Thank you, Håkan, for your patience and confidence in me during my struggle to learn more about the mysteries of psychology and statistics. I would also like to express my thanks to Rickard Nilsson, Division of Engineering Psychology, for your direct support with statistics in general and SPSS in particular.

The title of this work, the text and the front-page illustration would not be what they are without the assistance of Professor Brian Atkin, Jeanette Kliger and Hans Sandqvist. Thank you for your help in adding that final touch.

Special thanks also to Ove Lagerqvist for his detailed work on preparing for my pre-seminar, "paj seminaire", of this work, it was a great help.

This research project would never have been achieved without the great and joyful support of my colleagues in our research group, you are fantastic! Thank you, Anders Wennström, Kristina Laurell-Stenlund, Jutta Schade, Katja Osipova, Azam Forsberg, Håkan Norberg, Thomas Olofsson, Anneli Karlsson, Per Erik Eriksson, Jan Jonsson and Stefan Sandesten.

Further, I would like to express my joy at having had the opportunity to work with all my other colleagues at the Department of Civil, Mining and Environmental Engineering. There has always been a warm and friendly attitude, interesting and innovative discussions in the coffee room, which is due to all of you, thank you!

I am grateful for the support of my colleagues at NCC Construction from Luleå to Malmö to the headquarters in Solna. You have all enriched me with positive energy and I really appreciate this. Special thanks to Johan Gustafsson and Mats Eklund, who have trusted me to combine my research with other duties at NCC.

I would like to take this opportunity to thank all my friends who have given me support throughout the years, encouraging me when feelings of despair came too close.

As in the prior study I also want to thank my mom for help with linguistic matters throughout the year, it has been of great help, thank you Mom.

Finally, I want to acknowledge my precious and beloved family. You have shown tremendous patience and understanding in my struggle to overcome this challenge.

Jörgen, Emil and Hilda – I love you!

Definitions and concepts of use

AB (Allmänna bestämmelser) – General Conditions of Contracts for Building, Civil Engineering and Installation Work

ABT (Allmänna bestämmelser för totalentreprenader) – General Conditions of Contracts for Building, Civil Engineering and Installation Work performed on a package deal contract

Aleatory uncertainty – random uncertainty - possible set of outcomes is known, but the quantities of consequence and probability are not known, even though they can be calculated

Client – person or organisation that commissions buildings or constructions for itself or for someone else

Construction sector – very briefly, the construction sector is made up of consultants for design, clients as owners or commissioners and contractors for managing the construction and installation, plus the suppliers of material

Defect – a lack of something necessary for completeness, adequacy, or perfection, Merriam-Webster. (2008), Encyclopedia Brittanica Online Inc, retrieved November 19, 2008

Design-build – a procurement option where the contractor is responsible for construction and the full design

Design–bid-build – a procurement option where the client contracts separately with a designer and a contractor

Effective – is defined as "*Powerful in effect; producing a notable effect; effectual*" according to the online version of *The Oxford English Dictionary*, (September 2008), Retrieved 30 October 2008, from http://dictionary.oed.com/cgi/entry/50072311

Efficiency – is defined as "*Fitness or power to accomplish, or success in accomplishing, the purpose intended; adequate power, effectiveness, efficacy"* according to the online version of *The Oxford English Dictionary (1989)*, Retrieved 30 October 2008

Epistemic risk – lack of knowledge about possible outcomes, i.e. lack of knowledge about what you do not know

Error – an error can be regarded as a realised risk, a risk outbreak, with a negative outcome. Error can also trigger secondary risks

Heuristics – a heuristic process or method for attempting the solution of a problem; a rule or item of information used in such a process, online version of The Oxford English Dictionary (1989)

Individuality – in this thesis, the term individuality is used as the overarching term that consists of personality, education, experience and gender

Management system – the structured way in which organisations choose to control their business, including ingredients such as budget, organisation and problem solving. Examples of management systems include quality management systems, environmental management systems and knowledge management systems

Performance – the quality of execution of such an action, operation, or process; the competence or effectiveness of a person or thing in performing an action; specifically the capabilities, productivity, or success of a machine, product, or person when measured against a standard, OED online (June 2008), Retrieved November 19, 2008

Personality – personality is the description used by various researchers to define individuals by their thoughts, feelings, desires, intentions and action tendencies (Brody & Ehrlichman, 1998)

Risk – in this thesis, risk is defined as the sequential and negative outcome of an uncertainty. It is the combination of probability and consequence of

something occurring that has an effect on the ability to achieve set objectives for the project, related to economy, time or quality, as well as the objectives associated with personal safety

Site manager – the person responsible for production at the construction site

Uncertainty – an overarching term that can have two possible outcomes, a risk or an opportunity

1 INTRODUCTION

1.1 Background

1.1.1 Risk management, an historical perspective

The starting point for risk management as a separate field of research was concern for the environment and for human health. The fear and awareness that attracted the attention of the general public in the early 1960s led to increased legislation to minimise the risks for human health and safety. This in turn led to increased interest from the leaders of industry to analyse risks in their business. The founders of the Society for Risk Analysis, SRA, were primarily interested in the impact of chemical risk on human health. The SRA was founded in August 1980 (Thompson et al., 2005, p. 6).

The development of what is now known as project risk management emerged in the large engineering projects in the energy sector in the mid-1970s; they included BP's North Sea projects and pipelines in North America. The development continued in a diversity of business sectors where large projects were run. In this period from the mid-1980s until early this century, project risk management focused on finding the common structures for all projects and identifying the different approaches that were needed for each project (Chapman & Ward, 2003). The development that is currently taking place in the field of project risk management is focusing on extending the focus to include the wider scope of uncertainty management (Ward & Chapman, 2003) to incorporate the aspects of individual and cultural influence (Hillson & Murray-Webster, 2005) and the social construction of risk (Stahl et al., 2003).

Risk management, as it is currently being applied in the field of construction, has been on the agenda for about 25 years. It has focused in the main on large-scale projects with different kinds of complexity related to them, such as technology, international collaboration, geography or finance (Hintze et al., 2004; Jaafari, 2001). More recently, risk management has started to influence an increasing number of companies and not only the largest projects. In spite of this, the small projects in construction do not feature a great deal of systematic risk management (Azinim & Edum-Fotwe, 2006; Simu, 2006).

1.1.2 Reasons for applying risk management

Risk management is all about being able to deliver results with certainty. Risk is most often related to the negative outbreak of an uncontrolled uncertainty that can cause the loss of lives, money, time or quality/function. For many companies, these motives would be enough to apply risk management in their business.

In the insurance business, risk is the core business and the premium is the quantification of the risk that is being insured. Depending on the profile of the insurance taker, the premium and excess vary. Business with a history of mistakes and damage or individuals with a risk-prone profile, such as young male drivers, pay higher premiums due to the increased risk. As it is the core business, a great deal of interest focuses on controlling and calculating the risk in various ways in order to set the premiums at levels that make it possible to earn money. For companies taking insurance, interest in reducing the premium is based on the potential for saving money. A company or an organisation with a track record of not utilising insurance opens the door to lower premiums.

According to a study performed in the UK (Ashby & Diacon, 1996), the main purpose of risk management for managers is to avoid contractual, tortuous or statutory liability. In their study, the aim was to identify why large UK firms spend money on risk management. Their findings show that the drivers for using risk management are primarily negative. The aim is to avoid risk outbreaks. They also found that there were no common risk management objectives among the companies. Nor were there any associations between risk management and the firm’s financial characteristics or operating behaviour. This view is also emphasised by Hillson and Murrey-Webster (2005) who state that the influence of individual attitudes and corporate culture is probably more important than the actual risk management tools.

The benefits of being able to deliver in time, at the right price with the desired function cannot, however, be solely attributed to risk management but instead to effective project management. The additional benefits of risk management are the clear focus on trying to think about what might happen and then manage the project to avoid the negative scenarios, the risks, and making sure that the positive aspects, the opportunities, are actually realised. Risk management is also more explicit about handling changes and the companies that manage them in the most effective way are the survivors and winners. In a construction project that is in a constantly changing environment, risk management should be a key process and an integrated part of project management (Smith et al., 2006).

In the case of public limited companies, there is also interest from the stock market. Shareholders on the stock market are not fond of uncertainty, especially when it can cause losses. Unexpected events in economic forecasts from companies, regardless of whether they are positive or negative, signal a lack of control and the reasons for maintaining good control in the core business are therefore vital for most companies.

1.1.3 Swedish construction sector

It was estimated that the Swedish construction sector contributed 8% of the GDP (gross domestic product) in 2006, a year in which the construction sector employed approximately 270,000 people (Sveriges Byggindustrier, 2008). The total investment in the sector is SEK 221 billion, whereof SEK 59 billion is accounted for by investments from official government agencies (SCB, 2008). In other words, the construction sector is an important part of Swedish industry, as well as being an important recipient of tax revenue. So making the construction industry more efficient is also a way to save common resources for society as such.

In many ways, the Swedish construction sector could be described as resembling the international construction sector, as there are similarities in the problems that occur. The problems that are on the agenda are control of costs, sustainable construction, project risk management and shortage of skills (KPMG, 2008). There are also similarities in business structure, organisational structure and project orientation. This study is, however, geographically based in Sweden and the context described is therefore limited to Sweden.

History of Swedish construction industry

During the last decade of the 20th century, the construction sector followed the general trend of merging smaller companies to form fewer, larger companies. In Sweden, there were about twenty national construction companies in the 1970s, while today, in 2008, there are only three to four companies left. The market situation has changed from the previous scenario in which mainly national players were involved to also include new international market players, mainly from European companies. In spite of this, locally, on the regional market, the competition is fierce, due to smaller and geographically local companies with fewer overheads compared with the larger companies. This means that the larger Swedish companies have to compete with both large international companies and small local companies. Their challenge is to benefit from being a large company and at the same time adapt to the local market where business is largely dependent on relationships and local knowledge.

During the 1990s, the influence of quality management systems made its mark on the construction sector and management systems complied with ISO 9000. This was a time at which routines, checklists for self-assurance and third-party certificates were on the agenda, but they were not always understood by all the employees in these companies. Since then, the approach to and work on quality has matured and developed and is now more closely adapted to the processes and needs of the companies rather than to the requirements specified in the ISO standard. Risk management is a vital part of quality management, as well as other aspects such as the desire for continuous improvement and the involvement of leaders in the organisation.

Looking further back, the construction sector derived from the old guild system in which each guild had its own way of doing things. Today, this heritage has resulted in the Swedish construction industry being split into many disciplines of professional categories with consultants, contractors and subcontractors, see also Figure 1.1. Each skill has its own professional area and works in the project for a short, intense period and then leaves. For this reason, it can be challenging to organise the overall planning of construction projects with each skill only being responsible for its part of the project (Borgbrant, 2003; SOU, 2000).

Current situation in the construction sector

The construction sector is fragmented and complex, as it is made up of numerous projects of various sizes, managed by a number of different players and stakeholders throughout its lifecycle, see Figure 1.1. The project is owned by the client but run and managed at different stages and phases by different parties with their own interests and project objectives. This fragmentation and project focus has been described nationally and internationally and the need to change to a more process-oriented business has been emphasised by different researchers (Koskela, 1992; Lindfors, 2003; Nylén, 1999; Osipova & Atkin, 2008; Vennström, 2008).

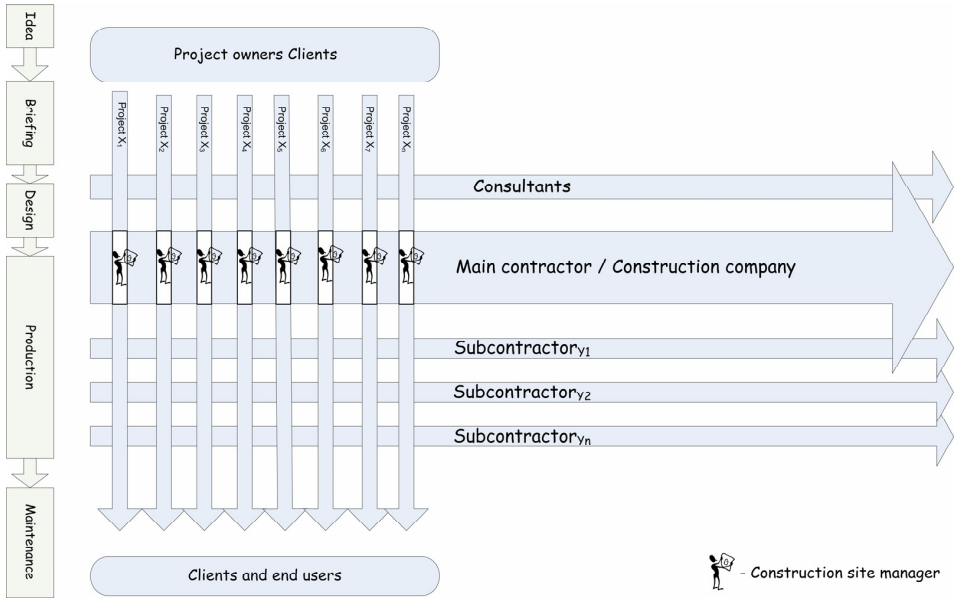


Figure 1.1 A simplification of the complex world of the construction process and its players, where the construction site manger is key for production fulfilment in the project.

In this process, there are individuals representing the players and stakeholders and one of these individuals is the site manager at the main contractor. This person is responsible for making the construction or production parts of the project succeed, with legal responsibility for the work environment and built environment, financial responsibility representing the main contractor, quality and functional objectives set in contractual documents and responsibility for keeping to the timeframes specified in the contract. The site manager at the

main contractor obviously plays one of the key roles in project success. The site manager also often works on his/her own at the site and, as a result of the complexity, he/she has to deal with many different heterogeneous activities. This is exposing the site manager to high levels of stress. (Djebarni, 1996; Styhre & Josephson, 2006)

Another feature in the construction sector is the shift from focusing on volume to focusing on the bottom line in every project. The previous volume focus was a way of keeping oneself busy and still delivering results through volume. The current shift implies that each and every part of the organisation must focus on the bottom line and therefore be more selective about the projects in which it becomes involved. In the selection of projects, one important ingredient is an estimate of the risks involved (Laryea & Hughes, 2008).

The construction sector is also often associated with increasing costs, cartels, defects due to a lack of quality control and a lack of ethics and morals (SOU, 2002). There is also a prevailing picture of the uniqueness and special conditions that are present in the construction sector and the special personal characteristics that dominate the workforce (Styhre & Josephson, 2006). Further, there is a widespread picture of the construction industry as being tough, macho and dominated by men ready for action (Cettner, 2008; SOU, 2000). The construction sector has problems delivering its products in time at the set cost and with the right quality. This picture applies within the sector and in society outside the construction sector. Having these problems and this image is naturally not profitable for any business in the long run and many construction companies are therefore looking for new ways of running their business. The profitability of the construction sector has been strained for many years and the challenge for the sector is to increase the profit on a long-term basis. Long-term profitability is associated with a stable, predictable business. The certainty gives the stability and securing the certainty is therefore important. Certainty is the opposite of uncertainty and the construction sector has been focusing for some years on controlling the uncertainties which are in turn closely related to what is called risk.

According to a Swedish study investigating the causes and costs of defects in construction projects, as much as 6% of the production cost is related to defects (Josephson & Hammarlund, 1999). Of these 6%, as much as 45-54% can be traced to production on site that is related to site management, the workers or the subcontractors. The relationship between defects and risks was not defined in their study, but the risk as such is defined as one influential cause. Reading further in this paper, it is revealed that many of the defects that are reported

could be related to shortcomings in the management of uncertainty and risk. Further, according to Love and Josephson (2004), the main causes of failure could be attributed to human error. This gives a further indication that the role of the site manager is central to defects and failures at the construction site.

According to a recent report by the Swedish Work Environment Authority (Jonsson, 2008), the construction industry sector is one of the most dangerous places to work. During the first six months of 2008, there were twice as many accidents (16) that proved fatal compared with the whole of 2007. The factors identified by this report are the stiff competition, the time pressure and the lack of competence. The smaller companies and those primarily acting as subcontractors are the ones that are most exposed.

Despite the many attempts to increase profits, reduce costs and errors and increase the reputation (good image) and quality delivered, construction companies continue to struggle with a lack of quality and increased costs in their products. In the past few decades, new management concepts have been introduced in the construction industry to solve this. These are management systems that have been shown to work in other industries but appear to lack success in construction companies (Bresnen & Marshall, 2001). In their research, they take a stand in the common belief that the construction industry sees itself as being different and they examine the effect this view of the construction community has on the adoption of new management ideas. Bresnen & Marshall (2001) have found that having this prevailing self-image could be a reason for the difficulty involved in implementing new management concepts in the construction industry.

1.1.4 The construction process

In general, the construction process could be described in five steps; idea, briefing, design, production and maintenance management, Figure 1.2. Depending on the scope of the construction companies' business concept, they enter this process in different phases. For this study, the site managers enter the process at either the design or the production phase and hand over the project at the end of production. The viewpoint in this study is that the phases of idea, briefing and maintenance are the responsibility of the client. This description of the construction process is a general one and several different ways of describing it can be found in the literature.

Figure 1.2 A general description of the construction process.

In the construction process, it is still most common with competition using a bidding process to obtain the project and finish it. Each of the competing companies submits a tender and the most favourable, according to the client, is the winner. The winner is then the one that continues with the project into the design and/or production phase of the construction process, see Figure 1.2. In some cases, the construction companies are exclusive and do not have to compete through bidding, but in this study these situations are excluded. The cost parameter has the greatest influence. Less often, parameters such as quality, safety and sustainability determine the outcome of the bidding process, although they do have a significant impact from time to time.

Contractual form and terms of collaboration

Before the client initiates the bidding process, the choice of contractual form is made. Depending on the contractual form, the risks are allocated differently between the project stakeholders in terms of liability. The two contractual forms that still prevail, even though other forms are used, are the Design-Bid-Build, DBB, or the Design-Build, DB. The DBB is characterised by separate contracts for the design team and the contractor. The client keeps the two phases separate and starts the bidding process with the contractor after the design phase is completed. In the DB contractual form, the client includes the design in the contract with the main contractor, who then takes responsibility for the design as well as the construction. The liabilities are allocated differently in these two contractual agreements. In DBB, the main contractor is only responsible for construction, as the client is responsible for design and any faults that may occur in that phase. From the contractor's perspective, this is often regarded as 'safer', as the client has to handle any consequences that may occur as a result of poor design. DB contracts, on the other hand, include both design and construction for the contractor. From the contractor's perspective, this is regarded as including more risk but also more opportunities. It creates potential, as the choice of design can be adapted to the strength of the contractor and tailored to his production. For the client, this is regarded as 'safer', as all the responsibility for design and construction is outsourced. Regarding the contract, Flanagan & Norman (1993, p. 180) put it this way "A building contract is a trade off between the contractor's price for undertaking

the work and his willingness to accept both controllable and uncontrollable risks. The price for doing the work partly reflects the contractor's perception of the risks involved".

Partnering as a way of collaborating has recently increased its 'market share' in the construction industry. This is not regarded as a contractual form in Sweden but has certain set components that should be present, such as common goals, conflict resolution, design-construct integration, continuous improvement, teambuilding, purchasing and contract, as well as relations and trust (Rhodin, 2002). This form of collaboration has been said to reduce costs as a result of fewer disputes and improved control of quality and time.

Hierarchical organisation

In the Swedish construction sector, many of the construction companies are organised in a similar hierarchy with the CEO at the top and, depending on the size of the company, some levels of organisation down and out to the site manager at the construction site, see the general outline in Figure 1.3. The profit in construction companies is generated at the construction site level and this is one of the attributes that differ from many other industries. In the construction industry, the CEO is not able to adjust volume or change the price per unit as a means of adjusting the profit for the company. In construction companies, the CEOs are dependent on the project performance on site and the individuals that are working close to project site; it is a largely decentralised organisation.

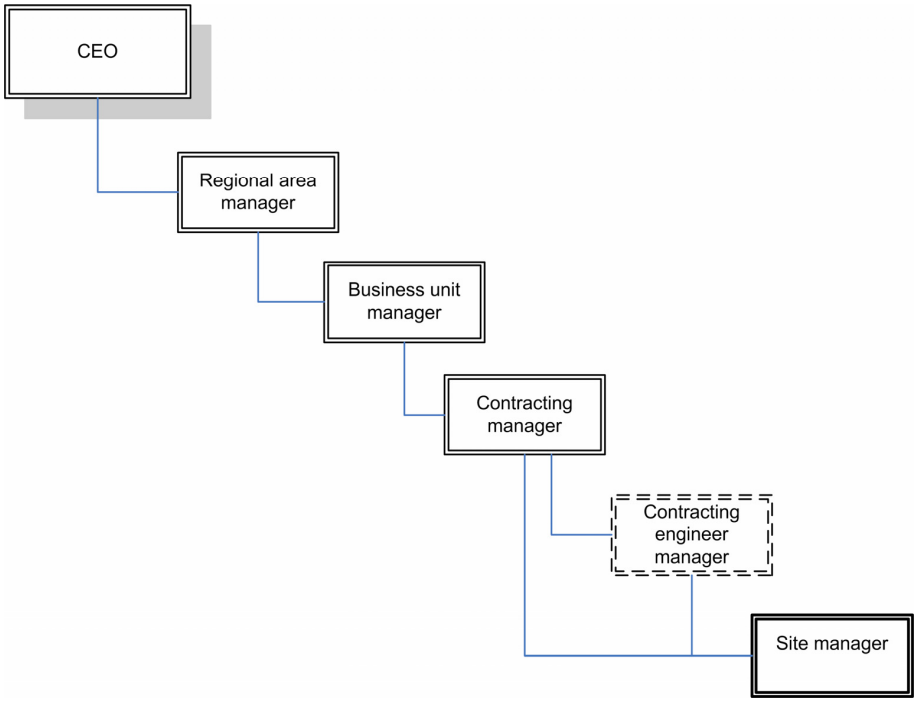


Figure 1.3 General outline of the hierarchical organisation common in construction companies.

The bidding process

In this decentralised organisation, the 'products' are largely brought into the construction companies through bids to the client and in competition with other construction companies. In the construction company, the bidding process, formulating an attractive bid to the client, is designed to ensure that project fulfilment is offered at the right price, Figure 1.4. In this figure, the flow in the bidding process is visualised with black arrows and the continuing process of a winning bid to the site manager is illustrated with dotted lines.

According to a recent study in the UK, there is a lack of systematic organisation in the way risks and pricing are taken into account in the bidding process in construction (Laryea & Hughes, 2008). It was found that, in the process of tendering, there are certain tendering gateways (TG) before submission, used to formalise the structure. In Figure 1.4, these tendering gateways are marked in the flow chart as TG. Laryea and Hughes' (2008)

description of the bidding process is well in line with the general description in this thesis.

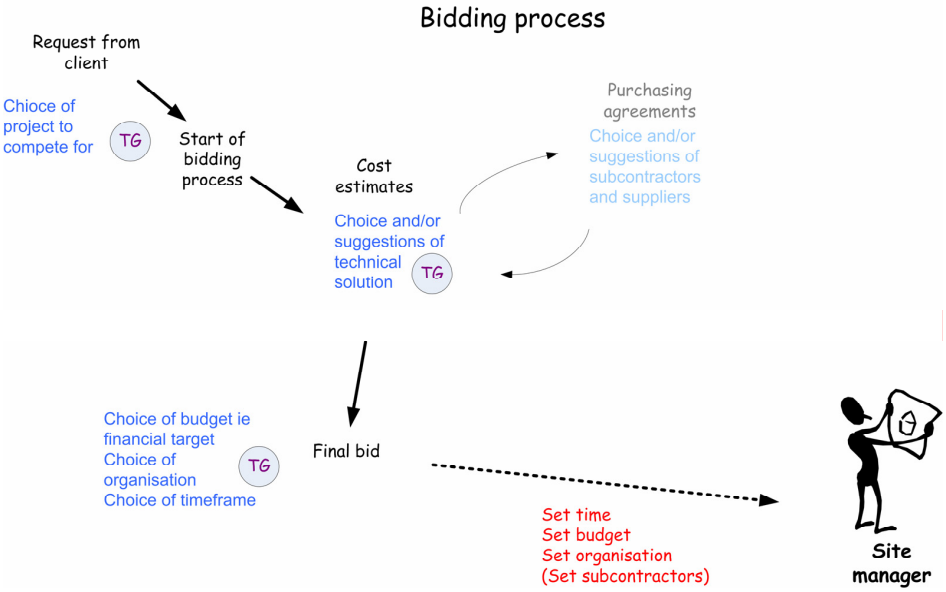


Figure 1.4 The role of the site manager in relation to the bidding process and the choices made prior to his or her involvement.

The first choice made by a superior manager relates to whether there will be any involvement in the bidding process. These decisions relate to the client, market situation, kind of project and the availability of in-house skills. Depending on project size, the decision maker is the contracting manager or a superior manager higher up in the hierarchy. The next step prior to the site manager's involvement is the cost estimates that are usually made by estimating engineers. If, due to the market situation, site managers are available, they might be involved in this stage of the process. Purchasing settlements and tenders from subcontractors are handled by the purchasing unit, without involvement by the site manager. The information from these units regarding cost estimates is put together by the unit for cost estimates. When this has been done, a final offer is prepared in which the financial targets, time frame, organisation and technical solutions are proposed to and decided on by a manager superior to the site manager. At this stage, it is usual for the intended site manager to be informed. If the bidding succeeds and there is a final agreement, the project is handed over to the site manager to continue work. At this stage, the budget is set, the time frame is set, the organisation and

subcontractors are also finalised. The site managers have their given prerequisites and the extent to which the project can be influenced is limited right from the start.

This is a general description that could vary from time to time and unit to unit, but the overall picture is as described. With these given prerequisites, the potential for the site manager to influence the final project outcome is restricted to some extent when it comes to the decisions taken prior to his or her involvement. The site manager's influence on the project is, however, significant in terms of production.

Construction site and its managers

The construction site is the place where things actually happen and the site manager is most frequently responsible for making things happen. In this section, this scenario is briefly described.

Choice of site manager
Construction site managers are in charge of production at a site. In this context, collaboration with stakeholders and client, subcontractors and consultants is vital to the production process. The site manager's ability to understand the present situation at the site and maintain control, despite collaborating with a large number of parties, is an important attribute. One decision that influences the project outcome is the choice of project organisation. The most difficult projects are most probably staffed with the "best" site managers in the group. If a project is contracted with a tight budget, it is most likely that a well-reputed site manager will be made responsible. The decision about who is the most suitable site manager, with those given attributes, is made by superior managers.

Relationship with client
The relationship with the client is very important and site managers often have a close relationship with clients in their own market. The choice or preference expressed by clients about who they would like as site manager is important input when specifying the right organisation for a certain project. The client's preferences and demands could also relate to quality and environmental work, costs, time frame and records from previous performance in projects.

Economic control
The first production budget in the construction company relating to the project is based on the cost estimates that were made during the bidding process.

When the contract is signed, the site manager re-calculates and draws up a new or updated production budget. The production budget is designed to control the production costs on site and should be easy to adjust and follow up throughout the project. The budget is then balanced on a regular basis, every month, for example, in order to make the right forecast of the final result. The project result shows how far above break-even the project has been run and to some extent also how well it has been run in relation to the given prerequisites. It is, however, important to remember the influence of both site managers and the given prerequisites when evaluating the economic results at construction site level.

Forecast of economic delivery

The ability to make good forecasts is closely related to the ability to maintain control of the project. It is possible for the site manager to stick to the original budget and actually not make adjustments to the forecast profit until the costs are added up at the end of the project. If not before, the true profit will be revealed at the end of a project. If the site manager has had poor control, the late difference in the final profit and the forecast profit will illustrate this. An illustration of what this could look like is given in Figure 1.5. The steep dip could have several explanations, but it is an indicator of lack of control in the project.

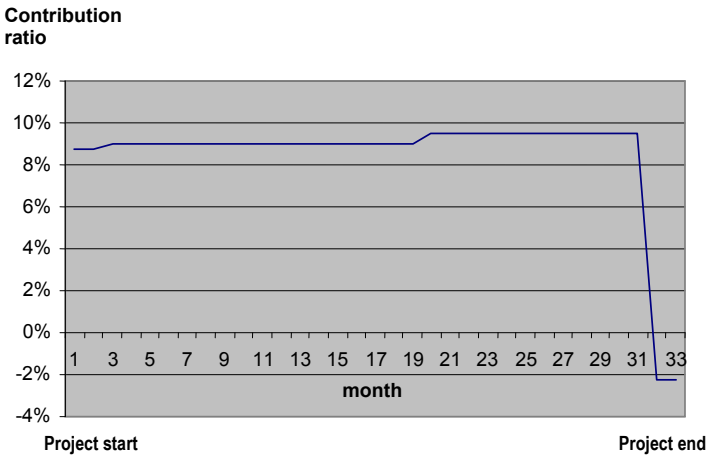


Figure 1.5 Example of how to visualise monthly reports of forecast profit when lack of control is revealed at the end of the project.

Co-ordination and logistics
On site, when production is running, several types of co-ordination need to take place between the different skills and subcontractors acting on site. The site manager is responsible for this. The different skills and subcontractors are dependent on the completion and the results of each other's work. If it is not finished in time or is done in a way that is not sufficient, the next skill/subcontractor/working team is affected. To control this, meetings of different kinds are held at the sites and the planning and communication at these meetings are vital for the working flow of the project. The planning and flow on site is also dependent on supplies arriving in time. If supplies arrive too early, there are problems such as storage on site, weather protection and protection from theft. If supplies arrive late, the problems relate to stopping or re-planning production.

Areas of uncertainty
Uncertainties and thereby also risks in a construction project have many different aspects. There are legal uncertainties, environmental, technical, organisational and financial uncertainties, to mention just a few. The legal uncertainties are often related to contractual issues where the General Conditions of Contracts (AB) recommendation for construction agreements is designed to reduce uncertainty about responsibilities. In spite of this, there are disputes about how to interpret the contracts between the players. In legal settlements, the responsibilities are the focal point and the uncertainties and risks are allocated to the party best suited to deal with them rather than being a common interest for everyone to deal with and work on proactively (Osipova, 2007).

Environmental uncertainty and risk is a phenomenon with several different aspects. The environmental issues on site relate to ways of handling waste and dealing with pollutants discovered during the construction period. Environmental uncertainty also relates to the risk of using materials in construction that contain hazardous chemicals that could start leaking in the longer term. For the companies involved, another side of the environmental uncertainty often relates to the reputation and brand of each company. No one can afford to be connected with a project that acquires a poor environmental reputation. From this angle, it could be more devastating for a company to be related to poor environmental behaviour than actually being responsible according to the legal settlements.

Technical uncertainties are often related to the practical solution on site and the design phase prior to construction has the greatest influence in this area.

However, as things are run today, this uncertainty and risk is largely handled on site. Technical uncertainty and risk could be due to either new technical solutions or lack of time and thereby poor performance in the design phase. It is devastating when a new technical solution is widespread and the construction does not work.

Organisational uncertainties have two dimensions, there is either a shortage of people and the people who are in the project do not have the time to control the project satisfactorily. The other side of the organisational uncertainty and risks is the ability for those involved actually to co-operate successfully. These uncertainties could well be related to the results reported by Josephson and Hammarlund (1999), who found that motivation is the main reason for defects in construction projects.

Financial uncertainty from the construction company's point of view is often sorted out high up in the organisation. On site, the focus is to control cost and invoices related to the project and the financial uncertainty instead relates to company security and the assessment of the solvency of its business associates.

Key role of site managers
Site managers in construction projects play a key role in the realisation of the project objectives. They control the projects and are responsible for budget, quality and safety on site, as well as the technical requirements set for the construction. To perform this task, it is essential that they have knowledge of project budget, technical construction, project management and work environment issues. The individual playing the role of the site manger is therefore vital to the success of the construction company.

1.1.5 Application of risk management in construction

Risk management in construction is used at different levels and with a different focus at the organisational levels in companies. At the highest CEO and board of directors' level, risk management is largely a question of financial risks. The focal point is the certainty of business deliveries and risk management focuses primarily on having the right business portfolio, composed of a variety of different products on different markets. Risk at this level also involves having a sound economy with a positive cash flow or making investments that pay off. It is also the responsibility of management to ensure that project risk management is applied in the organisation and to find systems to control this process.

The larger construction companies have their own solutions for project insurance and have special in-house business units to handle insurance cases. To secure the economy if larger insurance cases occur, the larger companies take out re-insurance in external companies. The smaller companies rely totally on external insurance companies. The premiums are, however, largely dependent on how well the company manages its business, regardless of whether internal or external insurance companies are involved. For companies with in-house insurance, the extent to which the internal insurance is used within the company is important. The less insurance that is used, the more profit that is left in the company. If the construction company performs well and does not incur large losses, the external premium is reduced and this also has a beneficial effect on the bottom line. The insurance excess is relatively high, with a maximum of three basic amounts (approximately € 12,000), according to the General Conditions (AB 04 and ABT 06). For damages where the repair or recovery cost never reaches the excess level, there are no basic data. Due to the size of the excess, the hidden data relating to the number of cases are supposedly large and the cost is instead hidden in the project result. This means that, in the case of smaller damage, the profit is lower than it would otherwise have been and this is almost impossible to detect in a systematic manner. The people responsible for the project are aware of this, but the incentive to report cases or to share this knowledge is limited. As a result, it is really difficult to find out how many errors, or possible risks there really are. This also works as a motive to apply risk management.

For some time now, research in the field of risk management has focused on finding better and more efficient ways to control the risks within projects and organisations. Numerous tools and methods are available and, depending on the industrial sector, the level of sophistication varies. The number of methods that can be used for risk analyses in construction has also increased in recent years (Laryea & Hughes, 2008), but their application in practice is rare (Akintoye & MacLeod, 1997; Azinim & Edum-Fotwe, 2006; Lyons & Skitmore, 2004; Simu, 2006). In the construction sector, risk management is applied through the projects and the methods that are applied are fairly straightforward and often based on subjective judgements. There is a lack of statistics that can be used for quantitative risk analyses and other measures are used instead, often based on experience and intuition. In spite of this, the aim and objective for many risk analyses is to set a figure for the risk, a risk number to relate to other risks, and put it in a risk matrix. The quality of this figure is no more true or valid than the ways it has been calculated, but, if there is a figure, the credibility is greater than a comparable description in words, high-medium-low, for example.

The fundamental characteristic of traditional risk management is that it is a circular, continuous process (Smith et al., 2006) based on identification, assessment, response and control, with a probabilistic approach, while the traditional construction process could be described as a linear sequential process with a deterministic approach. The necessary integration of these two different approaches appears to fail when it comes to risk management solutions (Kähkönen, 2007). Kähkönen (2007, p. 3) also claims that the prevailing traditional risk management paradigm is "too shallow for providing grounds for successful solutions". This is another argument in line with the results showing that the risk management system that uses risk matrices is difficult to apply in construction (Azinim & Edum-Fotwe, 2006; Lyons & Skitmore, 2004; Simu, 2006).

One method that is used to handle risk management in construction is to gather project staff for certain risk analyses (brainstorming meetings) where the common knowledge from different skills, such as technical, legal, economic and so forth, gives its view of the risks in a certain project. A common view of the total risk is then created and makes it possible to control the most severe risks in the project with the best resources available. This is an effective method as it brings all the stakeholders up to date with all the possible risks in the project. In small projects, the project team is reduced to a minimum and the risk analyses are most frequently made by site managers themselves. The quality of the risk analyses is therefore highly dependent on the site manager's individual capacity, knowledge and attitudes and his or her approach to risk and risk management.

The risks in small projects, on the other hand, are less extensive than they might be in a larger project. In most cases, there is limited damage to the construction company or the client when there is a risk outbreak in small projects. The amount of money added together for many projects could, however, be considerable. The margins for construction companies are stressed and the cost of construction has increased during the last decade (SCB, 2008). Every cost that can be cut by a construction company is money on the bottom line. Risk outbreaks cost money, regardless of whether they involve an error causing personal harm or an error causing quality shortcomings or damage to materials. In order to reduce the risk of faults that could cause damage, it is also possible to cut costs. Cost reductions, even small amounts, add up to considerable sums of money on the bottom line for a construction company, especially as the smaller projects represent a large percentage of the business (Simu, 2006).

It has been found that managers in construction do not use the available systems for risk management, with project staff relying predominantly on experience, personal judgement and brainstorming (Azinim & Edum-Fotwe, 2006; Flanagan & Norman, 1993; Laryea & Hughes, 2008; Simu, 2006). According to Flanagan & Norman (1993), there are two kinds of decision maker, those who are averse to risk and those who are risk takers. When it comes to the problems facing the construction industry, with increased costs, ethics and morals and defects in products, it would be interesting to know whether this is related to the site managers being risk-averse or risk-prone decision makers.

Risk management in small construction projects

To find out how risk management is applied in small construction projects, a research study was conducted between 2004-2006, comprising 10 projects from seven different construction companies and 28 interviews (Simu, 2006).

The most telling result from this study is that most managers in small projects rely on their gut feeling and traditional ways of controlling the project rather than on formal risk management based on identification, assessment and response. In this survey, the largest group of respondents, 17(28), took a similar approach to risk management. The following two quotations illustrate this phenomenon.

> *"The actual assessment is based on experience and [is] very much in my head."*

> *"These risk checklists are filled in, but the real meetings and the shared thoughts are done during coffee breaks or over the phone…"*

In some sense, this is a traditional way of controlling projects in construction, Figure 1.6. The traditional control process starts with the unstructured allocation of contingencies in the tender. The money is allocated according to a 'gut feeling' rather than in a systematic manner. Two of the respondents put it this way:

> *"I do not document the risk assessment…; I put some extra money in the tender. Sometimes I allocate the money specifically for a certain risk, but not so often"*

> *"Sometimes we allocate money in the tender for the site manager to see. The money is a combination of money allocated to prevent failures and as a measure for handling things that go wrong, but mainly for measures if things go wrong".*

Controlling the project continues with high reliance on schedules based on activities and resources. Quality assurance is where the quality of critical events is documented, if it is documented at all. A common way of controlling issues in the quality assurance plan is to produce detailed work plans, either verbal or through documents. Finally, the project is controlled through construction meetings where time, money and contractual conditions are handled. Construction meetings are formalised events between the client and contractor. There is a set agenda for these meetings and it has been agreed by participants in the Swedish construction sector.

These steps are found in most of the projects involved in the study, see Figure 1.6. There are connections found between the quality surveillance plan and the detailed work plans. There are also connections between the timetables and the construction meetings as the timetables are followed up at those meetings. The unstructured allocation of money in tender is also left without further attention. The steps are, however, not necessarily kept together and a systematic view and discipline are lacking.

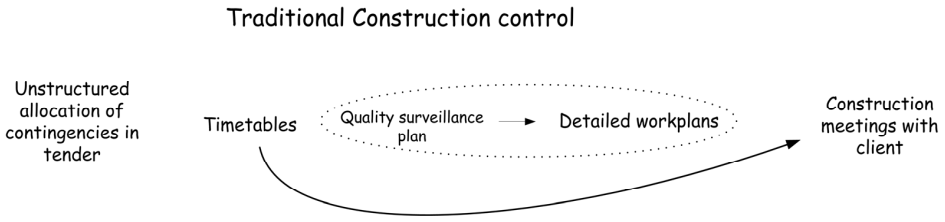


Figure 1.6 Traditional process to control small construction projects.

Another finding was that there was a lack of training and education in risk management in projects. More than half the respondents had not received any training or education in risk management and the rest had received it as a minor part in some other form of education.

The academic level of those who have been interviewed is split between those who are graduates 10(28) and those who have received engineering or vocational training 18(28) to supplement their (lower) educational background.

The identification and assessment of risks was formalised in only a few of the projects. Most often these steps in the risk management process are carried out on blank pieces of paper based on individuals' personal judgements and gut feelings. The use of systems is neither obvious nor a matter of course.

Instead of using the management system and the risk management tool, site managers control their projects through schedules. Planning is a key factor in projects that succeed, according to site managers. Schedules consist of activities and resources for the different parts of the project. One respondent made the following remark about the importance of planning.

> *"Good planning is a key to effective risk responses. If there is a shortage in any way it is my lack of planning that causes it. The system is a good help if I only have the time to use it as a tool in my planning."*

For the purpose of the above-mentioned study (Simu, 2006), the research questions addressed the issues of the methods and tools that were used in small construction projects and how they were used. The focus on small projects derives from the fact that more than 80% of the projects have a turnover of between SEK 1-15 M (~€1.65m). The short and simple answer to these questions is that small projects lack systematic risk management. However, in a business where the core value is continuously to handle any uncertainties that occur, there must be some way of dealing with this issue. The conclusion is that the accepted theoretical framework does not fit; small projects rely on the experience and personal judgements of individuals in undertaking their risk management continuously throughout the life of a project. Schedules, quality assurance and detailed work plans are commonly used methods. Tools are either checklists or blank pieces of paper. This way of controlling risk and uncertainty should not be regarded as evidence of systematic risk management. The reliance on the ability of managers is the key to the way the risks in these projects are handled. The individuals' risk attitude and risk perception are much more important than the available system supplied by the company.

1.1.6 Effects of risk management

Money is spent in companies to introduce and improve risk management systems with the supposed purpose of increasing profit, reducing uncertainty, reducing accidents, reducing the cost of insurance and minimising defects in delivered products. It is, however, difficult to find any research about the measured effects. Researchers in the field talk about effective or efficient risk management (Chapman & Ward, 2004; Hillson & Murray-Webster, 2005) and relate it to project objectives or expected performance, but the results of this research are lacking. As yet, no actual measurements of the effects of risk management processes have been made, possibly because of the difficulty involved in distinguishing risk management from general project management.

Risk management systems are used to reduce uncertainties and accidents, as well as defects and faults, as mentioned previously. The performance can then be related to the outcome of the project in relation to the aim of the risk management systems that are used, i.e. accidents, defects, uncertainties and perhaps even costs. The effects of risk management should therefore be measurable through variables or indicators of this kind of project performance.

1.2 Problem formulation

In this thesis, the problem formulation was based on the fact that, in spite of the many attempts to make risk management objective and quantified, people make the judgements and assessments. At the construction site level, these people are the site managers.

The previous study by Simu (2006) focused on determining the way in which risk management was applied in small construction projects and the method that was used. The result revealed that the reliance on management systems was low and the individual's, i.e. the site manager's, experience and personal judgement appeared to be more important. This reliance on individuals is also emphasised in the smaller projects, due to the fact that, in these projects, the organisation is reduced to a smaller number of individuals and fewer or somewhat more limited skills are therefore used in the project when managing risks.

To determine whether the effects of applying risk management are dependent on and influenced by the impact of individuals, it is necessary to define both the effects of risk management and who these individuals are. Further, set methods that can be used to measure those concepts are needed.

The site managers could be regarded as key-role individuals for risk management on site and it is essential to understand their function and their expertise both as individuals and as a group when relating to risk management. The individuals in an organisation are always in a larger context and are part of a culture, formed by the individuals together. The prevailing picture of the construction sector as macho should therefore be related to the individuals creating the sector. Further, there is a general picture of the character of construction workers, including the site managers, as being macho and possibly even risk prone. One common viewpoint within the construction sector is also that it is unique and different from other sectors on the labour market. Having those possibly prejudiced pictures preserves the way in which projects are managed and also the way in which new ideas are adopted.

1.3 Aim and research questions

The aim of this study is to determine whether the effects of risk management are associated with individual impact. In order to achieve this, the research model in Figure 1.7 has been created. In this model, three main areas for study have been identified, A, B and C. A is the area of risk management with definitions and formal risk management theories and its application in construction. Area B relates to the concept of measuring the effects of risk management, while area C deals with individuals and concepts that are supposed to form individual personality, behaviour and attitudes.

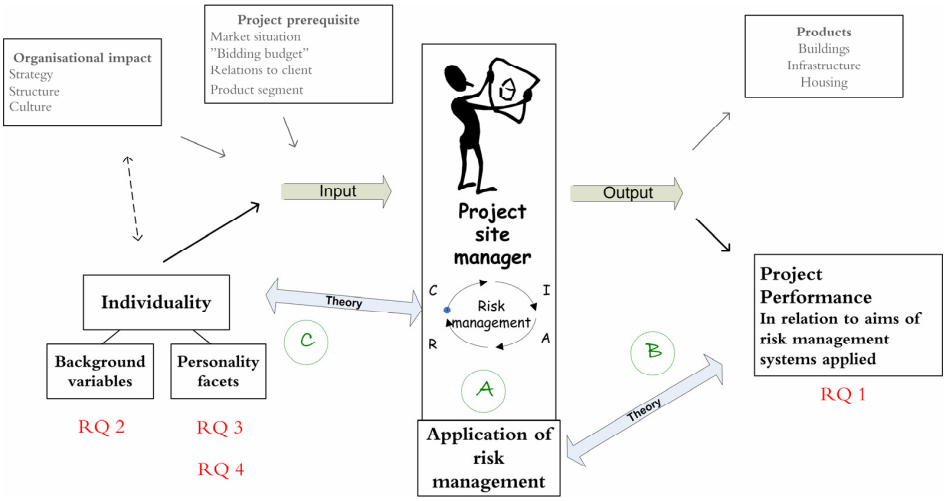


Figure 1.7 Research model with the focus on site managers and risk management at construction site level.

To realise this aim, the following research questions have been formulated.

RQ 1 In what way can the effects of risk management be measured at construction site level?

RQ 2 Which background variables, such as age, education and complementary training, are related to the effect of risk management?

RQ 3 What are the measures in personality traits that are related to the way risk management is performed, i.e. effect of risk management?

RQ 4 What are the differences between site managers in construction and other managers in terms of personal traits and in what way could they be related to risk management?

1.4 Scope and limitations

This study was performed at a single construction company in Sweden, NCC Construction Sweden AB, as a case study. The limitations of the study are:

- Site level in construction projects is the focus and, as a result, only the design and production phases in the project process have been included
- The context is described for primarily larger Swedish construction companies
- Site managers from the main contractor are the focal point
- Project sizes of less than SEK 50 M (~€ 5m)
- Impact on risk management performance from other sources such as organisation, culture and project conditions are only included as a contextual, theoretical framework and in the final discussion about future work.

This is a study that has been conducted with the theoretical framework of risk management theories and theories from behavioural science and psychology and it should therefore be regarded as cross-scientific research.

1.5 Layout of the thesis

Chapter one is the introduction to the thesis in which the background, problem formulation, aim and research questions can be found. The purpose of this chapter is to help the reader understand why this thesis needed to be written.

Chapter two is the theoretical framework and the state-of-the-art for the area on which this thesis focuses. This chapter gives the theoretical foundation for the thesis and the aim of this chapter is to ensure the reader that this thesis is at the cutting edge of the research in the chosen area.

Chapter three is the guideline, the "log of journey", or, more traditionally, the description of the method used to realise the aim of the study. This chapter aims to explain to the reader how the study has been realised to ensure its validity and reliability.

Chapter four contains the results and analyses of the collected data. This chapter aims to present the collected data as objectively and completely as possible for each of the research questions.

Chapter five contains the discussion and conclusions of the study. It also discusses the strengths and weaknesses of the study, as well as the researcher's view of how the results should be used, together with suggestions for further research.

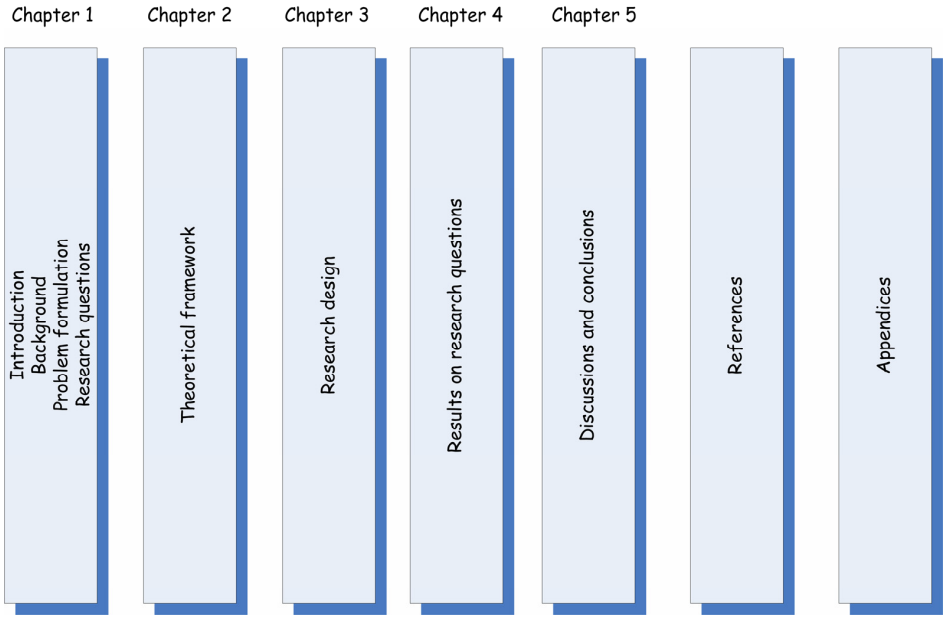


Figure 1.8 Layout of the thesis.

2 THEORETICAL FRAMEWORK

This chapter embraces a variety of scientific areas in order to create the interdisciplinary theoretical framework needed to address the research questions in this study. The first part, Sections 2.1-2.2, addresses the definitions and concepts of risk and risk management, referred to as A in Figure 1.7. The second part, Section 2.3, addresses the issue of the effects of applying risk management, referred to as B. The third part, Sections 2.4-2.6, focuses on the individuals and their personality in relation to risk and risk management, referred to as C. The fourth and last section, 2.7, addresses the context of project risk management and its relationship to individuals.

2.1 Uncertainty, risk and error

This section aims to define the theoretical references for concepts and definitions in the area of uncertainty, risk and error.

Project risk is defined as a "combination of the probability of an event occurring and its consequences for project objectives", according to the international standard IEC 62198:2001. This is a somewhat technical definition of a topic that has been shown to be fairly individual and also somewhat philosophical. To set the scene for the risk definition chosen in this thesis, the different approaches to uncertainty, risk and error are presented.

2.1.1 Uncertainty and risk

Uncertainty is part of everyday life, as we are unable accurately to predict the future. The amount of uncertainty and how we handle this uncertainty can, however, be defined and structured. Risk is closely associated with uncertainty and is a commonly used term in contexts of all kinds, but it is often related to

the negative outcome of a certain event. There is a trend towards the use of the word "uncertainty" instead of "risk", as it is regarded as more appropriate for the purpose of the work that is going to be done (Ward & Chapman, 2003). Ward and Chapman state that there is a need for a clearer focus on the upside effects, i.e. the opportunities. They believe that it is desirable to forget the close connections to historical events, conditions and sets of circumstances and instead focus on the different sources of uncertainty that could lead to threats of failure or, equally, opportunities. Instead of closely connecting specific objectives of the risks and uncertainties involved, they suggest that uncertainty management is about anything that has an impact on the success of the project. This could be the objectives, but it could also be the perception of risk and uncertainty that are given in a project. In Ward and Chapman's opinion, it is vital to understand where and why uncertainty is important in a given project context and not to focus solely on the threats and opportunities connected to given events, conditions or circumstances. They continue their line of argument with the suggestion that "uncertainty management" should replace "traditional risk management" to indicate that a wider perspective is being sought. It is also important to realise that the key issues help people to understand where and why uncertainty plays an important role in a specific project and its context.

Regardless of this development in the field, the term "risk" has been preferred in this thesis, because it is more established in both theory and practical use. The term "uncertainty" was tested in interviews in a pre-study (Berggren, 2005)[1], prior to the licentiate thesis (Simu, 2006), and its use instead of "risk" confused the respondents. The statement in this thesis is also that uncertainty is the stage prior to both risk and opportunity.

According to the Project Management Institute, PMI (PMBOK, 2000), a definition of risk should consider both the positive and negative effects on a project objective. This is a broad view in terms of threats and opportunities and how they are connected to an event, a condition or a specific circumstance. This is the definition that works in theory but fails in practice. Despite the enlightened definition, opportunity is neglected when it comes to practical use. According to the PMI, risk includes the upside effects, the opportunities, but tradition focuses on the downside, i.e. the negative effects.

[1] Researchers maiden name, changed to Simu July, 2007

Uncertainty could also be described in a more theoretical sense. It could be addressed as either aleatory or epistemic. An aleatory uncertainty is a risk that could be regarded as random, estimated with probabilities and consequences to a set of possible known outcomes, but still, in the end, with a random outcome. To obtain a better understanding, this can be viewed as something done in the right way, in the right system, but with the wrong outcome, because the outcome is random and not predictable. An epistemic uncertainty is more related to a lack of knowledge of matters that have an influence on the outcome. These uncertainties are more closely related to lacking the essential knowledge or using the wrong methods and tools to identify or assess risks and uncertainties. There could also be a lack of information to identify or assess. An epistemic "uncertainty" is thus an "unknown event from an unknown set of possible outcomes" (Hillson, 2004). This way of describing epistemic uncertainty leaves the door open for an interpretation that uncertainty is prior to risk in some sort of logical process, Figure 2.1. As a result, the concept of uncertainty could lead to opportunities as well as risks.

This way of regarding risk is also found in the book *Risk Management and Construction* (Flanagan & Norman, 1993) and in the philosophical view of decision theory (Hansson, 1994). Risk is somewhat calculable in their view, as it is associated with probabilities, whereas uncertainty has no previous history to which to relate any probabilities. Uncertainty is divided into epistemic or aleatory uncertainty and is associated with uncertainty of outcome and is related to system performance (Aven, 2003).

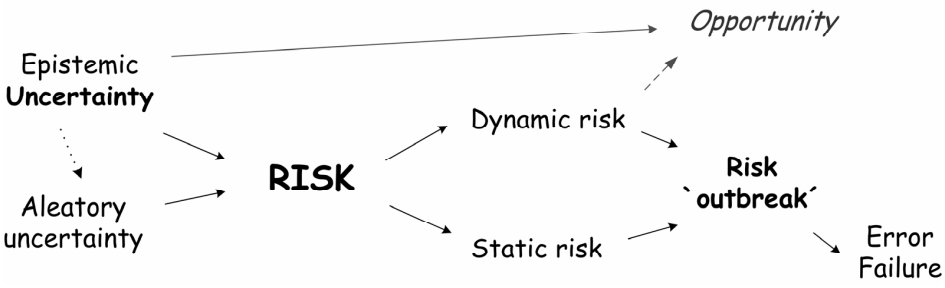


Figure 2.1 Epistemic uncertainty, aleatory uncertainty, dynamic and static risk and their relationship to outcome, risk "outbreak", in the form of error and failure.

Risks and uncertainties are handled every day in a construction project, but not all of them are of the type that requires special attention. A dynamic risk is a risk where there is an opportunity to gain something at the end, whereas a

static risk is only associated with losses in some way (Flanagan & Norman, 1993). Both types of risk could require special attention, depending on the project context, and relate to concrete risks classified according to their outcome, the effect of the risk. However, the epistemic and aleatory uncertainty addresses risk and uncertainty from a theoretical perspective.

To describe this theoretical subject using a practical example, the task of crossing a frozen lake as a short cut to the final destination could be visualised. The epistemic uncertainty could be compared to the lack of knowledge about the white field ahead; is it a frozen lake or is it a field covered in snow? The knowledge of the field increases, you are certain that there is ice, but the quality of it is still uncertain. This could be compared to the aleatory uncertainty. The risk occurs when you decide to cross the ice and the assessments that are made are whether it is probable that the ice will support you and what the consequences might be if the ice breaks. Uncertainty could also lead to opportunities and the opportunity in this example is that the ice actually will support you and you will shorten your journey to the final destination considerably. The risk outbreak is finally if the ice breaks and you have to deal with the consequences of finding yourself in icy cold water.

The concepts of uncertainty are important during the early stages of the process, as they emphasise the difference between risk and uncertainty, Figure 2.1. According to this interpretation, it is possible, but not necessary, to start with a high degree of epistemic uncertainty that develops into an aleatory uncertainty, as knowledge of the project increases. With a large degree of background knowledge, the amount of epistemic uncertainty decreases and knowledge of the quantities of probability and consequence is the only part that remains uncertain. It is, however, essential that project managers are aware of both epistemic and aleatory uncertainty, as both could greatly impact the project outcome and call for different management approaches.

Risk is the combination of consequence and probability in terms of being able to deliver results according to the objectives within an organisation or a project (Hillson & Murray-Webster, 2005). This definition is based purely on an economic viewpoint. Managing risk also means controlling the certainty of the results to be delivered, i.e. how to check how certain the results are in relation to the set objective.

In this thesis, the definition of risk is based on the negative outcome of an uncertainty. It is the combination of probability and consequence of something occurring that has an effect on the ability to achieve the set objectives for the project, economic, time or quality related, but also the objectives for personal safety. In this thesis, there is a close relationship between the ability to control the project and manage the risks. The assumption is that, if there is a lack of control in a project, there is also a lack of risk management. No distinction is made between static or dynamic risks. Further, the negative outcome of the risk is called "risk outbreak" and this is seen as the events causing an error or failure.

2.1.2 Error and its relationship to risk

An error could be regarded as a realised risk, a risk outbreak, with a negative outcome. Error could also trigger secondary risks, which bring us back to the necessity of working in the continuous loop of risk management, see also Figure 2.2. It is therefore interesting to see how and why individuals make errors and understand what the causes are. According to Reason (1990), errors can be divided into three categories: those related to slips and lapses, i.e. skill-based errors; those related to previous experience and knowledge, i.e. rule-based errors; and, finally, those related to the fact that relevant knowledge is lacking, i.e. knowledge-based errors. Of these three, the first two are related to situations in which sufficient knowledge and experience is available. In construction, the reliance on personal knowledge and experience is high (Azinim & Edum-Fotwe, 2006; Simu, 2006) and the implication of the findings of Reason (1990) is therefore important for the construction sector.

One problem that occurs is that individuals make incorrect assumptions in new situations; they use previous knowledge and experience even though the situation is new. The attitude that is illustrated by the statement "this is something we have done before, so we know what to do" could be fatal. The decision could consequently be wrong and the error is what Reason would call "strong but wrong", as the individuals regard it as the right decision based on the right probability and consequence of estimating the proper risk. This implies that, even though the systematic approach with calculated probability and consequence is used, there might be an error at the end, making it difficult to realise the project objectives.

Experts, as well as skilled site managers, are experienced and have extensive knowledge which they can apply when making decisions. Novices and new site managers and foremen are required to seek new knowledge for many of the

decisions that are needed and the decision process is therefore longer. As Reason has found, novices tend to focus on the surface features of the problem, whilst the experts focus on problems at a more abstract level. In a theoretical sense, this means that experts never need to work at the knowledge-based level, as they have a complete knowledge of what they do. In reality, however, it is more likely that the expert makes a strong but wrong decision at the skill-based or rule-based levels of performance. The application for construction is the site manager with many years' experience and thereby knowledge of certain types of work who is put in a new situation with a new project. Relating to experience, instead of seeking new knowledge more suitable for the new circumstances, then jeopardises his/her ability to consider the right probability and consequence for the risk assessment. New circumstances could be anything from new techniques to a change in rules and legislation. Only when individuals realise that their knowledge is insufficient they will move from the rule-based levels of problem-solving to the next level, the knowledge level. At the knowledge-based level, the process involves finding cues to remind oneself of previous experience continuously as the process of finding new knowledge proceeds. People seek patterns and sort information, using the same processes to handle new information as they do to organise memory. This ability to organise and process information helps us to make simplifications in problem-solving; i.e. to make things easier (Reason, 1990). This explains why some people have a faster problem-solving process than others, an important skill for site managers in construction. The ability to make decisions at a fast tempo is vital if things change and action is needed on site to solve new problems. On the other hand, there is a risk involved with decisions that are taken too quickly. All the necessary information may not have been taken into account and the result might be an error. Working at the knowledge-based level can also be regarded as a matter of being able to work with continuous learning according to the descriptions used by Anheim (2001) and Senge (1995).

Errors at different performance levels

At the different performance levels – skill-based, rule-based and knowledge-based levels – errors can be described according to the way they appear, according to Reason (1990). Errors occurring at the skill-based level are most often related to either inattention or over-attention. This is exemplified with the simple miswriting of the current year when writing dates at the beginning of January each year: you know it is a new year, but, due to inattention you write the previous year. The implication in a work situation would be that, with tasks that are too routinely based, the risk of skill-based errors increases.

The errors occurring at the rule-based level are mainly related to either the misapplication of a "good rule" or the application of a 'bad rule", as described by Reason (1990). Misapplications of "good rules" could occur when different signs are used when trying to find a match to an applicable rule and the closest fit is used but is not right for the given situation. The signs are used to find satisfying conditions for a rule and, conversely, countersigns are used to remove specific rules in favour of more general rules. According to Reason (1990), the application of "bad rules" is sorted into either deficiencies in encoding or deficiencies in action. Encoding deficiencies in rules is very largely a question of being able to code more than one rule at the same time and then applying them simultaneously. Deficiencies in action take place when the wrong rule is used or when rules that are either awkward or simply not advisable are used. The results of using these rules are, however, that, despite the correct use of the rule, an error occurs. An example of this is calculating a mathematical problem using the wrong equation but the "right" calculations; for example, using the equation for volume when you ought to calculate the area. If this theory is put into the scenario of the management system at a construction company, the implication is that, no matter how well routines for management are written, if they are misunderstood or misused, there might be an error somewhere down the line. The same thing applies if the routines for work performance are badly written, either not applicable or completely wrong for the given situation. The result of following such a routine (rule) is an error.

The root cause of making a rule-based error could thus be related to the ability to take in information about the present situation and code this information to find matches with the applicable rules and routines or use it to trigger a search for complementary information and knowledge. This key information is referred to as signs, according to Reason (1990), and there could be either signs or non-signs. In his theoretical framework, Reason also writes about *non-signs* that are merely information that does not relate to any existing rule but nonetheless disturbs the process of recognition when seeking a match. One difficulty with the different signs that are used to find a match to an applicable rule is a huge amount of information, a situation Reason calls informational overload. In such situations, it is difficult to detect signs and *countersigns* and, as a result, it is difficult to recognise the match with an applicable rule. There could also be difficulty detecting and sorting out the important signs from the less important signs. When there is an inadequate match to a rule, an individual's cognitive system tends to favour something Reason calls stronger rules. These are, in this sense, rules that have been used previously with success and there are also indications that general rules are stronger than rules that are used less frequently. The use of rules merely because they have

worked before, without any other analysis of the match to different signs, is called rigidity. An example of this is illustrated by the following quotation: "To a person with just a hammer, every problem looks like a nail" (Reason, 1990).

At the knowledge-based level, the failure modes according to Reason can be divided into two root causes that are aspects of human cognition; bounded rationality and the lack of complete, relevant or accurate information. An example of limitations for proper decisions at the knowledge-based level is the available heuristics. This means that the information that comes into one's mind first is given disproportionate weight, while other pieces of information are ignored; this could be described as "out of sight, out of mind". Another example of limitations is what Reason (1990) calls overconfidence. This means that individuals are likely to be overconfident in evaluating their own knowledge. The tendency is to focus on evidence for correctly made decisions and disregard signals that indicate that the chosen decision is somehow wrong.

Sources of problems leading to errors and accidents

In this thesis, errors are described as the negative consequence that follows a risk outbreak, Figure 2.1, due to the inability to make proper assessments of probability and/or consequence. As has been discussed in the previous sections, the types of error can have different origins. In the book *Barriers and Accident Prevention,* Hollnagel (2004) discusses why things go wrong and focuses on an understanding of the nature of accidents rather than finding their causes.

Several sources of problems are suggested, of which some are presented here, where some have implications for individuals:

- insufficient training and experience
- ineffective communication and collaboration

as well as those that have implications at organisational level:

- poor work conditions
- misleading design and underspecified task and performance criteria
- incomplete or incorrect procedures and plans and non-supportive organisational climate

This is interesting for the approach to risk management discussed in this thesis, as an accident, as well as an error, is a realised risk. The sources of problems that are suggested could therefore also be valid for risk management.

In simplified terms, it is either the interpretation of information that produces the decisions causing errors or it is the lack of information that is the initial cause of an error. The unifying word for risk and error is therefore information in some sense. To a large extent, errors are also related to individuals, as described earlier, and to some extent also to social context. The impact on the effects of risk management therefore appears to be dual.

2.2 Risk management

This section aims to provide an overview of risk management as it is traditionally described and used in construction. This thesis is not aiming to provide an extensive presentation of the various tools and techniques for risk assessment, only a brief overview.

2.2.1 Risk management process

Managing construction projects involves making decisions relating to changes in conditions associated with construction, the environment, geotechnical, economic and legislative aspects and so on. In spite of this, risk management has only been applied in the construction industry for a little more than two decades (Flanagan & Norman, 1993, p. 1).

Formal and traditional risk management as used today is based on the logical structure of identification, assessment, response and finally also control, see Figure 2.2. This broadly follows the guidelines and terminology used in numerous standards and associations used in engineering projects (Chapman & Ward, 2003; IEC62198:2001, 2001; PMBOK, 2000; Raz & Michael, 2001; Smith et al., 2006). The levels of detail vary, however, in different approaches, together with what needs to be achieved in each step. They all share the engineering approach and the project environment and the fact that the actual content of the process is similar.

One way of visualising this is to use the continuous cyclic approach, in line with Deming's PDCA (plan-do-check-act) circle for continuous quality improvement, showing the similarities in these management approaches.

Figure 2.2 The cyclic and continuous view of a formal risk management system.

Risk identification

Risk identification is the step which has few systems and tools related to it. In spite of this, it may still be the most important and time-consuming step in the above process. According to Maytorena et. al (2007) the identification step has received the least attention and the tools and techniques for increasing effectiveness have focused on the risk register, RBS (risk breakdown structure) and brainstorming. The consequences of incorrectly identifying risks are that, when these risks are considered in the management system, incorrect assessments and responses will follow.

The SHAMPU[2] model introduced by Chapman and Ward (2003) emphasises the importance of correctly and extensively identifying risks and uncertainties, both aleatory and epistemic. The authors do not restrict themselves to risk events but include all sources of uncertainty and associated responses. This is a very thorough approach that includes many steps relating to risks and uncertainties related to *who, why, what, which way, wherewithal, when* and the *Project Life Cycle*. By using a model that includes all these factors, the danger of missing risks along the way is minimal or is at least reduced. The disadvantage of using such an extensive approach is the threat of losing users along the way.

In the process of identifying risks in a project, it is necessary to consider the different sources of risk present in the project and the different classifications of risk that could be of current interest. It is also important that there is a clear distinction between the risk source and a risk effect (Flanagan & Norman, 1993).

[2]Shape Harness And Manage Project Uncertainty, SHAMPU

Risk assessment

Risk assessment is performed in numerous ways. Tools and techniques have been developed to consider probabilities and consequences, using historical data, statistical data or estimated judgement translated into numerical information (Aven, 2003; Grey, 1995). There are also assessments grading certainty in scales such as *rare-almost* certain and *low-extreme*. They share estimates of probability and consequence and the use of software tools to manage the data. Scoring techniques (Grey, 1995) are developed checklists that include the evaluation of both probability and the consequence of a risk breakdown and those are used to produce risk matrices. This is a common technique for risk assessment in construction projects that is widely used due to its simple approach. As with checklists, the disadvantage is that some aspects are forgotten. The bias that also needs to be considered is that different evaluations will appear depending on the individuals carrying out the assessment.

Using models or simulation to assess risks is another approach. Models are simply a breakdown of a complex project into manageable bits and pieces, often by using mathematics to show how these bits and pieces are linked together. The disadvantage of any model using figures is that the user could easily be blinded by exact figures, without having any more precise information than a more qualitative answer. It is important to remember that, with models and simulations, the saying "what goes in is what comes out" is very applicable.

Risk response

In the risk response step, action is taken to control the risks analysed in the first two steps. Responses are often graded on four levels, namely risk retention, risk reduction, risk transfer and risk avoidance (Flanagan & Norman, 1993).

Risk retention means accepting the presence of risk and still conducting business as usual. The reasons for retaining the risk could be that the estimated probability, consequence or the combination of the two is low and at an acceptable level. A good everyday-life example is the choice of insurance premium. People either pay a high premium and reduce the excess or choose a lower premium and pay a higher excess. The risk is still there and retained.

Risk reduction means reducing the probability, the consequences or a combination thereof of a risk breaking out. This can be done in several ways,

of which sharing with other parties or taking some action where the probabilities or consequences are reduced is common. One action to reduce risks is through the educational training of employees to increase their awareness of the possible risks and make people think in terms of "what if". Having employees with this way of thinking reduces the disadvantages of shortcomings in supporting systems. Checklists and different types of scoring technique can be used as support without the risk of being too much in control. Other measures can include physically reducing the risk by building systems, rails to eliminate falls, sprinklers to eliminate fire and so on. A third party, such as extra assurance and quality control of projects to ensure that nothing is forgotten or overlooked, could also be included. A common way of reducing risks at construction sites is through work planning. The work plans consist of time schedules and the allocation of resources such as staff and equipment.

Transferring the risk to another party is a fairly common way of dealing with risks in the construction sector. The risk is transferred from the client to the contractor through the agreements in the contract, or from the contractor to the sub-contractor. In the Swedish construction sector, Design-Bid-Build is less risky for the contractor, as the client is held responsible for the building documents according to AB 04. In Design - Build contracts, contractors take a great risk, as they take full responsibility for both the design and construction according to ABT 06. Another way to transfer the risk is to have insurance, which is a way of transferring the uncertain cost of a potential loss to a certain sum of money for the premium.

Risk avoidance means refusing to accept a risk. This is done either by simply refusing a project that is too risky to proceed with or by writing exceptional clauses in the tender.

Risk control

The final step in the description of the risk management flow chosen in this thesis involves ensuring the use of the prior steps. It is a question of making sure that the identified risks, which are regarded as important, are also controlled in the way that was planned in the response step. In the control step, it is also possible to identify new risks that emerge and the continuous process proceeds. In the international standard for project risk management (IEC62198:2001, 2001), this step is called monitoring and review and has two main purposes, to ensure that the treatment of the risk (response) is effective and that new risks that arise are identified. A comparative survey study from

Australia also reports that this step is the least frequently used amongst practitioners in the construction sector (Lyons & Skitmore, 2004).

2.3 Effects of risk management

This section aims to set the theoretical framework for the first research question: In what way can the effects of risk management be measured at construction site level?

The word "effective" is defined as "Powerful in effect; producing a notable effect; effectual"

Effective risk management involves achieving the set objectives for the project by using the available tools and techniques. According to Hillson & Murray-Webster (2005), p 12, "the very purpose of risk management is to maximize achievement of objectives" and "achieving the set objectives or delivering the promised benefits". Objectives in the majority of construction projects are measured in financial terms. So the effect of risk management should have a strong correlation to the actual profit and cost for client.

Efficiency is defined as "Fitness or power to accomplish, or success in accomplishing, the purpose intended; adequate power, effectiveness, efficacy"

According to (Chapman & Ward, 2004, p. 620), risk efficiency is "the minimum risk decision choice for a given level of expected performance, expected performance being a best estimate of what should happen on average, risk being the possibility of adverse departures from expectations".

The disparities between effectiveness and efficiency are related to internal or external performance, where effective and effectiveness is about doing things right and efficiency is about doing the right things. A third concept of efficacy is defined to combine both effectiveness and efficiency in one term (Bull, 2005).

The effects of risk management are related to the objectives of the project. Common objectives for construction projects are time, cost and quality, but, according to Bresnen (2001), they are difficult to use due to the difficulties involved in disaggregating them from the effects of other project management processes.

To define the site manager's performance in relationship to stress, project effectiveness has been measured using three variables, leadership performance,

relative delay of the project and quality of finished work (Djebarni, 1996). Leadership performance was measured by an evaluation of the site manager's performance that was made by his/her superior manager. The relative delay was measured through a combination of answers about the duration of the project, the start of the project and finally when it was due to be finished. The quality of finished work was measured through the site manager's superior's opinion of conformity to set standards.

In 1998, Sir John Egan presented the Egan Report entitled *Rethinking Construction*, a report focusing on the improvements needed in the UK construction sector (Egan, 1998). To be able to measure the improvements made in construction, certain indicators for improvement were suggested. They have since been referred to as Key Performance Indicators, KPIs (Crane, 2002; Fernie et al., 2006; Yeung et al., 2007). These Key Performance Indicators can be found in Table 2.1.

Although a great deal of interest has focused on risk management in both research and practice during the last decade, not much has been said about ways of using measurements or indicators to confirm the results or effects of risk management. There is one study that was conducted in South Africa (van Wyk, 2008) which discusses risk management practice and one of its conclusion is the need to establish the effectiveness of risk management strategies, i.e. to find ways to measure what is generated by investments in risk management strategies.

In another study performed in Indonesia, risks are related to project performance in the form of time and project delays (Wiguna & Scott, 2006). Its findings, based on path modelling, reveal that there are causal effects between the authors' index of project risk and project performance. The findings indicate that, the lower the risk, the lower the negative impact on time deliveries. However, this study only considers the time-related performance in the project, while other performance measurements, such as safety, defects and costs, which might be interesting are not considered. These results are interesting and take research in the field of risk management one step further. The question that still needs to be answered is, however, how the effects of risk management at project level should be measured in an organisation with many projects and not merely on a few projects to identify the causal relationship between risk index and time-related performance.

To be able to see whether an organisation is benefiting from using project risk management, indicators such as KPIs should be used. The difficulty then is to

define which of these indicators are actually related to risk management, disaggregated from other management processes in use (Bresnen & Marshall, 2001). For this reason, the KPIs need to be related to risk in some way, to identify the way in which it is likely that performance in risk management is related to either of the KPIs, see Table 2.1.

At first sight, all the KPIs could be related to risk management, as risk management is commonly viewed as part of project management in general. Going back to the specific aims of risk management, KPIs relating to safety, certainty, defects and cost are found to have a closer relationship with this specific part of general project management (Khalaf, 2008; Love & Josephson, 2004; Zeng et al., 2007), also referred to as direct relation to risk in Table 2.1.

The Provisions and General Recommendations issued by the Swedish Work Environment Authority have a clear-cut aim to reduce the number of accidents within the construction sector. In these legal documents, risk assessment is a vital part. For this reason, measuring the number of accidents as a direct indicator of risk management performance should be relevant, see also Table 2.1.

Organisations can be described in relation to their ability to have a safe work environment, i.e. enough safety space in the organisation (Reason, 1997). In an organisation with good safety space, there are fewer accidents than in organisations with less safety space. In this sense, the number of accidents reported could then be an indicator of how well the risk management is working in the organisation.

Risk management is close to uncertainty management and it therefore has the clear-cut aim of reducing uncertainties in the organisations or projects in which it is applied. Predictability should therefore be a relevant measurement of the effects of risk management, see also Table 2.1.

Table 2.1 Key Performance Indicators (KPIs) and their original measurements, relation to risk and possible measurements at construction site level

KPI	Original measurement	Relation to risk	In theories found measurement (on site) for indicators related to risk
Client satisfaction Product Service	Percentage score in set survey	Indirect	-
Defects	Number of defects on handover	Direct	Number of defects on handover
Safety	Number of reportable accidents	Direct	Number of reportable accidents
Predictability Design cost Design time Construction cost Construction time	Completion in time within budget	Direct	- - Compare budget and time schedule with final result
Profitability	Median profit before interest and tax	Direct and indirect	Median profit at site level before overhead cost is taken
Productivity	Mean turnover/employee	Indirect	-
Construction cost	Change compared with one year ago	Direct and indirect	Not applicable
Construction time	Change compared with one year ago	Direct and indirect	Not applicable

Various researchers have focused on defects and errors in construction projects (Josephson & Hammarlund, 1999; Love & Josephson, 2004) and their relationship to risk and risk management is fairly obvious when studying what the differently used concepts actually mean and the implication of their use. For example, "error is defined as deviation from what is intended and caused

by human actions" (Love & Josephson, 2004, p. 71) and a consequence of risk is defined as an outcome of an event (Aven, 2003). Further, Love & Josephson (2004, p. 70) claim that "Errors can be essentially avoided by eliminating root causes using techniques embedded with the philosophy of total quality management (TQM), for example, benchmarking, root cause analysis and failure mode analysis (FMEA)". In other words, the avoidance of errors is close to managing risks, i.e. risk management. To continue this line of argument, it appears to be relevant to measure defects as the effects of risk management, see also Table 2.1.

Construction cost and profitability are different aspects of similar things – the ability to earn money in construction projects. The margin measured in profit is the difference between income and cost and one way to increase profit is therefore to reduce cost. Cost in turn is a product of several different sources, while income, on the other hand, is most often only related to one source, the client. So increasing profit should focus on the different sources of cost instead of trying to increase income from clients.

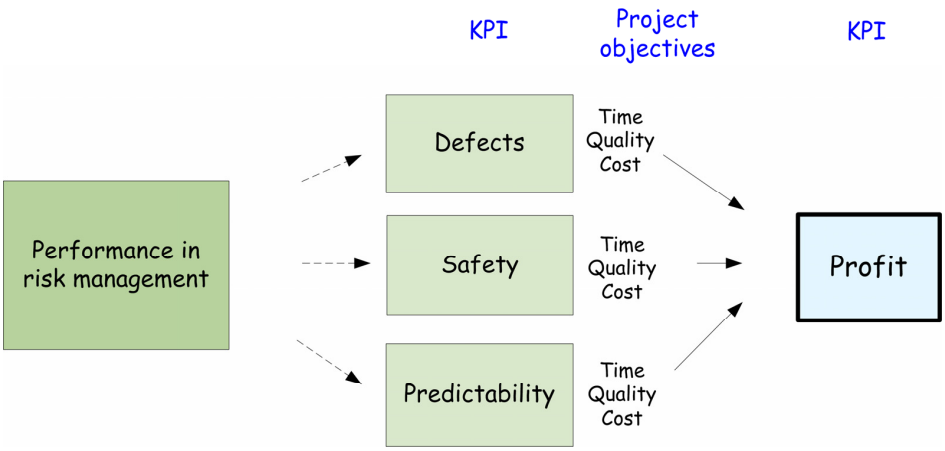


Figure 2.3 The links between the effect of risk management performance, project objectives and increased profit in relation to Key Performance Indicators (KPIs).

Some of the sources of costs in construction projects are safety, the ability to deliver at the set time at the set budget, i.e. predictability, and also as a result of shortcomings in quality performance such as defects. If either of these sub-deliveries fails, it will have a direct impact on the final economic result. It is

therefore vital to understand the relationship between economic result and these other indicators.

When a risk outbreak occurs as a consequence of poor risk management, an error or a failure that causes harm to either people or material, i.e. defects in the final product, might also occur. Further, a risk outbreak might cause disturbances in the work flow in production on site. When either of these occurs, the subsequent result, partly due to the harm, defect or disturbance itself, is that there will be consequences for the objectives of the project, in terms of quality, time schedule or cost. For the project, any of them would have an impact on the final profit, see Figure 2.3.

The suggested measurements that could be used as indicators of the effects of applying risk management at site level are, as been shown in Table 2.1.

- Quality performance in terms of *defects* in the delivered product
- *Safety* in terms of accidents
- *Predictability* in terms of the relationship between plan and delivery
- *Profit* on bottom line at project level

2.4 Experience, decision theory and assessments in connection with uncertainty

This section aims to define the theoretical framework within theories of behaviour and attitude, experience, decision theory in relation to risk and risk perception.

2.4.1 Individual experience as an influence on risk management

It has long been assumed that experience is an important key to risk management and perhaps in particular to risk identification. Recent research has, however, found that experience is not the key ingredient for effective risk identification; it is instead educational attainment and training that can improve the risk identification performance (RIP). Maytorena et al. (2007) have found that experienced project managers' approach to risk scenarios is less questioning and more reliant on procedures and their prior experience than that of more novice managers in the same situation. According to their study, there also appears to be a correlation between their definitions of experience, age, years in management role and years in current job, and the "orphan risks" and the more reactive approach of using checklists. Their definition of "orphan risks" is risks that are identified without prior searches for information or

follow-up. Using the theories of Reason (1990), this would imply that experienced managers make decisions at the rule-based or possibly skill-based level, while the more novice managers work at the knowledge-based level, aware of their shortage of knowledge and searching for complementary information prior to decisions.

According to Brehmer (1980), trusting experience for the purpose of judgement and decision is not well founded when it comes to the ability to make better judgements and decisions. This is in line with the results reported by Maytorena et al.(2007). Brehmer's (1980) line of argument comes from the suggestion that, in order to obtain value from experience, one has to be able to learn from experience. He states that experience often gives us little information from which to learn. According to Brehmer, for most individuals in most situations, decisions are based on a deterministic approach instead of probabilities, in spite of the fact that the experience ought to provide knowledge about the probability that events will happen.

Coming to these conclusions about experience and the apparently contradictory reliance on it in construction, it is vital to understand more about the essence of experience and its relationship with judgements and decision-making.

Several researchers have found that decision-making in connection with uncertainty and risk is a matter of judgement based on experience, knowledge and the individual ability to manage the risk (Lazarus & Folkman, 1994; Skitmore et al., 1989). Risk is often described as a combination of probabilities and consequences, as mentioned earlier. In order to undertake a proper assessment of a risk, an estimate of the probability and some assessment of the consequences if a risk were to break out are needed. In terms of probability, there are two ways of doing this: either estimated by experienced individuals or calculated from historical data or statistics. Experience, as a base for a probabilistic estimate, is a powerful tool that is frequently used in risk assessment. When an individual makes an estimate of probabilities, it is the experience and heuristics of that person that are used. The way a person perceives the world is also the way the same person makes judgements, evaluates information and makes decisions. If the information in a given situation is diffuse, reliance on long-term memory and experience is high. The ability to take in new information is therefore essential for judging probabilities. With the theories put forward by Reason (1990) fresh in one's mind, this would mean the ability to be aware of when there is sufficient knowledge, when work at the skill-based or rule-based levels is appropriate, or when it is time to go on to the more time-consuming, knowledge-based level

and search for more information. If there is an expectation that things are going in one direction, the individual is making a judgement that this is also the most probable outcome, see also Figure 2.4. The risk outbreak and errors occur when this is the wrong judgement (Wickens & Hollands, 2000). Using the same line of argument, the consequence of a risk is assessed similarly and derived from the individual's ability to take in relevant information and use it in combination with experience.

2.4.2 Judgement in connection with uncertainty influenced by individual heuristics

Tversky and Kahneman (1974) have suggested that there are three different groups of heuristics that influence judgements in connection with uncertainty:

- Representativeness
- Availability
- Adjustment and anchoring

Representativeness is when people tend to make judgements based on sometimes irrelevant information that should not actually influence the probability of an outcome –for example, people's prejudice relating to the way other people with certain occupations should act and dress. The effect of this is that people make judgements based on information that should not affect the probability of outcome. Tversky and Kahneman show in their study that people use available, albeit irrelevant, information as a basis for their judgements ahead of using accompanying prior probabilities that are more relevant.

Another heuristic that influences judgements in connection with uncertainty is the phenomenon Tversky and Kahneman call *availability*. This means, for example, that a situation or information that comes easily to a person's mind when making a decision is more likely to influence the judgement than other situations that are not so easily retrieved, even though the situations ought to have the same probability of occurrence. As an illustration of this phenomenon, the authors use the example of the subjective probability of traffic accidents, which they argue is temporarily higher for a person who has recently seen a traffic accident than for a person who has not seen an accident recently.

The third heuristic presented by Tversky and Kahneman is what they call *adjustment and anchoring.* Their study has focused on people's tendency to

adjust and anchor to specific values when estimating new values. This means that the initial value influences judgement with respect to new values.

Experience as such could therefore be regarded as the input to several heuristics that influence judgements in connection with uncertainty, Figure 2.4, but there is still no complete definition of experience.

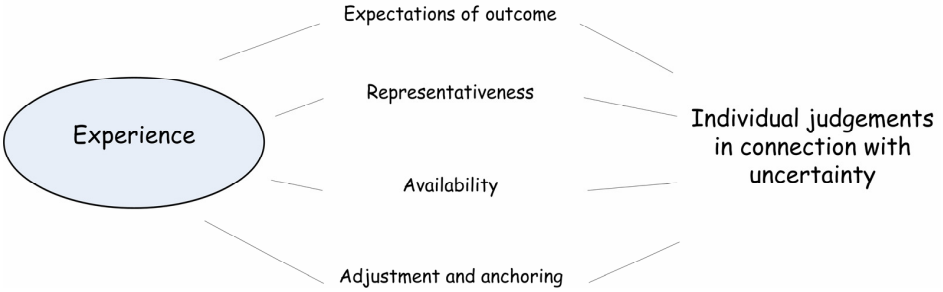


Figure 2.4 Experience has an impact on individual heuristics that then have a large impact on judgement in connection with uncertainty.

Experience has an impact on the heuristics that are used and it also functions as input in itself in the process of decisions taken in connection with uncertainty. Apparently, researchers have found that experience in itself does not ensure that the estimation of probabilities will be better or more accurate (Tversky & Kahneman, 1974), but it is still used and relied upon and the value of experience is questioned by researchers in the field (Brehmer, 1980).

2.5 Theories of personality

The purpose of this section is to discuss theories that are said to describe the concept of personality and the extent to which this concept is measurable. Since individuals are supposedly important for the outcome of risk management, it is important to understand the theoretical framework for this field of science.

2.5.1 Overview of general theories

There are several ways and theories that attempt to explain why individuals act and behave as they do in order to find a way to explain an individual's personality. The main personality theories can be put into different groups related to their different views of personality (Cervone & Pervin, 2008):

- psychodynamic theory

- phenomenological theory
- trait theory
- evolutionary theory
- behaviourism
- personal construct theory
- social-cognitive theory

The first is one of the best known ones, *psychodynamic theory*, pioneered by Freud. This theory claims that personality is driven by needs that are often addressed to the unconscious part of our system. The next theory, *phenomenological theory*, states that our personality is driven by our conscious experiences from our surroundings and that our needs and motives are biological but also driven by higher motives such as self-fulfilment and personal growth. *Trait theory* is the next theory to be presented. The theorists representing this theory believe that personality can be explained by certain common traits that explain the main differences between individuals. The key issue is to identify the traits that are common to all individuals and then how to measure them. This theory has developed during the 20th century and there is now a common view of these traits and an established way to measure them. The *evolutionary theory* to explain personality emanates from the biological evolution that has supposedly developed our social behaviour. This theory searches for genetic explanations for the personal traits found in individuals. *Behaviourism* as a theory of personality represents the idea of learning as being important to the personality. According to this theory, behaviour is a consequence of the adoption of rewards and punishment. This means that the environment shapes the personality, not the personal trait, needs motives or genetics, as in the previous theories mentioned. The *personal construct theory,* also called cognitive theory, states that individuals construct their own world and, depending on this construct, the behaviour and personality differs between individuals. The last theory to be mentioned is the *social-cognitive theory* that is closely related to the prior theory. This theory believes that personality develops from back and forth influences from social surroundings.

These short descriptions have been taken from Cervone and Pervin (2008) and the purpose in this thesis is to give a brief overview of this vast area of knowledge.

2.5.2 Personality and individual traits – trait theory

Among the many theories used to explain personality, trait theory has become the prevailing one and the field of personality psychology relies on measurements (Brody & Ehrlichman, 1998). This area within the field of personality is also the one that has been most commonly adapted in the field of work assessment, such as job recruitment, and numerous tests are currently used for this purpose (Ones et al., 2007).

Trait theory is based on the idea that personality can be described through certain traits that are common to all individuals. This approach assumes that the personality has certain traits that are stable and consistent and can be measured and compared between individuals. These traits could also be used to predict future behaviour and are structured hierarchically, which means that various traits can be linked together at a secondary level to form traits at a more general level, also called factors.

In the research area of psychology, and within trait theory, the Big Five personality factors are the common and established way of describing individuals (Goldberg, 1992; McCrae & Costa, 1989; Tupes & Christal, 1992). "Big Five" is a general description that is theoretically accepted and is therefore valid as a reference to other tests claiming to describe individuals' traits. The five factors, the Big Five, were originally defined in 1961 by Tupes and Cristal in their work for the United States Air Force. The Big Five factors are: Surgency (extraversion), Agreeableness, Conscientiousness, Emotional stability and Intellect (openness to experience).

2.6 Risk perception and performance in relation to individuals

This section aims to create a theoretical framework for theories of personality in relation to risk and performance, as this supposedly has an important impact on the way risk management is applied.

There have been several attempts to relate personality factors or traits to different kinds of performance, so far without any significant degree of explanation (Chuvin et al., 2007). The studies that have been performed have focused on individuals' perception (explained by personal facets) of risk in relation to;

- personal health
- energy production including nuclear power

- pollutants
- sex
- deviance
- addictions and weapons

to mention a few. The results show that the personality facets can be used to explain certain risk perceptions but not all.

The personality traits chosen in a study from 2007 (Chuvin et al.) are the same as those that are used to describe in the Big Five factors. The facets found to be most predictive included the following:

- moderation and tranquillity - associated with energy production or pollutants
- rationality and efficiency - associated with pollutants, sex, deviance, addictions and weapons
- creativity, imagination and reflection - associated with energy production, pollutants or common individual hazards
- self-disclosure - associated with outdoor activities.

According to Sjöberg (2003a), there have so far not been any results showing that personality dimensions according to Jung could be related to risk perceptions.

The relevance to risks that might appear in construction appears far removed, as does the applicability of the results found in recent research (Chuvin et al., 2007; Sjöberg, 2003a; Slovic, 1987). Risks in these studies focus primarily on risks mentioned in the media and in public in general, not in work-related environments such as projects or construction, where risk is closely related to the inability to realise the set objectives.

One interesting aspect of risk perception is, however, the statement made by Sjöberg (2003b) that "risk is perceived as more important than the added value", meaning that the risk associated with a new power plant, no matter which, is higher than the perceived utility. According to Sjöberg, this is important to consider when talking about risk and risk perception. His results have also shown that, depending on who you are, male or female, higher level of education or not, neuroticism as a personal trait and expert and specialist, the perception of risk differs. It would be generally true to say that males, those

with higher education and experts within their field perceive less risk than others.

Risk perception is also found to differ depending on its relationship to personal risk or if it is a more general risk that could have an effect on others. Research in the area (Sjöberg, 2003b) shows that risk perception relating to the individual self is lower than the perception of risks that could affect others. The implication of this is that individuals neglect risks that are related to their own person, such as the risk of diseases, inappropriate diet and so on. This is related to the feeling of control, such that the perceived risk decreases with an increased feeling of control. According to Sjöberg (2000b), risk is most often regarded as general rather than personal and, as the way different individuals perceive these different risks varies, it is important to remember this when conducting risk-related research. In this study, the risks are related to project objectives and therefore not to individuals' personal risk. Sjöberg (1999; , 2000a) has also found in his research that it is the consequences that are perceived as the main aspect when assessing risks; the probability is not as important an issue, which is the same as the finding reported by Brehmer (1980).

According to Butler (1995) cited by Smallman (1996), "there is sufficient evidence to support the contention that managers with a high risk propensity are more likely to take decisions at short notice". The interpretation of this statement is that personal traits influence risk management in organisations. This is also in line with the ability to work quickly at the rule-based level (Reason, 1990), with the possible outcome of "strong but wrong" decisions rather than working at the more time-consuming, knowledge-based level. Speed in decision-making thus appears to influence risk-related outcome.

It has also been found that there is a relationship between stress and increased risk (Hartzell et al., 2008). Working in a stressful situation has a negative impact on performance and increases the risk of defects, errors and accidents at construction sites (Djebarni, 1996). A study in the UK (Davidson & Sutherland, 1992) found that some of the main reasons for perceived stress at construction sites are time pressure, lack of resources and responsibility for situations outside the control of the site manager. During the last two decades, there has also been an increase in time pressure in construction projects (Theorell, 2006).

A study of relationship between attitudes and risk perception has found that the individual perception and attitude do influence the behavioural intentions, i.e. that the individual attitude is a predictor of behaviour (Rundmo et al., 2007).

The efficiency-thoroughness trade-off (ETTO) is an interesting ingredient presented in Hollnagel's (2004) book as a common feature of human performance that is claimed to influence both individuals and the organisational level. In experimental studies, he states that the inability to perform with high accuracy and at high speed is generally accepted. This means that, in the long run, it is impossible for people to be both fast and accurate. The trade-offs made in decision-making could be related to this or to another phenomenon Hollnagel call ETTO rules (Hollnagel, 2004, p. 154), rules that are used during assessment that have an impact on the outcome of a decision. Examples of ETTO rules include:

- *Not really important*, looks wrong but is judged to be of lesser importance
- *This is normally OK,* postpone that for later
- *It worked last time,* assume that it will work this time as well

The criterion for making trade-offs such as those exemplified is that they are not fixed or simplified to one criterion but are suggested to depend on the context in the given situation. The behaviour of the individuals and the groups is therefore largely dependent on the present situation. Further, risk perception and risk behaviour at individual level is highly dependent on the attitudes to risk in the group around the individual (Hillson & Murray-Webster, 2005).

2.7 Organisation and culture as a context for risk management

This section addresses the wider influence the context for project risk management has on the individuals in an organisation. It does not address any research question but is essential in order to understand the role of individuals in organisations, since they co-exist.

Risk management is applied in many diverse ways in different companies and organisations. It appears that, depending on the culture, chosen approach and organisation, the context and perceived effects of risk management differ. Different researchers have described this in different ways, probably depending on the different disciplines they represent, see Figure 2.5.

Reason (1997) states that an organisation handles safety in different ways depending on its organisational culture. Organisations that have a dominant pathological culture punish failures or conceal them, shoot the messenger and shirk responsibility. At the other end of the scale, there is the organisation Reason defines as having a generative culture. In this organisation, there is shared responsibility, new ideas are welcome and failures lead to reforms for improvement.

In a similar way but with other expressions, Smallman (1996) defines two different approaches to risk management, either a reactive approach, the traditional and prevailing one, or the less applied, proactive (holistic) approach. The reactive approach (Smallman, 1996) focuses on using quantified data of outputs and the organisation reacts to this information. These organisations are also typified by quantifying insurance cases and paying premiums according to outcome rather than the management to prevent losses as a result of events. They also have clearly defined decision-making rules for managing risk and the risks that should be managed. The reactive approach is also described as the event-driven action to retain or transfer risks. The transfer of risks on an economic basis always leads to financial loss, such as either an event (risk outbreak) or premiums paid for insurance. Smallman (1996) states that the losses from events are large, as there is seldom compensation for them and there are "figures that indicate that less than one-seventh of losses are paid for by insurance".

The proactive approach (Smallman, 1996) is holistic and social and is largely dependent on the organisational behaviour. One difficulty with the proactive approach is that it is subtle and difficult to arrange in systematic order with structured rules for decision-making. The reason for this is that this approach takes account of what he calls "scientific uncertainty" and influence from surrounding culture. Risks in organisations applying this approach are instead avoided, prevented or reduced rather than retained and transferred. In the proactive approach, all risks are considered, their inter-relationships are included and the management is driven by what the potential risks could be rather than events. In the proactive approach to risk management, one vital aspect is the ability for organisational learning. To be able to work proactively, there need to be systems for following up faults and errors and then learning and using the knowledge for new forecasts of potential risks. To define an organisation's approach to risk management Smallman (1996) uses three factors: Structure, Strategy and Culture. The *structure* relates to the way the organisation has organised its risk infrastructure; in other words, if there are specialists, i.e. risk managers or senior managers, that take responsibility for

risk management. The *strategy* refers to the extent to which risks are included and the techniques that are used to identify and control the risks. Finally, the *culture* refers to the prevailing attitudes, values and actions with which the organisation lives and which influence risk management.

Hillson (2006) uses a similar description and, instead of generative culture or proactive approach, it is called integrated risk management. Integrated risk management includes both tactical and strategic risks, as well as the opportunities. In the current risk management scope, according to Hillson (2006), only the tactical risks, i.e. risks that concentrate on project performance and mainly focus on technical or health and safety matters, are included. Strategic risks relate to the objectives that go beyond the scope of the project and include the organisation or company objectives at a strategic level.

Chapman & Ward (2004) talk about best practice and common practice of risk management to define their terminology for what they see as more efficient risk management. Efficient risk management is also a key term that is used to describe how best practice could be applied in companies and organisations. Chapman & Ward (2004) state that efficient risk management is a question of being able to choose the smallest risk for the best performance. To be able to adopt more holistic risk management, an understanding of efficient risk management is vital. The choice of the most risk-efficient alternative is based on issues of probability, cost and "cost risk", where "cost risk" is the cost of reducing the probability of a risk occurring. Further, their line of argument for being able to apply best practice risk management includes issues relating to

- Culture, where a "blame culture" is fatal
- Opportunities, not only threats have to be considered to achieve best practice
- Strategic choices and risks need to be considered, i.e. a top-down approach
- An end to focusing on specific events as risk generators

Chapman & Ward also argue for simplicity and awareness when applying formal risk management systems and suggest that, for small and simple projects, formal risk management might not be best. It is, however, important that every decision that is taken should be taken within the best practice context.

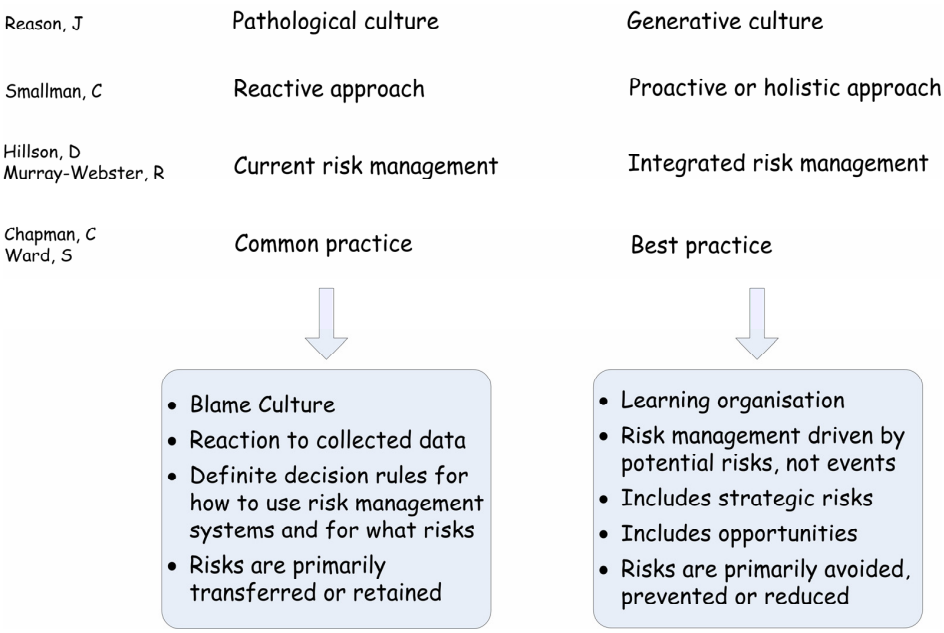


Figure 2.5 The two different approaches, reactive and proactive, to risk management are described by various researchers, from various fields of science.

The similarities in these different researchers'(Chapman & Ward, 2004; Hillson, 2006; Reason, 1997; Smallman, 1996) statements are noteworthy, especially as they are derived from different fields of research. It also appears that the researchers (Hillson, Chapman & Ward) that are closest to construction in their research feel that the current way of working is closest to what is described as a reactive approach or pathological culture by the other researchers (Reason and Smallman).

There is empirical research indicating that risk is more dependent on situational factors than on differences in organisational and individual attitudes to risk, according to Smallman´s (1996) interpretation of the research of Kahneman & Tversky (1979) and March & Shapira (1987). The conclusion that can be drawn is that there is no unifying theory of what has the main influence on risk management in organisations; it could be situations, organisations or individuals.

According to Reason (1997), errors within an organisation are also mainly due to the circumstances and the context in which people work. Even if it is an

individual at the end that makes the error, it is the organisational circumstances (culture) that create the attributes that make an error actually occur. For an error to occur, there often need to be a number of events going on in a certain direction and a number of safety systems to pass before the error is a fact. The contribution from the individual in this paradigm is therefore limited. This paradigm regards the errors as faults due to systematic errors rather than errors due to individuals' attitudes and behaviour. In construction, on the other hand, the individuals, especially at site level, are strong characters that have a large amount of freedom to create their own way of working. It is a decentralised organisation and the autonomy of each and every individual is high. The safety system in such an organisation is therefore dependent on the individuals to a large extent and the reliance on the management system is not as great (Simu, 2006).

Culture is a description of the way people act and socialise; it is a question of symbols and rituals that give the activities meaning and significance. "The culture systems glues the organisation together because it (1) provides members with cognitive maps with which to understand and influence behaviour in the organisation, and (2) it provides a social justification for what people are doing, i.e., providing service to the customer" (Katz & Kahn, 1978). The content in a corporate culture consists of the core values in the company, according to Tichy (1983). He also describes how this content is reflected in different ways in organisations; through special jargon, stories that are told, symbols of success or failure and also through role models. The content of a corporate culture is also reflected through management systems, information systems and resource systems. The culture therefore appears both to be influenced by individuals within the organisation and to influence the behaviour and attitudes of each individual.

2.8 Summary of theoretical framework

This section wraps up the conclusions drawn from each of the theoretical chapters, with the aim of clarifying the theoretical model for analyses used in this thesis, Figure 2.6.

Risk is defined as a combination of the probability and consequence of an event happening; it is thus related to the outcome of something that occurs. Risk is also closely related to the prior stage, uncertainty, which, as a divergence of risk, does not necessarily have its probabilities and consequences defined or assessable. Due to the close relationship between these two concepts, it is not always easy or even necessary to define which one needs to be managed, the management of risk or the management of uncertainty. Both

must be controlled by projects and for this reason they often appear jointly in practice. A risk outbreak is perceived as the realisation of a risk and is the prior cause of an error or failure.

Risk management is the continuous process based on the steps of identification, assessment, response and control (IARC) used to manage the risks. As this is the traditional way, it is also the one most commonly referred to in the construction industry, albeit with different levels of detail depending on the reference. In the risk management process, there are two important steps in which judgements and assessments are especially important; (1) the identification of risks and (2) the assessment of risks. In construction projects, these judgements and assessments of the consequences and probabilities are largely made by individuals rather than being based on historical data and statistics from business operations. Previous research also reveals that the methods and tools applied in construction do not appear to be the key issues for the risk management performance. Instead, it appears that individuals are responsible for managing risks in the way they feel is appropriate (Simu, 2006).

Individual judgements are based on a variety of ingredients which have an impact on the result of a decision. Experience is one of the concepts of heuristics that influence individual judgements and thereby also decision-making in conjunction with risk. Reliance on experience has been found to be of special importance in the identification of risks. In this phase, the ability to take in information and relate it to the current situation determines the outcome of judgements that are made. The level of reliance on experience in the process of risk management is also high in the construction industry. The concept of experience is, however, complex and relying on it with such a high level of dependence could create false security.

Individuals solve problems at three different levels, the skill-based level, rule-based level and knowledge-based level. The difference when it comes to the level at which problem solving takes place is determined by the individual's previous experience and knowledge. Problem solving at the first two levels takes place when sufficient experience and knowledge is available and this process is fairly rapid. Problem solving at the knowledge-based level is more demanding, as it is necessary to search for new information and knowledge.

Personality and traits are other ingredients with an impact on the individual assessments of risk. The personality of individuals is used to describe and explain how a person behaves and acts. Traits, or facets, as they are called, are

also used to enable measurements and compare different individuals and groups of individuals and also to make predictions about future behaviour.

The next step in this theoretical framework of reference is finding the relationships or connections between the individual, i.e. personality traits and education, experience and risk-related behaviour. In this area, it is, however, difficult to find evidence to prove that any relations are relevant and so the suggested traits are derived from what could be supposed and is probably relevant based on the theories. On the basis of this theoretical framework, it is suggested that the individual ability to plan ahead and focus on details has a positive effect on the way in which risks are managed. This suggestion is based on the level of abstraction that is involved in making estimates of future events, probabilities and consequences and this should be favoured by individuals with a good ability to plan ahead and pay attention to detail. On the other hand, a hasty, rapid and ill-considered way of working and making decisions creates the basis for a suggestion that this could have a negative effect on the way risks are managed. These suggestions have implications for both the individuals in relation to the effects of risk management that are going to be measured at site level and the group of site managers as such in comparison with managers from other industries. There is also research suggesting that experience is not such an important ingredient, but that the educational background is more important when it comes to the ability to make valid identifications of risk. Further, there are findings that show that perceived stress has a negative impact on performance and increases the risk of defects, errors and accidents.

In theories about individuals and their impact on risk management, it is not possible to exclude theories about the things that affect the way individuals act and behave, in addition to personality, i.e. the context of organisational impact. The organisational impact includes the corporate culture, which is created by the individuals within an organisation. There are two opposite ways of approaching risk management that are described in this theoretical framework; the reactive and the proactive approach. The organisation that focuses on the retention and transfer of risks uses a reactive approach in its risk management. The organisation that adopts a proactive approach is represented by continuous learning and focuses on preventing and reducing risks. In this theoretical framework, the section on organisational impact mainly serves as an extensive, theoretical context to be used as the foundation for further work and discussions.

Interest in discussing any impact on certain events is marginal unless it is related to the effects that result from some kind of action. Effective risk

management is discussed by researchers and also defined to some extent. However, the theoretical gap appears to be how actually to measure the effect or performance of applied risk management, especially at construction site level. Based on previous research, the following indicators have been found to be applicable for use as measurements of the effects of applied risk management at construction site level:

- Quality performance in terms of *defects* in the delivered product
- Safety in terms of *accidents*
- Predictability in terms of *the relationship between plan and delivery*
- *Profit* on bottom line at project level

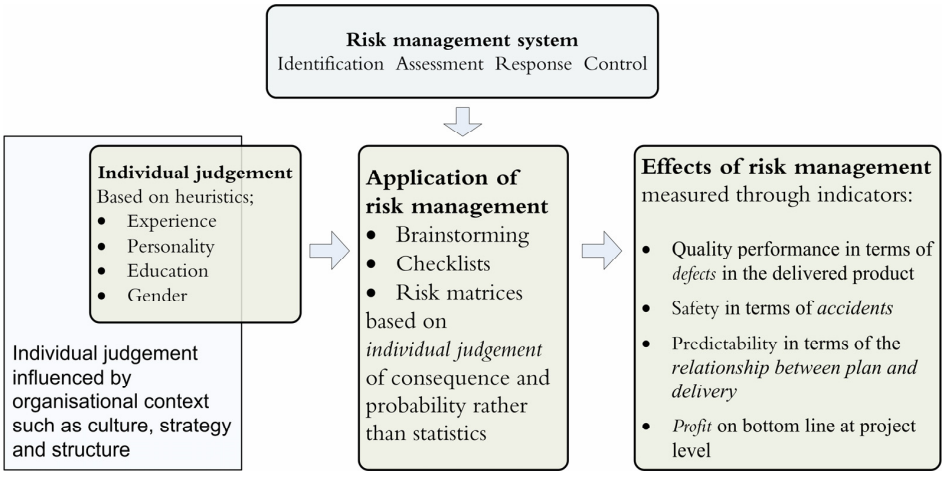


Figure 2.6 Theoretical model for the study.

With this theoretical framework, it is clear that the model for analyses could be viewed as having three parts, see Figure 2.6. The first part, individual judgement, could be regarded as the input to a process. The process in this case is then the application of risk management in construction projects at site level. The third part is consequently the output, the effects achieved by applying risk management.

3 METHOD

Doing research is in some senses the same as making a journey. If you make the scientific journey of your life, you would like as many people as possible to follow you to the end. This chapter is the guideline, the map, to follow my journey to the completion of this thesis.

3.1 Researcher's background

It is not possible to conduct research or analyse data in research without considering and being aware of the biases due to the researcher's background and the subjectivity of the researcher (Merriam, 1998). The knowledge derived in a study like this is most dependent on the researcher's skills and background. As Kuhn (1996) notes, "what a man sees depends both upon what he looks at and also upon what his previous visual-conceptual experience has taught him to see".

My background is an MSc in civil engineering, structural engineering, and so my understanding of research is based on the natural sciences. I started my career in the construction industry in 1995 as a trainee at NCC, one of Sweden's largest construction companies. During my trainee period, I worked as a site foreman and learned about project management from the practical angle. After finishing my trainee period, I started working with and was involved in developing NCC's environmental management system. In 2000, when NCC Civil Engineering Sweden, a business unit within NCC AB, received accreditation for its environmental system according to ISO 14001, I was Chief Environmental Officer. During the years prior to beginning and parallel to this research project, I have worked on quality and environmental

management systems at regional level within NCC Construction Sweden, situated in Luleå.

3.2 Research project

From the very start, this research project has been a study that has "fluctuated" between practitioners in the construction sector and the academic world, see Figure 3.1, with the aim of using knowledge from both worlds. The academic world has been used to find research in the field that has made it possible to define the theoretical framework. Knowledge from academics has also been used to discuss methods and research strategies to enable this research project to progress. The practitioners from industry have been used to define limitations and areas of interesting deliveries from their perspective. Further, the close connections with practitioners have enabled the use of the empirical material needed for this study. The type of empirical data used in this study is sensitive and it is not self-evident that it would have been available for research.

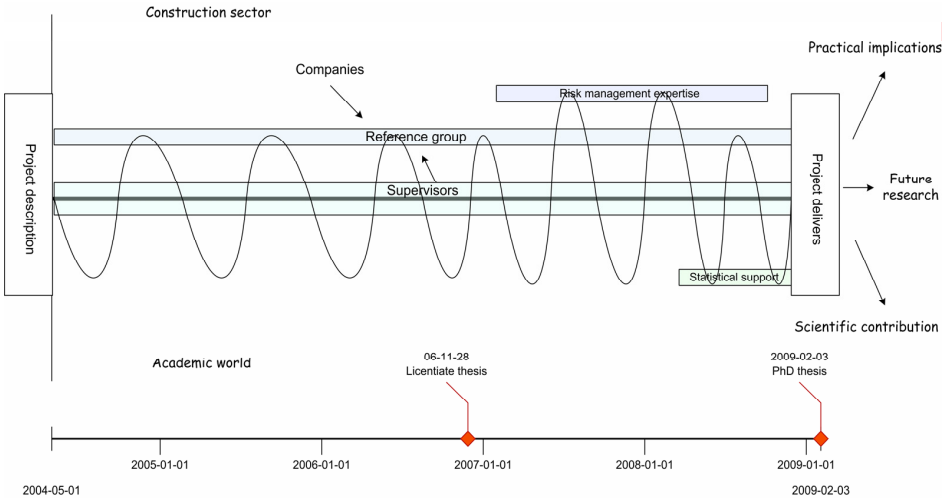


Figure 3.1 The influences on and contributors to this research have been both academics and practitioners.

Throughout the research project, there have been regular meetings with the reference group[3] used in this study. This group consists mainly of practitioners, some of whom have an academic background as researchers, while others do not. However, they all work with or have connections in their work to the management of risks. One of the greatest benefits with this group has been the mix of skills that has given this research study a unique opportunity to discuss the application of identified theories and results in practice. For the research study, these meetings with the reference group have functioned as clearly defined points at which the focus for the research has been defined and clarified. In addition to the influence from the reference group, influence and information have been collected from specialists within risk management with the aim of increasing knowledge about the practical application of risk management.

3.3 Literature search

The literature searches and theory base in this study are derived from two different angles, the field of risk management and the field of behavioural/psychological research. The context is the construction industry, but the literature review is not limited to this area. Key words for searches have been risk perception, risk management in construction, error, uncertainty, project performance, experience, behaviour, decision theory, risk attitude, personality and personality traits. Further, the "snowball method" has been used, meaning that new searches for articles are made using information from the lists of references that are found in relevant articles or books.

Organisational impact and organisational learning have not been included in the primary searches, but they have been shown to be of such importance as a context for individual behaviour that they have been described in the theories.

[3] Ingegerd Simonsson, Hercules, Kalle Nylén, Byrå Idun, PO Larsson-Kråik, Banverket (Swedish Rail Administration), Ulf Håkansson, Skanska, Anders Lundgren LKAB, Lars Bergqvist, Thomas Carlsson, Henrik Szentes, Larisa Pekka, Staffan Hintze, Birgitta Berglund at NCC, and supervisors Jan Borgbrant,, Lennart Apleberger and Håkan Alm at LTU.

Table 3.1 The different theoretical fields that have been used in this thesis

Purpose of theory in the thesis	**Field of theory**
Contextual theoretical framework and definitions	Risk management Construction management
RQ 1	Measures of performance, risk management
RQ 2-4	Personality, behaviour, decision theory, risk perception, human error
Method	Methodology, case study
Discussion	Risk management, construction management, organisational impact, organisational learning

Of these theories, all the theories used for the theoretical framework can be found in Chapter 2. The theories related to the applied method can be found in this chapter.

3.4 Choice of research strategy – research design

With the given research questions, the appropriate research strategy had to be chosen. For this study, the aim was to determine the extent to which the effect of risk management is an individual matter and, to be able to realise this aim, four research questions were formulated. The research questions have been formulated as "what" and "which" questions. Those questions imply that the strategy needs to be flexible, i.e. both quantitative and qualitative data collection might be needed (Robson, 2002), and a survey might therefore be a suitable strategy. Another possible strategy that might have been useful is archival analysis, according to Yin's table (1994, p. 6), for relationships between research questions and different research strategies. A pure archival analysis strategy would not, however, be the best choice for finding answers to research questions searching for results and correlations related to personality facets and organisational issues. For these questions, specially adapted, even tailor-made questions and tests need to be used. To put this study in context, contextual descriptions are necessary. The conclusion from this reasoning is that no single research strategy would suffice and a combination of several is more suitable, Table 3.2.

Table 3.2 The chosen research method for each research question

Research question	**Chosen research method**
RQ 1 In what way can the effects of risk management be measured at construction site level?	Literature searches Semi-structured interviews Archival analysis of historical data
RQ 2 Which background variables, such as age, education and complementary training, are related to the effect of risk management?	Literature searches Archival analysis of historical data
RQ 3 What are the measures in personality traits that are related to the way risk management is performed, i.e. effect of risk management?	Literature searches Test of personality facets through established test
RQ 4 What are the differences between site managers in construction and other managers in terms of personal traits and in what way could they be related to risk management?	Test of personality facets through established test

The chosen methods for each research question make it clear that the most suitable strategy for the thesis is the case study strategy (Yin, 1994), combining different sources of information, quantitative and qualitative data, while most of the data have been collected from a single company, i.e. one case. A detailed presentation of empirical data and methods for analysis can be found in the following sub-sections.

3.5 Case study context – NCC Construction Sweden AB

Within the research project (researcher and supervisors), discussions were held about the collection of data. The conclusion from this discussion was that there would not be any opportunity to obtain extensive data on individuals and economic performance without the close relationships that exist between the researcher and NCC and for this reason this organisation was chosen as the case study.

NCC AB is a construction company with the Nordic region as its home market. NCC AB has approximately 21,000 employees and had a turnover of SEK 58 billion in 2007. This study has been conducted at NCC Construction Sweden AB, which has approximately 7,700 employees and a turnover of SEK 24.9 billion.

NCC as it is today has grown as a company through mergers with other companies. This means that, within the NCC organisation, there are several different company cultures that form the current NCC company culture. Some of the employees still relate their affiliation to former companies that once hired them as employees. In other words, there are units within the NCC organisation that have certain subcultures originating from former company cultures. The latest large merger was with the Swedish construction company Siab and this occurred in 1997. According to M. Hellström[4], those sub-cultures can be one explanation for the differences that can be seen between the regions.

3.5.1 Organisation

In NCC and many other construction companies, the organisational structure is traditionally hierarchical, with the CEO at the top and four to five steps "down" to the site manager and the project organisation described in Figure 1.3.

Apart from the line organisation, there are supporting units with different specialities such as Human Resources, Risk Management Group, Business Control, Organisation and Process Development. These supporting units are present at both CEO and regional level.

[4] Hellström, Mikael, risk manager, Risk Management Group, NCC AB (personal communication, August 2008)

Human Resources (HR) has two focal areas; recruiting new employees and caring for existing employees. When it comes to caring for existing employees, the development of skills is one important part. HR supports managers at different levels with administration and basic data, as well as the development of educational programmes with specific courses. The supporting HR unit also works on environmental issues, such as preventing and keeping track of accidents that occur.

The risk management group (RMG) is a supporting unit working at the highest CEO level, at NCC AB, and focusing primarily on insurance. The specialists working at this level collaborate with the risk managers at the next, national CEO level. In the RMG, there are rarely in-depth follow-ups of specific damage. This is done at the national CEO level. Follow-ups in the RMG focus on setting liabilities and regulating costs.

Business Control keeps track of all the economic transactions in the company. Each project has its own account and these accounts are put together at the separate units for contracting managers throughout the hierarchical organisation. Controllers work at several levels in the organisation, from departmental level in the regions to the highest CEO level.

Organisation and Process Development focuses on the development and implementation of management systems for the core process, i.e. the construction projects. Within this unit, there are specialists working on environmental issues, as well as process improvements.

From having focused on volume to actually securing the future workload, the focus has changed during the last decade both within NCC and in the construction sector as whole to a more clearly defined focus on the actual profit, what is left on the bottom line (KPMG, 2005). As a result, greater interest has focused on risk management. Risk outbreaks, errors, influence on the final result and avoiding this have become an important part of the business concept for many companies. This has also resulted in some projects being turned down due to their having too little predicted profit or overly high risks.

3.5.2 Risk management

Within NCC, the different business units, such as Construction, Roads and Housing, have been accredited with certificates according to ISO 9001, as well as ISO 14001, in order to improve their work on both quality and environmental impact. One key issue in these management systems is

controlling the risks in business and construction projects. At NCC Construction Sweden, there are formal routines and management tools for risk management, in accordance with the aims of these standards. The system is designed to work from the earliest stages of project involvement and follow through the different stages until the project is finished. The routines include the levels in the organisation at which approval decisions need to be taken. The approval of senior managers is required before submitting a tender and before starting construction on site, for example. The risk management system that is applied is the traditional one, with steps such as identification, assessment, response and control. The system consists of routines as well as checklists for the project staff to use, for guidance and memory. For larger projects, certain risk managers are available to help the project organisation complete a more detailed process in which several different disciplines are involved. In the smaller projects, which are the principal focus of this study, the normal project organisation manages the risks, as well as other aspects of the management system itself.

Damage reports are prepared for each case of damage in which the excess reaches the limit of SEK 100,000. These reports are written by specialists from external companies at the request of NCC's risk management group. The focus in these reports is the technical issues, what went wrong and who is responsible. Further inquiries into why something went wrong are not part of this report, regulating the costs. In-house risk managers take things further and conduct inquiries into why things went wrong and they do this in a wider perspective. The risk managers also include issues that need to be dealt with if there are systematic faults or isolated cases.

3.5.3 Corporate culture and management of human resources

The employees at NCC are a fairly homogeneous group; male, with experience of the construction industry, engineering or vocational training in the field of construction, Swedish nationality.

The development of the skills of the staff is the responsibility of each manager with employees. Each individual has a plan for development and education. This plan is checked and revised every year in collaboration with the manager's immediate superior, if everything goes according to plan. Many of the courses give the employees qualifications for certain tasks, regulated by clients, the authorities or by in-house requirements. To some extent, when recruiting managers and specialists in the organisation, personality tests are

used. The results of these tests are used primarily for recruitment but also for the development of skills.

To create a career step for site managers, NCC introduced an opportunity for promotion for site managers called "Certified Site Manager" in 1995. This is a way to recognise and promote the most competent site managers in the company. To be promoted to the position of certified site manager, an analysis is performed. It focuses on three different areas; customer, construction process and colleague. The process to become a certified site manager is initiated by either the site manager or his/her senior manager, the contracting manager, and takes the form of an application to be filled in. There are certain criteria that need to be met regarding factual information and assessments of individual capabilities in the defined areas. The factual information is the completion of education in:

- contract, environmental and work environment law
- economics
- work environment
- construction management, including risk management and general environmental issues
- leadership

Further, the factual requirements relate to financial project performance in the four most recent projects, work experience of at least five years, of which three years were spent as an independent site manager.

The assessment of capabilities takes the form of self-assessments by the site manager, complemented by assessments by superior managers. The application is then processed by the regional management board, which decides whether or not to suggest approval. If the application is approved, a final test of contract and work environment law is made. The final decision about who is going to be a certified site manager is made by a special committee at CEO level.

Systematic learning from mistakes and faults is highly dependent on the individual's desire to improve. At the CEO level of risk management, there are routines for implementing knowledge from experience and avoiding the reported faults that have caused damage in projects. The way this experience is utilised is still largely dependent on the managers between the CEO and the site managers.

3.6 Selection of data

3.6.1 Population and samples

In this study, interest focuses on the individuals at the construction site, the site managers at NCC Construction Sweden AB, also referred to as NCC in the following text. In accordance with the delimitations, the project sizes were limited to SEK 50 M to reflect common projects on the Swedish market and to exclude larger projects with their special features.

During the autumn of 2007, the NCC Human Resources Department decided to conduct a validity study of the personality tests used in the company. The validity test was performed using the PAPI (Personality and Preference Inventory) and OPQ (Occupational Personality Questionnaire) tools and was sent out to all site managers within NCC. The response rate was 34% and 251 of 731 completed the PAPI test. These results from the PAPI test were made available for this study and formed the basis of what became sample 1 in this study. The limitations set for this study reduced the number of site managers to 171 in sample 1. The limitations reduced the number when the actual work situation for those individuals did not match the individuals that were being sought; they were too new in the job, which meant that there was a lack of data for the dependent variables or they were no longer employed by NCC or the project sizes of their projects were larger than SEK50 M.

The population used in this study is 701 site managers and the population participating in the validity study totalled 731. The difference between the groups is due to organisational limitations. The larger group includes affiliated companies within NCC that are excluded in this study.

Since the first sample was given, the researcher had not chosen or interfered with the selection of individuals in the sample, it was important to ensure that the sample was representative of the population of site managers. When studying the first sample from different angles, it was found that it was not sufficiently representative of the population of site mangers. The differences that appeared related to the number of insurance cases reported and the number of site managers who were promoted to certified site managers. Due to this skew, a second random sample was chosen.

The second request to participate by taking part in the PAPI-N test was sent out in the spring of 2008. This sample of site managers consisted of a random selection of 13% (93 individuals) of the population of site managers at NCC (701) at the time of the study. The request to take part in the PAPI test was sent

to people who had not taken part in the test in the autumn of 2007, a total of 65 individuals, while the remainder (25 individuals) had already done the test and were also part of sample 1, Figure 3.2. The response rate for the second sample was 58% (54 of 93 responses in the PAPI) and two reminders were sent out to those people who did not answer. Of these, an additional 10 individuals lacked information about project performance and, as a result, in sample 2, there is complete information about both personality traits and measurements of project performance for 45% (42 individuals).

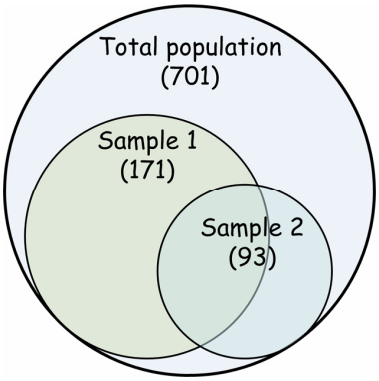


Figure 3.2 The samples in relation to each other and the population of site managers.

3.7 Collection of data

The choice of a case study as a research strategy means that the empirical data are collected in a variety of ways. Apart from the more formal and structured manner in which data are collected, there were also observations, personal communication and studies of internal documentation. These empirical data are used to describe the case study context and the personal communication is also used for specific questions or discussions of specific matters.

3.7.1 Observations

These empirical data form the basis of the general knowledge that the researcher obtains through continuous contact and work with the NCC organisation. There was no specific documentation of these data and the level of reliance on this source is therefore fairly low. In spite of this, it is still important to understand that this has occurred.

3.7.2 Personal communication

There was personal communication with supporting staff on various occasions throughout the research study to define and structure the collection of data and also to verify the findings that were made. Personal communication was also used to acquire a deeper understanding of the background to and condition of the different data that were collected.

3.7.3 Internal documentation

To find out more about the management systems used in the company, the researcher has studied and learned about the management system available in NCC's internal network, Starnet. This has been used primarily as background information to describe the case study context.

3.7.4 Qualitative data – interviews

To determine whether there are parameters in construction companies that are already being used to estimate how risks are managed and also to have a basis for the contextual descriptions, interviews were conducted with a few individuals performing key roles. The respondents were strategically chosen, two CEOs (from Skanska and NCC respectively), two risk managers (from NCC) and one independent risk consultant who had been working closely with construction industries and other industries for several years. The interviews were open ended and semi-structured and lasted for about 1-1½ hours. The transcripts from the interviews were sent to the respondents to ensure the correctness of the answers that had been given.

3.7.5 Quantitative data – internal historical data from NCC

The variables relating to background data such as education, training courses, age and gender were provided by the Human Resources Department. These data were available and therefore also collected for the entire population of site managers.

The variables that were collected as indicators of the effects of risk management were only collected for those site managers included in the samples; i.e. those who had completed the PAPI test. These data were collected from three different units within the NCC organisation; Business Control, Human Resources and Risk Management Group (RMG). The variables relating to economic results were collected with the support of the internal economy system by controllers. The figures showing the number of cases relating to

insurance were taken from an internal database with the aid of NCC risk managers in the RMG. These figures show cases where the cost of damage exceeded the excess of SEK100,000 (~€10 350). The figures for accidents related to working environment and personal safety were collected with the assistance of the unit for human resources and work environment and the staff working on work environment and safety at regional level.

To keep these variables anonymous in relation to each other, the researcher received the data from the different units separately. For the statistical process, all the variables were put together in a summary matrix in which individuals are coded as numbers. Due to the integrity of the individuals in the study, it was not possible for anyone other than the researcher to make connections in the uncoded data.

3.7.6 Quantitative data – personality facets

The PAPI test was conducted on two different occasions, during the autumn of 2007 and the spring of 2008, with the assistance of the Human Resources Department at NCC Construction Sweden AB.

Information necessary for comparisons between the samples in this study and norm groups from other industrial sectors was provided through Cubiks[5] and its established norm groups (*Sweden PAPI-N Norms*, 2006) for the Swedish labour market. The chosen norm group used in this study comprises 186 Swedish managers, where 38.2% were male and 61.8% female. Information about age was available for 33% of the group and the mean age was 39.55 years with a standard deviation of 9.06.

3.7.7 Collection of data in relation to the research questions

The first research question addressed the issue of measuring the effects of risk management. This question consists of three parts.

- Firstly, if there is theoretical support for measuring the effects of risk management through indicators – this is found in the theoretical framework.

[5] Cubiks is the International HR consultancy providing the PAPI test used in this study. Further information is found on www.cubiks.com

- Secondly, if there are indicators that are used in organisations to measure the effects of risk management – this is found in the results of interviews.
- Thirdly, if it is possible statistically to test whether the available data confirm the use of a model for measuring the effects of risk management – this is found in the analyses of collected data.

The second research question deals with background variables, education, age and gender that are supposed to have an impact on risk at individual level. The empirical evidence comes from the population of site managers, as well as from sample 1 and 2, and is related to the performance measurement found in the first research question.

The third research question addresses the issues related to personality and risk. This question has two parts.

- The first part involves finding personality facets that are likely to have an impact on risk management according to theories.
- The second part involves finding empirical data actually to analyse personality facets in relation to project performance.

The empirical data consist of the results of personality tests performed by site managers in the two samples and the performance measurements defined in the first research question.

The fourth research question addresses the image of construction site managers as individuals and the way in which they differ from managers in other industries. The empirical data used here are the results of the personality tests in sample 1 and 2 compared with a norm group of managers supplied by Cubiks, the owner of the personality test that was used.

3.7.8 Quantitative data for answering RQ 1

The third part of the first research question focused on testing the model with available data to find out whether there were significant correlations between the indicators. The indicators that were used were the number of accidents, number of insurance cases, contribution ratio, precision of economic deliveries and audit results. Since correlation analyses are sensitive to outliers in the data, a scatter plot, see Appendix A was made for the indicators to identify any outliers. In the indicator of economic results, CR, two outliers were identified and they were excluded from further analyses. The outliers give a CR of -54%

and 81%, which is probably a result of some mistakes or faults in reporting economic results. This reduced both the sample sizes since these individuals are included in both sample one and sample two. This gives that sample 1 consists of 169 individuals and sample 2 consists of 91 individuals.

Number of accidents (2005-2007)

The number of accidents reported in 2005-2007 related to the site managers who were responsible for the work environment in the project. Both accidents causing absence from work and those merely causing minor injuries were included. This information was collected at regional level by work environment engineers and was then made available to the researcher.

Number of cases for insurance (2005-2007)

The number of cases reported to NCC Risk Management Group (RMG) which involved making use of insurance in 2005-2007 related to the specific site manager. Insurance cases are reported at project sites where site managers are responsible and there is therefore a connection to individuals. Cases of damage are reported where the cost of damage exceeds the excess of SEK100,000 (approximately €10,350).

Contribution ratio (CR), i.e. economic result at project level (2006-2007)

The contribution ratio is one way of measuring the economic result at site level. The measurement used in this study is the mean value of ratios for all the projects for which one site manager was responsible during a period of 24 months, related to each individual site manager.

Precision of project delivery

Project certainty/precision can be measured by looking at the deviations in the economic forecast at the end of a project. This gives an indication of the certainty of the project. There are, however, different kinds of deviation, where some are within the margins that make them acceptable or even good. The deviations sought for this study are those that appear as surprises late in the project lifetime and are not caused by new or innovative technical solutions. The deviations sought are those that result from a lack of control or bad planning. The difficulty and bias in this variable is then to be able to distinguish the different kinds of deviation. The chosen measurement in this study is the difference between the CR at 20% of project progress and the final reported CR and both positive and negative deviations are of interest. Due to

the complexity involved in obtaining these data (time consuming for controllers to collect and the researcher does not have access to the economic report program), the sample was selected from the top and bottom results for the contribution ratio. Of those site managers with a fairly good average contribution rate, four individuals were chosen, while, of those with a poor average contribution rate, five individuals were chosen. This resulted in a total number of nine site managers and 33 projects where detailed information about the monthly forecast ratio is given. This variable does not work as quantitative data in this study due to the small sample sizes (33 projects for this parameter) and the difficulty involved in transforming the information to a set measurement.

Results of internal audits

Internal audits are conducted in the organisation by auditors with the appropriate education and the results are documented on a prescribed form. Further, certain issues must be covered in each audit and one of these issues relates to risk management. For some of the site mangers in the samples, internal audits were conducted during the period 2005-2007. The results of these audits when it came to the ability to manage risks in projects have been assessed and classified by the researcher with the aid of audit reports into three different groups: excellent, average and poor performance. This variable is used as a quantitative measurement and treated as a variable on an ordinal scale, but the information has a strong influence from being qualitative, with two steps of assessment, firstly by the auditors and then by the researcher.

Table 3.3 Available data in samples 1 & 2 and for the population

Available data **(outliers excluded)**	**Number of site managers** **sample 1**	**Number of site managers** **sample 2**	**Total number** **NCC Construction Sweden AB**
Empirical base	169 (856 projects)	91 (376 projects)	701
Reported accidents	41	15	Unknown number of site manager (822 accidents)
Number of site managers with reported insurance cases	0	11	~150 site managers (390 cases)
Number of site managers with information about contribution ratio	169	77	-
Certainty in economic delivery	9 (33 projects)	-	-
Result of internal audits	27	14	Unknown number of site manager (158 audits)
Number of site managers with completed PAPI test	166	52	-

Concluding remarks

Of these variables, the contribution ratio is the dependent variable that is most reliable for all the site managers since it was available for all 169 of site managers in sample 1 and for 40 of 52 site managers who performed the PAPI test in sample 2, (outliers excluded). The result for economic delivery is also the variable that is found to sum up the result for other variables, see also Figure 2.3.

3.7.9 Quantitative data for answering RQ 2

Background variables

The background variables were chosen to make it possible to determine whether education, experience or gender could be associated with the chosen

indicators suggested to be related to the effects of risk management, i.e. research question 2. The choice of background variables was based on the finding that both experience and education have an impact on risk management performance and also that males perceive fewer risks than females.

Educational background
Educational background was categorised into three different groups:

- Vocational training
- Engineers
- Bachelor or master of engineering

Risk management training through NCC internal course 1555
At NCC, there is one specific course/training in risk management that is offered to employees as additional training and education.

Experience
Due to the difficulty involved in measuring experience, **age** is the measurement that is used to represent this.

Certified site manager or not
At NCC, there is a distinction between what are called ordinary site managers and certified site managers. To become a certified site manager, one has to fulfil certain requirements relating to:

- the ability to meet clients' requirements
- the ability to control the construction process
- the ability to manage employees

Certified site managers have also completed internal training in areas such as budget control, construction management and risk management and have achieved good financial results at projects. So being a certified site manager includes both experience and education.

Gender
The aim was initially to be able to use this variable to look for patterns; however, there are too few females in both samples to be able to use the variable at all.

3.7.10 Quantitative data for answering RQ 3 and 4

Personality traits

To be able to distinguish individual influence that is supposed to derive from each individual's personality, a test that is established had to be used. Before the definite choice to use PAPI where data had been made available, the validity and reliability of the test was analysed. Other tests that are available on the commercial market, such as Gordon's personality inventory, GPI, and Hogan's personality inventory, HPI, were also considered. The researcher have personally tested PAPI and GPI and based on this experience the conclusion was that PAPI was easier to use when it came to comparing results and also for statistical analysis.

"Personality and preference inventory" – PAPI

In the early 1960s, Dr M Kostick at the Department of Industrial Psychology at State College, Boston, designed what has now been further developed to become PAPI (Personality and Preference Inventory). The theoretical foundations of PAPI were mostly influenced by the research of Murray (1938) and his "need-press" theory of personality.

PAPI™ is an instrument used for testing personality and preferences by individuals in work situations. The first Swedish version was introduced in the early 1980s and the present version was introduced in 1997 with both the ipsative (PAPI-I) and the normative (PAPI-N) version. The ipsative version, PAPI-I, is designed to be used for personal development, while the normative version, PAPI-N, is meant to be used for comparison and selection. Since the purpose in this study is to search for correlations and make comparisons, the normative version, PAPI-N, has been used and is referred to hereinafter as PAPI.

Scales in PAPI

Different scales in PAPI are defined with the aim of describing the individual traits first and foremost in a working situation. According to the Technical manual retrieved from Cubiks (Lewis & Andersson, 1998) there are ten scales for need and ten scales for roles that are identified in PAPI,

Table 3.4, see also Appendix B. The needs express the preferences of the individual and the roles express the perception of the individual. It is this interaction between the needs and the roles that is the core of PAPI and it is claimed that the results spotlight the interaction between the individual and the situation. Through factor analyses, seven factors at a higher level were obtained, see Table 3.4.

Traits that do not generally have an impact on the work situation are not included in PAPI. One such trait is emotional stability that is included in the Big Five, Table 3.5.

Table 3.4 PAPI scales and factors (Lewis & Andersson, 1998)

Factor	Scale (n)=*need* (r)=*role*	Description
Active Dominance	P Need to control others (n) L Leadership role (r)	Measures the extent to which someone seeks to control others. It is concerned with a desire to influence, persuade and control others and the perception of effective management performance.
Conscientious Persistence	C Organised type (r) H Integrative planner (r) D Attention to detail (r) W Need for rules and supervision (n)	Measures the extent to which an individual tends to approach his/her work in a steady, prescribed way. It is concerned with tidiness, planning, attention to detail and the desire for rules and close supervision in performing the work.
Openness to Experience	R Conceptual thinker (r) Z Need for change (n) N Need to finish a task (n)	Measures the way in which an individual responds to change, diversity and different ways of doing things. It is concerned with creative, conceptual thinking, the desire for change and the challenging of these attributes to produce a positive outcome.
Sociability	X Need to be noticed (n) B Need to belong to groups (n) S Social harmoniser (r) O Need to relate closely to individuals (n)	Measures the extent to which an individual deems it important to have other people around him/her. It is concerned with being noticed, being in a group, harmony and seeking close relationships.
Work Tempo	I Ease in decision making (r) T Work pace (r)	Measures an individual's speed throughout his/her work. It is concerned with task pace and decision making.
Agreeableness	K Need to be forceful (n) E Emotional restraint (r)	Measures the extent to which an individual is pleasant in the workplace. It is concerned with forcefulness and the control of emotional behaviour.
Seeking to Achieve	A Need to achieve (n) F Need to be supportive (n) G Role of the hard worker (r)	Measures the extent to which an individual actively strives for job or career success and advancement. It is concerned with the desire to achieve success, the perception of the importance of hard work and the desire to be seen favourably by the boss and organisation.

Validity of PAPI

Different studies (Cubiks, 2006; Sanz et al., 2008) have been performed to investigate the relationship between PAPI and the Big Five. The findings from these studies show that the scales in PAPI correlate to the Big Five factors.

The implication of this finding is that PAPI is a relevant way to measure personal traits and that the Big Five are a relevant way to describe personality in work-related situations as well. The match between the different factors is not perfect, however, as the Big Five factor describing emotional stability does not have any strong correlations with any of the scales measured in PAPI.

PAPI also appears to cover dimensions of personality expressed by four needs that are not reflected in the Big Five factors (Sanz et al., 2008). These four needs are Need for rules and supervision, Need to be supportive, Need to be forceful and Need for change. If personality traits are compared at factor level, the similarities are listed in Table 3.5, where the three factors, Work Tempo, Active Dominance and Seeking to Achieve, are factors that are measured in PAPI but are not reflected in the Big Five factors (Cubiks, 2006).

Table 3.5 Relationship between PAPI factors and Big Five factors

PAPI factor		**Big Five**
Sociability	Correlates to	**Extraversion**
Agreeableness	Correlates to	**Agreeableness**
Openness to experience	Correlates to	**Intellect/openness to experience**
Conscientious persistence	Correlates to	**Conscientiousness**
	No correlating scales	Emotional stability
Work tempo	No correlating scales	
Active dominance	No correlating scales	
Seeking to achieve	No correlating scales	

There is a common view that the Big Five are a stable way to describe personality according to the trait theory. The close relationship between factors relevant to this study in PAPI and Big Five also reveals that PAPI is valid for

descriptions of personality traits. The implication for this study is that the chosen test, PAPI, complies with the desirable requirements for the purpose of this study.

3.8 Methods for analyses

3.8.1 Transcripts of interviews

The four interviews, with five individuals, were transcribed and analysed according to the similarities and differences in the answers that were given. These empirical results, together with the results of previous research (Simu, 2006), are input for the qualitative results that are used in the first research question and also for the case study description. These results were then compared and analysed in relation to each research question in Chapter 5 and the theoretical framework of reference presented in Chapter 2.

3.8.2 Statistical processing of quantitative data

To analyse these data, Statistical Package for the Social Sciences, (SPSS) version 15 was used as a tool for statistical work.

Research question 1 aims to find a model to measure the effects of risk management and to test whether the indicators in the model could be used as indicators of the effects of risk management. To find an answer to the third part of this research question, the statistical processing of collected data was necessary and a statistical model was created in which the indicators were used to measure the latent variable effects of risk management, see Figure 3.3. During the collection and analyses of the data, it was found that some of the data (Results of audits and Certainty in economic delivery) had a more qualitative character than the other three. The statistical processing of these data therefore had to be separated and treated differently.

The statistical analyses were both linear Pearson's correlations, $p = 0.05$, and non-parametric correlations using Spearman's rho, $p = 0.05$, as some of the variables were found to have other than normal distribution. Further factor analysis and Fisher's exact test was performed.

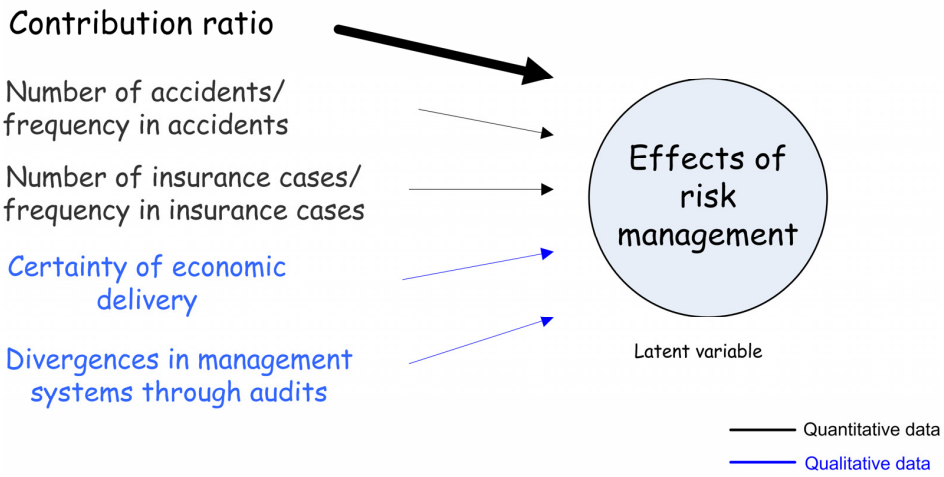


Figure 3.3 Statistical model used to measure effects of risk management.

Research question 2 aims to determine whether it is likely that experience and education are related to the effects of risk management. The methods used for analysing the data were comparative analyses using the Mann-Whitney test, the t-test, Fisher's exakt test, ANOVA and correlation analyses using both the linear Pearson correlation, p=0.05, assuming normal distribution, and Spearman's rho, p=0.05, where normal distribution is not necessary.

Research question 3 aims to determine whether there are certain personality traits that are related to the effects of risk management. Based on the findings in the theoretical framework that planning ahead and focus on details might have a positive influence, while a high working tempo and quick decisions might have a negative influence on the performance in risk management, the following hypotheses were tested.

- High scores on the PAPI scales H (integrative planner) and D (attention to detail) are correlated to good economic results and thereby to effective risk management.
- High scores on the PAPI scales I (ease in decision making) and T (work pace) are correlated to poor economic results and thereby to less effective risk management.

The methods used for analysing these data were the linear Pearson correlation, p=0.05, for the variables with a normal distribution, i.e. all the personality

scales and the contribution ratio. For the variables that do not have a normal distribution, accidents, insurance cases and audits, correlation analysis using Spearman's rho, p=0.05 was used.

Further, regression analyses were conducted to search for answers to the third research question. Although three variables were used as dependent variables, the regression analyses were only conducted with the variable for economic result, CR, contribution ratio. There are too many missing values in relation to the size of the samples in the other dependent variables to be able to perform any meaningful regression analyses. A general rule suggests that there should be about five observations for each independent variable that is added (Hair et al., 1998), which means that the regression analysis for sample 2 in this study is neither is relevant. The statistical power and generalisability of the results would be too weak to be of any use. Regression analyses were performed using both the enter method and the stepwise method in the joint sample. The dependent variable is total CR, i.e. contribution ratio at project level. The independent variables or predictors are the scale parameters in PAPI. The requirements set for the variables used in regression analyses are that they have a normal distribution and that they do not have a strong correlation with the predictor (independent) variables. In this sample, the parameters, CR and the PAPI scales, have an individual normal distribution. A test for collinearity was made to ensure that the independent variables were sufficiently independent. Collinearity among the independent variables was also tested and the result indicates that the collinearity is not high, since the tolerance is close to 1, and the VIF (Variance inflation factor VIF= 1/tolerance) is therefore low (Hair et al., 1998), see also Appendix C.

Research question 4 aims to determine whether there are significant differences between site managers from the construction sector compared with mangers from other industrial sectors and especially in terms of traits (PAPI scales) that could be related to risk as described in the theoretical framework.

Cohen's *d* (Cohen, 1992) has been used to calculate the effect sizes in the differences between the means in the PAPI scales and the means for the selected norm groups. *d* is defined as the difference between means divided by the standard deviation for those means.

$$d = \frac{meanA - meanB}{\sigma}$$

Different researchers offer different advice when it comes to interpreting the resultant effect size, but the most frequently accepted opinion is that of Cohen (1992), where 0.2 is indicative of a small effect size, 0.5 a medium effect size and 0.8 a large effect size.

4 RESULTS OF DATA COLLECTION

The results in this thesis focus on the application of risk management and the impact of individuals on the effects that are produced. This chapter addresses the research questions in sequential order and the analyses are made in relation to each of them.

4.1 Results addressing the first research question

RQ 1 In what way can the effects of risk management be measured at construction site level?

The first research question is divided into three parts. The first part was dealt with in the theoretical framework and resulted in indicators that were found to be related to the effects of risk management.

The indicators are:

- *Quality performance in terms of defects in the delivered product*
- *Safety in terms of accidents*
- *Predictability in terms of the relationship between plan and delivery*
- *Profit on bottom line at project level*

The second part aimed to determine whether there are ways in which the effects of risk management in construction companies are currently followed up and also to make a comparison with the indicators found in the theoretical framework.

The third part involved testing the model for measuring the effects of risk management using authentic data available at NCC.

4.1.1 Results of interviews

The purpose of the interviews was to find answers to the second part of the first research question, to find the results that are expected from using risk management systems at CEO level at two large Swedish construction companies. The interviews also helped to find answers to whether and, if so, in which way the effects of risk management are measured and to identify the obstacles and drivers for applying risk management. This section summarises the contents of these interviews, sorted into headings from the questions that were asked and discussed.

According to the interviewees, risk is a variety of purely negative events, affecting the company's result.

Expectations and indicators of effects of risk management

The CEOs of the two construction companies share common expectations in terms of the risk management work in their organisations. They want predictability and certainty in the results delivered by the organisation. Their aim is to have high predictability and high profitability and they expect risk management to be one way of ensuring this. Profitability relates to both the short term and the long term. According to the two risk managers who were interviewed, the expectations of risk management are similar; they talk about profitable production and the avoidance of problems or "black holes". In order to follow up and see whether the organisation delivers, interest focuses on economic deliveries but also on internal audits, statistics relating to insurance cases and accidents and certainty in the forecast of costs. To summarise, it would be true to say that there is no set method for measuring the effects of risk management. There are instead different indicators, but they are not used in a systematic manner. The indicators used in the company which were also made available for this study are:

- *Contribution ratio*
- *Number of accidents*
- *Number of insurance cases*
- *Results of internal audits*
- *Certainty in economic delivery*

4.1.2 Summary and analysis of the first and second parts of RQ 1

According to the theories, there are four indicators that are related to the effects of risk management. They are derived from the KPI indicators first suggested in the *Egan Report, Rethinking Construction* (Egan, 1998). In practice, according to the interviews, five indicators are used to determine whether or not risk management produces effects. A comparison between the indicators showed large similarities, Table 4.1.

Table 4.1 Comparison between indicators for measuring effects of risk management

Indicators found in theories	**Indicators used in practice**	**Comparison between indicators**
Profit	Contribution ratio	Both indicators focus on economic results and are identical.
Safety in terms of accidents	Number of accidents	Both indicators focus on safety and are identical.
Quality performance in terms of defects in delivered product	Number of insurance cases	There is a slight difference in measurements. Insurance cases only include those defects that could be related to insurance and those where the excess limit is reached. Defects that are minor in terms of economic loss are not measured systematically in practice.
	Results of internal audits	This indicator focuses on the quality of the process and could therefore be related to the quality performance indicator found in theories.
Predictability in terms of relationship between plan and delivery	Certainty in economic delivery	Both indicators focus on certainty in deliveries. This indicator includes both internal certainty and certainty that the client will receive what can be expected.

Despite the difficulties involved in disaggregating the effects of risk management from those of more general project management (Bresnen & Marshall, 2001), it has been found that there are indicators that are used in practice to evaluate the effects of risk management. In practice, the indicators found in theories that focus on defects do not focus on defects in the final product, as discussed in theories (Love & Josephson, 2004). Instead, the focus

in practice appears to be related to defects where damage is involved which in turn leads to cases of insurance. The defects that are found to be related to the product, according to Josephson & Hammarlund (1999), and cause increased costs at project sites are not measured systematically, according to the respondents in the interviews. On the other hand, quality performance in the process, through audits, is measured in practice but is not discussed as an indicator in theories.

There are two different approaches to risk management described in the theoretical framework, proactive and reactive, see also Figure 2.5. According to the interviews the driver for risk management is avoidance of negative events. The risks focused on were most often related to project performance and could be regarded as tactical risks rather than strategic risks which would indicate a reactive approach according to Smallman (1996).

4.1.3 Results of archival analyses of available data

In order to test the model for the effects of risk management, authentic data was used. Data for the indicators are collected and analysed through correlation analysis and factor analysis with the aim of establishing whether or not the model is valid.

The correlation analyses performed, see Appendix D, did not reveal any correlations that were significant and it is therefore not possible to confirm the latent variable for "Effect of risk management", i.e. validate the model, with this empirical evidence. Further, a factor analysis with principal components is performed to determine whether the variables load on one and the same factor, which they did not, see Appendix D. In sample 2, there were too little input for it was therefore not possible to perform any factor analyses. For sample 1 and for the joint sample, there were enough data, but the amount of explanation is scattered and does not therefore support the model of a latent variable for "Effects of risk management".

The results that support the model with indicators for measuring the effects of risk management are shown in the descriptive statistics, Table 4.2, when comparing the two samples. Due to the differences revealed comparative analysis was made.

During the same period, the number of insurance cases is equal to zero in the larger sample 1 and, in sample 2, the comparative number is 11. In the follow-up of insurance cases, there are about 150 site managers with reported

insurance cases[6], which is about 21% of the total population. Sample 1 consists of 29% of the total population and, if sample 1 had been representative in terms of insurance cases, more insurance cases should have been reported in that group. Assuming a linear correlation between the number of cases and the number of projects, approximately 29 insurance cases should have been reported in sample 1. Further, there is a difference between the samples in terms of contribution ratio, CR, where sample 1 shows a higher CR than sample 2.

The descriptive statistics from the two samples show that there are differences in economic results (CR); the mean result in sample 1 is more than one percentage point higher than in sample 2, but a one-way ANOVA revealed that this is not a significant difference ($F_{1,245}=1.59$, $p=0.209$).

Moreover, the descriptive statistics show that no insurance cases were reported for the site managers in sample 1. The difference between the samples regarding insurance cases is found to be significant (two-tailed Fisher exact $p=0.00$), see also Appendix E.

These results indicate that a smaller number of insurance cases are related to higher profit which support the model of indicators found.

[6] M. Hellström, Risk Management Group, NCC AB (personal communication, April 2008)

Table 4.2 Descriptive statistics of dependent variables for the two samples in the study

Dependent variables **Indicators**	**Sample 1** **169 site managers** **934 projects**	**Sample 2** **91 site managers** **385 projects**	**Joint sample** **239 site managers** **1 122 projects**
CR (mean)	8,3%	7,2%	7,8%
Number of accidents	41	15	51
Number of insurance cases	0	11	11
Number of audits (regardless of the result)	27	14	39

Certainty in economic delivery

There are data that could be used to illustrate how certain the economic deliveries have been in a project. These data are a comparison between the forecast budget and the final result when the project is finished. The change in forecast throughout the project lifetime shows how certain the project organisation has been in its economic deliveries and also how good it has been at controlling the project in relation to a certain economic goal.

When the company (NCC) uses the information revealed by the follow-ups of forecasts, an attempt is made to find the dips and black holes. The aim is to determine whether the project is going according to plan or is starting to deviate in any direction. Moreover, large deviations in forecast are used as indicators that things have gone wrong in some way. The number and total economic volume of dips in the forecast are measured and followed up by management groups throughout the organisation and the aim is to produce a constant decrease in these figures[7].

[7] S Pettersson, Manager of Organisation and Process Development, NCC Construction Sweden AB (personal communication, Sept 2008)

In this study, 33 projects from a total of nine individuals who have had poor average results and a fairly good average result have been thoroughly analysed, with the emphasis on the forecast throughout the projects. This reveals that, of these 33 projects, 15 had a result that deviated more than five percentage points up or down from the set budget. Of these 15 projects, seven produced a lower result than the set budget and eight produced a better result than the set budget. The distribution of projects that deviate is scattered for the same individuals. So there is no individual who consistently delivers what the budget specifies. They either fluctuate and deliver better results in per cent than the budgets specify or they fluctuate between both better and poorer results than the budget, see Appendix F. These results reveal that the certainty in economic delivery at project level is somewhat uncertain, but they do not show why this happens. They only reveal the symptoms. A deviation from budget could have many causes and so these symptoms have to be regarded concurrently with other results in order to be useful for any conclusions in management groups.

These results reveal that even those site managers that deliver economic results do not do this with high certainty. As certainty is vital for CEOs and the projects have a major impact on the results at CEO level, the cause of the fluctuations ought to be interesting.

4.1.4 Summary and analysis of the third part of RQ 1 – model for measuring effects of risk management

The third part of the first research question aims to test the model using authentic data from NCC. It is, however, difficult to find any significant correlation between the indicators from the available data. The relationship originates from the comparison between groups where there is a connection between a slightly higher economic result (CR) and no insurance cases reported for sample 1 compared with sample 2. The conclusion from these results is therefore that the suggested model for using these indicators to measure the latent variable effects of risk management could be neither fully rejected nor fully supported.

Due to the complexity inherent in the data for certainty in deliveries and the difficulty involved in transforming the information into a useful indicator, this information has not been used in the statistical analysis. What could be found from these results, however, is that the certainty of delivery is not related to the mean result, the contribution ratio. This means that the predictability could not be regarded as having a strong relationship with the result, which is differing to findings in the theories that argue that risk management is a way of reducing

uncertainty and thereby increasing profit (Chapman & Ward, 2004; Smith et al., 2006).

According to Hillson and Murray-Webster (2005), risk management is a way of being able to deliver in accordance with the set objectives in organisations or projects. In organisations and projects, common objectives relate to economy, i.e. cost/profit, safety and functional deliveries and so there ought to be a relationship between them, as suggested in the model. It is then interesting to ask why no strong correlations were found. The answers to this probably come from different sources; quality of data collection, too small sample sizes and also the fact that there might not be a strong correlation between the variables. The difficulty involved in distinguishing risk management from general project management could also be a reason for the weak correlations.

4.2 Results addressing the second research question

RQ 2 Which background variables, such as age, education and complementary training, are related to the effect of risk management?

The second research question aims to determine the extent of the impact of age, i.e. possibly experience, and education in different forms on the effects of risk management. The results used for these research questions are derived from both qualitative and quantitative data.

Comparisons between the samples and the total population show that there are no differences in the distribution of age between the groups. They all show a similar pattern, see Appendix G. However, when comparing the number of certified site managers in the two samples and in the population, differences are revealed, see Figure 4.1. In sample 1, the number of certified site managers is significantly higher than in sample 2 and the total population. The mean age of the certified site managers in the total population is 54, while the corresponding figure for the site managers is 46. If experience is reduced and measured solely through age, certified site managers are generally more experienced.

To determine whether the difference in the number of certified site managers is significant between sample 1 and the total population, a non-parametric test, Mann-Whitney, was performed and it revealed that there is a significant difference between the groups ($U=52043$, $N_1=701$, $N_2=168$, two-tailed $p=0.007$).

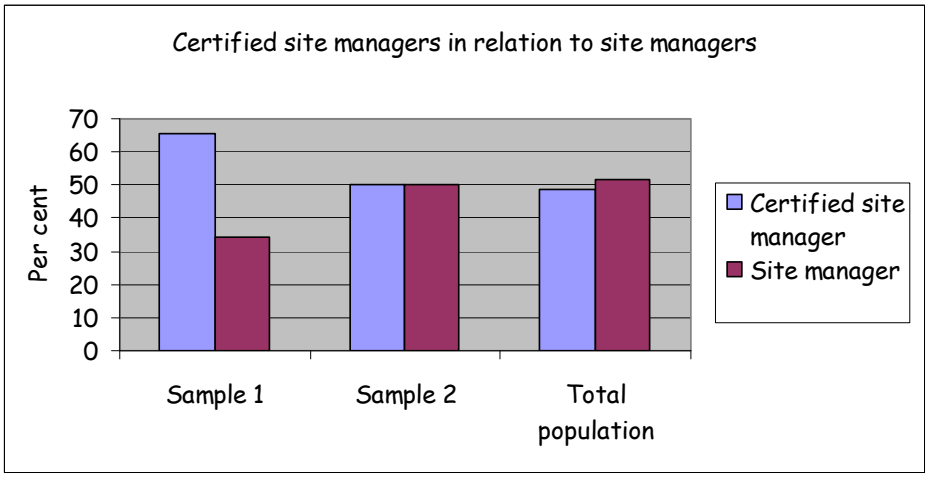


Figure 4.1 Number of respondents that have been promoted to certified site managers in relation to those that have not.

Moreover, when comparing the number of site managers that have completed an in-house risk management course, differences are revealed between sample 1, where a larger number of site managers have completed the course, and sample 2 and the total population, see Figure 4.2

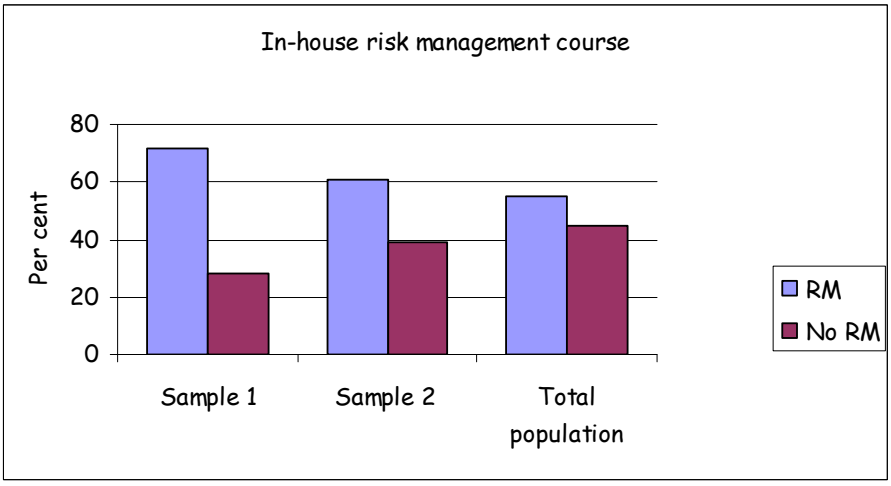


Figure 4.2 Number of site managers that have attended an in-house risk management course.

The basic education received prior to employment at NCC is another background variable that is interesting to examine. The results show that the most common background education is technical college engineers and that the smallest number of site managers with vocational training is found in the first sample. The number of engineers at graduate level, i.e. bachelor or master, is fairly even, just above 10%, except when considering the population split between certified site managers and those who are not, see Figure 4.3. It is then revealed that, in the group of site managers, there are more than 20% with higher education. The probable reason for this is that those with higher education do not stay in production long enough to be promoted to certified site managers compared with those with a technical college engineering education. Most engineers that are employed at construction companies start their career at the production site and work as site managers for some years. This could also explain the lower mean age among the group of site managers.

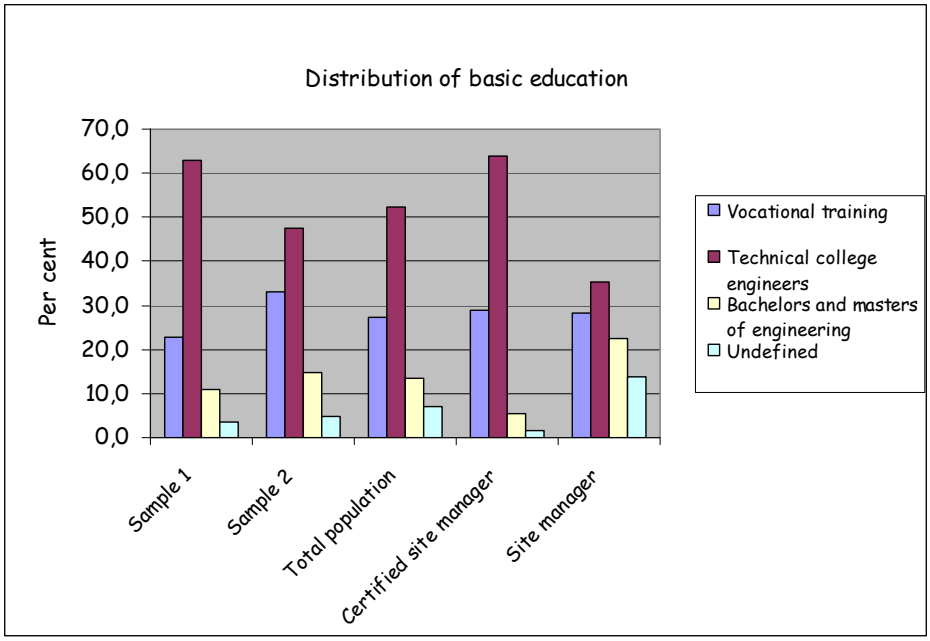


Figure 4.3 Distribution of basic education for the two samples and for the total population of site managers and for the population split into certified site managers and site managers.

To determine whether there are any differences between the economic results, CR, in relation to the basic education individuals have, a one-way ANOVA test

was performed. It shows that there are no significant differences between the groups ($F_{3,214}$ =.419 p=0.740), i.e. between economic result in relation to the different levels of education, see Appendix H.

To determine whether there is any difference in CR in relation to being a certified site manager or not, a t-test was first performed in sample 1. This test did not reveal any statistical significance in terms of difference (t=1,170, *df*=166, two-tailed p=0.244). Furthermore, a test was conducted on the joint sample to see whether there was any difference between site managers who are and are not certified. This test did not reveal any significant differences (t=1,551, *df*=213, two-tailed p=0.122), see Appendix H.

The difference between the groups of certified site managers and those who are not certified regarding insurance cases is not found to be significant (two-tailed Fisher exact p=0.108), Appendix H.

4.2.1 Summary and analysis of the second research question

The second research question addressed the issue of whether background variables (age, basic education, complementary risk management course and being promoted to certified site manager) had any impact on the effect of risk management. Further comparison between the samples and the total population reveals that those in sample 1 perform better than sample 2 in that they report fewer insurance cases and produce a slightly better economic result. Also it was found that certified site managers did not perform significantly better than those not being promoted. The differences between the samples regarding insurance cases and slightly better economic results were therefore not explained by the higher amount of certified site managers in sample 1.

These results show that knowledge and experience do not have a significant correlation to risk management performance. Certified site managers have a higher mean age, more education and, according to these results, they also put in slightly better performance regarding economic results and report fewer insurance cases, however not with statistical significance.

One implication of this could be that the certified site managers are better at adjusting their work and the way they work at the different performance levels (skill based, rule based and knowledge based) suggested by Reason (1990). This is, however, in part a contradictory result to that suggested by Maytorena et al. (2007), who found that experience as such is not the key to better performance in identifying risks. They also found that complementary

education and training could improve the performance in identifying risks and the results of this study could be seen as supporting this finding. Experience as such is, however, difficult to define and the correlations found here are reduced to the age of the participants. Experience is also only valuable if one is able to learn from it (Brehmer, 1980), which means that, even if a correlation is found between age and the people who are certified site managers, this does not necessarily mean that they have learnt from the experience. To become a certified site manager, a person has to be able to show positive economic results that are lasting and complete various in-house courses on various topics and these requirements may also be the cause of the differences in performance found in this study.

According to (SOU, 2002), only about 8% of all employees have a higher education (graduate level, bachelor or master) in construction compared with 28% in the total labour market. For the site managers in this study, the educational level is slightly higher for all three groups; sample 1, sample 2 and the total population. Once again referring to the results from Maytorena et al. (2007), this could mean that, since the educational level is slightly higher in the results of this study (13.5% for the total population), the risk identification performance (RIP) might be higher for this group than in the construction industry in general.

4.3 Results addressing the third research question

RQ 3 What are the measures in personality traits that are related to the way risk management is performed, i.e. effect of risk management?

Having identified probable personality traits and PAPI scales that ought to have an impact on risk management performance in the theoretical chapter, the results of the statistical analysis are presented in this section.

4.3.1 Results of the analysis of quantitative data

The third research question attempts to determine whether there are personality facets that could have an influence on the effect of risk management. The personality facets are the scales from PAPI and the dependent variables are those identified as indicators of the latent variable effects of risk management. The assumption of normal distribution is valid for the CR variable and for the PAPI variables and, for these variables, linear Pearson correlation analyses were performed. For the other variables measuring performance, the

assumption of normal distribution is not valid and non-parametric correlation analyses were therefore made with Spearman's rho.

Table 4.3 Summary of correlations between dependent variables and PAPI scales in samples 1 and 2, p= 0.05

	Pearson's correlation sample 1	**Pearson's correlation sample 2**	**Spearman's rho sample 1**	**Spearman's rho sample 2**
CR (contribution ratio)	Z Need for change (r=.171, *df*=164) S Social harmoniser (r=.168, *df*=164) K Need to be forceful (r=.192, *df*=164)	No correlation found	Not applicable	Not applicable
Insurance cases	Not applicable	Not applicable	No correlation found	No correlation found
Accidents	Not applicable	Not applicable	No correlation found	No correlation found
Audits	Not applicable	Not applicable	G Hard worker (rho=-.467, *df*=164)	No correlation found

The correlation analyses reveal that the most correlations are found with the dependent variable for economic results, CR, and those correlations were only found in the first sample, see also Appendix I. The variances explained by these correlations are low; for example, only 3,7% (r^2) of the variance could be explained by the scale K (need to be forceful).

Further analyses conducted with the aim of finding correlations between the dependent variables and the personality facets (PAPI scales) are multiple regression analyses.

Regression analyses were performed on the joint sample in three steps.

- First, with the personality facets (PAPI scales H and D) that are suggested in the hypotheses as having an impact on the results of risk management and thereby also on the economic results
- Second, with all the personality facets (PAPI scales) to ascertain whether there are others parameters that could explain a regression model
- Third, with all the personality facets (PAPI scales) but using a "stepwise" regression method instead of using "enter" as a method in the analyses

The results of the first regression analyses, entering PAPI scales H and D, show that 0% of the variance is explained, ($F_{2,182}$=0.38, p=0.963, r= 0.02, r^2= 0.000), Appendix C. In other words, it is not possible to explain the economic results as being dependent on the personality scales in PAPI.

The results of the second regression analyses, entering PAPI scales I and T, show that 1.1% of the variance is explained ($F_{2,182}$=1.048, p=0.353, r= 0.107, r^2 = 0.011). In other words, it is not possible to explain the economic results as being dependent on the personality scales in PAPI.

The results of the third stepwise regression analyses, with all the PAPI scales, only include the personality facet, K (need to be forceful), in the model, with an explanation of variance of 3.7% (r^2) ($F_{1,183}$=6.936, p=0.009, r= 0.191, r^2= 0.037). This shows that there is a low level of explanation for the regression model in this analysis as well.

None of these three regression models is stable or robust enough to use as a model for the way CR varies due the PAPI scales, see also Appendix C.

Comparison of personality traits between samples and the certified/non-certified site managers

With the knowledge from the prior research questions that reveals differences between the samples and the background information about who is or is not a certified site manager, analyses were performed to see whether there are differences in personality scales. The joint sample has been split between those people who are or are not certified site managers and are compared in a spider diagram, Figure 4.4 to illustrate how the groups differ. Maximum value is 42 and minimum is 6 for each scale. It was found that those in sample 1 have a

positive effect on the indicator *number of insurance cases* and also, to a smaller extent, on *CR*. It was also found that there were more certified site managers in sample 1 than in sample 2. To find out if those differences could be related to the personality traits comparisons of the PAPI scales were done.

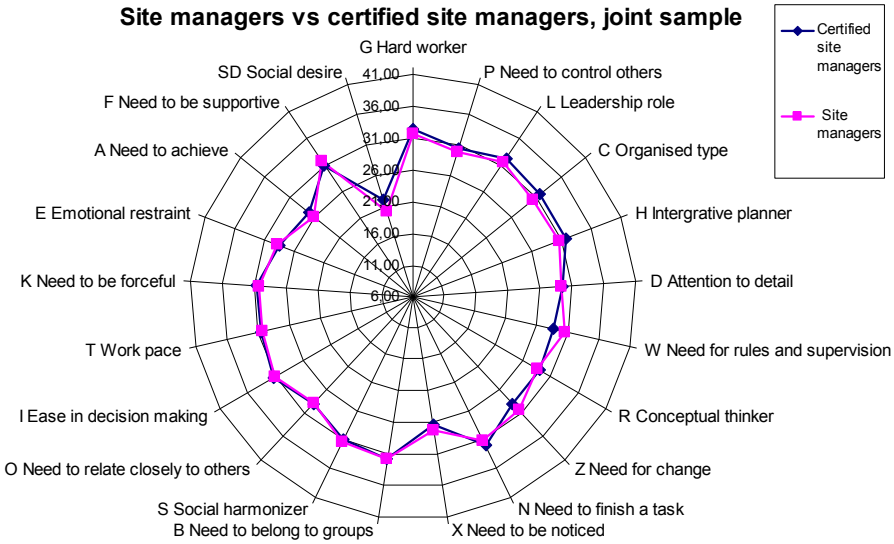


Figure 4.4 Comparison between PAPI scales for certified site managers and site managers in joint sample.

There are seven scales in which differences are revealed between the people who are or are not certified site managers. The scales that have an effect size of d >0.2 are C (organised type), H (integrative planner), W (need for rules and supervision), Z (need for change), F (need to be supportive) and SD (social desire). The powers in the differences should be regarded as low to medium, see Table 4.4. This means that there are hardly any differences between those being certified site managers and those who are not.

Comparing Figure 4.4 and Figure 4.5 it is found that the differences between the samples are even smaller than between the certified site managers and not certified site managers.

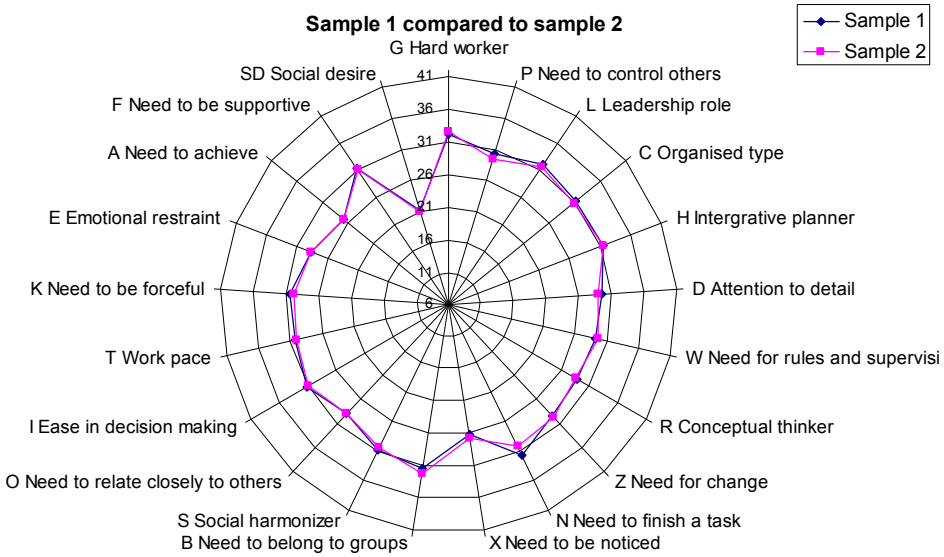


Figure 4.5 Comparison between PAPI scales for sample 1 and sample 2

The differences in ability to deliver good economic results with less insurance cases could therefore not be related to those personality traits.

Table 4.4 Effect size calculations for comparison of samples and between site managers and certified site managers, joint sample 1 & 2

Compared groups / PAPI Scale	Certified site managers		Site managers		Effect Size d
	Mean	Std	Mean	Std	
G Hard worker	32,37	4,64	31,65	4,65	0,154
P Need to control others	30,35	4,13	29,75	4,12	0,147
L Leadership role	32,14	4,13	31,37	3,84	0,192
C Organised type	31,65	4,43	30,13	5,11	**0,321**
H Integrative planner	31,65	4,13	30,56	4,30	**0,258**
D Attention to detail	29,50	4,99	29,31	4,85	0,039
W Need for rules and supervision	28,62	4,51	30,51	4,39	**-0,425**
R Conceptual thinker	28,93	3,42	28,55	3,27	0,113
Z Need for change	28,94	4,41	30,38	3,92	**-0,344**
N Need to finish a task	31,98	5,26	31,12	6,09	0,154
X Need to be noticed	26,17	5,84	27,20	5,18	-0,185
B Need to belong to groups	31,76	4,98	31,87	4,88	-0,021
S Social harmoniser	30,85	3,61	31,19	4,30	-0,086
O Need to relate closely to others	28,90	3,44	28,82	4,16	0,021
I Ease in decision making	31,28	5,48	31,15	4,76	0,025
T Work pace	30,57	4,43	30,13	3,76	0,107
K Need to be forceful	30,53	4,56	30,26	4,56	0,058
E Emotional restraint	28,45	4,42	28,68	5,25	-0,047
A Need to achieve	26,99	4,88	26,04	4,82	0,197
F Need to be supportive	30,85	4,35	31,69	3,69	**-0,208**
SD Social desire	22,03	5,41	19,89	5,82	**0,382**

4.3.2 Summary and analysis of the third research question

The third research question addressed the issue of correlation between personality facets and the effects of risk management. Due to the available data, many of the statistical analyses were performed with economic results (CR) as the dependent variable representing the latent variable of effect of risk management. Two hypotheses had been put forward to help answer the third research question and they were as follows.

The first hypothesis addressing the third research question suggested that there would be a correlation between the PAPI scales H (integrative planner) and D (attention to detail) and high economic results. It received no support from the correlation analysis. However, the group of certified site managers obtains slightly higher values on scale H (integrative planner) than the rest of the site managers, indicating that they are probably keener on planning ahead.

The second hypothesis addressing the third research question suggested that there would be a correlation between the PAPI scales I (ease in decision making) and T (work pace) and poor economic results. This was not found in the results and this hypothesis was therefore also rejected.

There appears to be some support in the theories for the hypothesis that personality traits I (ease in decision making) and T (work pace) ought to be related to risk management performance (Butler, 1995; Hollnagel, 2004) and it was therefore expected that these scales would be found to correlate to performance as measured in this study. According to Appendix B and Cubik's manual (Lewis & Andersson, 1998) for the descriptions of the scales, a high value on the T scale (work pace) could indicate "someone who responds well to external demands and has a strong sense of urgency" or a person who "may become error prone".

The unbiased analyses that were performed with no prior hypothesis reveal that the following PAPI scales are correlated to CR, albeit with a low degree of explanation:

- Z (need for change)
- S (social harmoniser)
- K (need to be forceful)

Need for change (scale Z) only correlates to contribution ratio in the first sample. This is a positive correlation, indicating that a greater need for change

correlates to a better economic performance. According to the descriptions of scales found in Appendix B and in Cubik's manual (Lewis & Andersson, 1998), high values on this Z scale could indicate a person that is easily bored with routine work and/or a person that is keen on trying new things. When comparing certified site managers with site managers, it is found that those with the smaller need for change are the certified site managers, see Table 4.4 Comparing the two samples in this respect there are no differences, see Figure 4.5.

In addition, there is a positive correlation between the contribution ratio and the PAPI scale S (social harmoniser), indicating that those individuals who see themselves as sociable and keen on a harmonious workplace have a higher contribution ratio. This could indicate that it is important for the project to have a project team working in a positive atmosphere.

The last scale to correlate to contribution ratio is K (need to be forceful). According to Cubik's manual (Lewis & Andersson, 1998), this scale measures the extent to which individuals are prepared to "fight" for what they want. High values indicate a person that can be powerful in negotiations and does not hesitate to face conflict. The role of site manager also includes co-operation with other stakeholders within the same project, such as sub-contractors, consultants and suppliers. Within any business co-operation, there are always negotiations to some degree and these results could indicate that the people who are good at negotiating and therefore obtain a high value on the scale K (need to be forceful) also succeed when it comes to the ability to obtain a better economic result. This does not, however, mean that they succeed with risk management, even if this study suggests that there is a strong relationship between economic result and risk management performance.

In the first sample, a correlation was found between the results of audits and the PAPI scale G (role of the hard worker). The correlation shows that those individuals with better results in audits are also motivated by hard work.

When it comes to the differences between the people who are promoted to site managers and those who are not, there are differences with medium power on two scales and differences with low to medium power on five scales. The two scales with larger differences are W (need for rules and supervision) and Z (need for change), where the certified site managers obtain lower values than the other site managers. This could be interpreted as meaning that the certified site managers have less need for guidance and are more conservative in their approach. It could also be interpreted as meaning that they might create their

own rules if the company polices does not suit their purposes and that they are content with remaining at the same work for long periods of time.

Other scales where differences are found are C (organised type) and H (integrative planner) where the certified site managers obtain higher scores than the others, with a difference with low power. One interpretation of this would be that the certified site managers are better at planning ahead and organising their work and are keen on being successful in their job performance.

On the other scale, F (need to be supportive), the certified site managers obtain lower scores than the others, with a difference that has low power. This indicates that the certified site managers manage on their own without praise from their superiors and they might lack commitment to the rest of the organisation. This scale, in combination with the lower scores on scale W (need for rules and supervision), emphasises the fact that certified site managers are fairly independent individuals.

4.4 Results addressing the fourth research question

RQ 4 What are the differences between site managers in construction and other managers in terms of personal traits and in what way could they be related to risk management?

The fourth research question focuses on determining whether site managers in construction differ from managers in other industrial sectors. If construction site managers are shown to differ on these scales, this could indicate more risk-prone behaviour and then also explain some of the problems with errors and a lack of quality that apparently exist. The personality traits represented by the PAPI scales which, according to the descriptions of the scales found in Appendix B (Lewis & Andersson, 1998), could be related to risk are the scales I (ease in decision making) and T (work pace), as well as H (integrative planner) and D (attention to details), and they are therefore of special interest.

The comparisons made in this study focus on managers in construction represented by the joint sample 1 & 2 and Cubik's norm group for managers (Norm 10) from other sectors in the Swedish labour market.

The joint sample and norm table 10, general managers, are compared in a spider diagram, Figure 4.6, to illustrate how the groups differ. Maximum value is 42 and minimum is 6 for each scale.

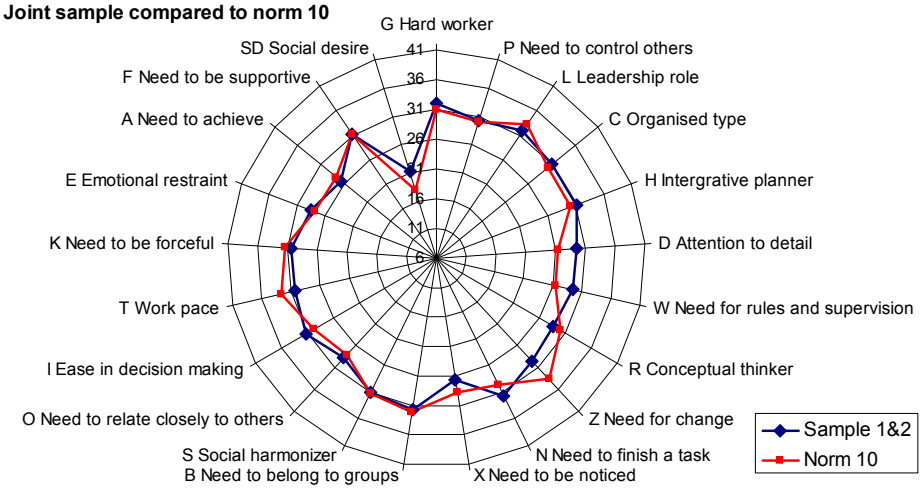


Figure 4.6 Comparison between PAPI scales for joint sample and norm group 10 (managers).

In order to discuss whether there are any significant differences in each scale, the effect size is calculated, see Table 4.5. Effect size at 0.2 is thought to show a small effect, around 0.5 is medium and above 0.8 is regarded as high (Cohen, 1988). For this study, effect sizes above 0,25 are highlighted.

Table 4.5 Effect sizes in comparison between the joint sample and the chosen norm group

Compared groups / PAPI scale	Joint sample		Norm group 10 Managers		Effect Size d
	Mean	*Std*	*Mean*	*Std*	
G Hard worker	32,062	4,65	31,04	4,71	0,218
P Need to control others	30,093	4,12	29,89	4,4	0,048
L Leadership role	31,804	4,01	33,06	4,73	**-0,288**
C Organised type	30,990	4,78	30,15	5,8	0,159
H Integrative planner	31,175	4,23	30,15	5,08	0,221
D Attention to detail	29,418	4,92	26,44	6,5	**0,523**
W Need for rules and supervision	29,438	4,55	26,65	6,27	**0,517**
R Conceptual thinker	28,763	3,35	29,83	4,16	**-0,285**
Z Need for change	29,562	4,26	33,77	4,07	**-1,010**
N Need to finish a task	31,608	5,63	29,43	5,88	**0,379**
X Need to be noticed	26,619	5,58	28,65	5,36	**-0,371**
B Need to belong to groups	31,809	4,92	32,29	4,92	-0,098
S Social harmoniser	31,000	3,92	31,16	4,25	-0,039
O Need to relate closely to others	28,866	3,76	28,14	4,65	0,173
I Ease in decision making	31,227	5,17	29,65	5,39	**0,299**
T Work pace	30,381	4,15	32,66	4,34	**-0,537**
K Need to be forceful	30,412	4,55	31,31	3,91	-0,212
E Emotional restraint	28,552	4,79	27,76	6,2	0,144
A Need to achieve	26,577	4,86	27,66	5,16	-0,216
F Need to be supportive	31,211	4,09	31,18	4,43	0,007
SD Social desire	21,103	5,68	18,15	6,54	**0,484**

These results reveal that there are some differences that are significant, according to Cohen's effect size calculations.

The greatest differences appear in the scale Z (need for change). This result shows that the site managers from the joint sample have less need for change than the norm group. Moreover, on the scales of L (leadership role), D (attention to details), W (need for rules and supervision), R (conceptual thinker), N (need to finish a task), X (need to be noticed), I (ease in decision making), T (work pace) and SD (social desire), there are differences, with powers close to average.

The scale T (work pace) shows that site managers in this study have a lower value than the norm group, implying more risk-averse behaviour. When it comes to the other scale that is supposed to be related to risk, I (ease in decision making), the difference indicates that construction site managers find it easier to make decisions, i.e. might make decisions that are not always well considered. The effect size for the difference in scale I should, however, be regarded as small.

Within the scales D (attention to detail), W (need for rules and supervision) and N (need to finish a task), the site managers from the samples show a greater attention to detail and a greater need for rules and supervision, as well as a greater need to finish their work than the norm group of managers from other industries.

When it comes to the scales L (leadership role), R (conceptual thinker) and X (need to be noticed), there are differences with close to average effect sizes, indicating that site managers have less confidence in their way of managing things, less need to be noticed and that they also perceive themselves as less creative in addressing work-related problems than the norm group.

The last scale that was found to be different as an average effect size is the scale SD (social desire). Construction site managers in these samples appear to be keener on being perceived in a positive manner, as the results show higher values on this scale. This could also indicate that site managers set themselves a high personal standard or that they might have poor self-knowledge – according to the interpretation of the descriptions in the PAPI manual reference found in Appendix B.

4.4.1 Summary and analysis of results addressing the forth research question

Site managers from construction (Joint sample 1 & 2) and managers from other industries (Norm group 10) appear to differ in a third of the PAPI scales (7 of 21). However, these differences do not support the prevailing picture of site managers from construction being more risk prone and totally independent, as one might suppose with reference to the macho picture that is generally painted. Instead, a picture emerges of managers that pay attention to detail, need rules and supervision, work at a good tempo, are tolerant of stress and are keen on finishing their work. The one thing that supports the prevailing picture is the clear difference indicating little need for change that could be regarded as indicating that site managers from construction are more conservative than those from other industries. In the theoretical framework (SOU, 2000), images of construction employees as being more conservative than others could be seen as being confirmed by the large difference found in the comparison with the norm group.

The norm group of managers chosen for comparison contains a majority of women (61.8%) and a minority of men (32.8%) (Lewis & Andersson, 1998). This means that, when it comes to this background information, there are differences between the samples and the norm group that might be important.

5 DISCUSSION AND CONCLUSIONS

The aim of this chapter is to come to some conclusions about the studies that have been conducted. The first part, 5.1, relates to the way in which risk management is applied. These findings are based on the licentiate study prior to this study and this part is therefore the first to be presented. Chapter 5.2 deals with the findings relating to the impact of individuals where the results are based on answers to the second, third and fourth research questions. In Chapter 5.3, the findings relating to measurements of the effects of risk management are presented and they are based on the answers to the first research question. Chapter 5.4 aims to examine the context of project risk management and the conclusions in this chapter are based on information and knowledge collected throughout this study and the previous licentiate study. The last part of the chapter, relates to the validity and generalisability of the study, together with the implications for industry. Finally, there are also suggestions about future research.

5.1 Application of risk management

There is research that states that the application of risk management in construction is fairly simple. Checklists and brainstorming are used rather than calculations of probabilities based on statistics. Risk matrices are also used, but the assessments of consequences and probabilities are based on individual judgements. Most often, the focus in the risk management approach is also on the tactical risks rather than on the strategic risks, which implies that the approach used is reactive.

The conclusion drawn from the previous study, focused on small construction projects, is that there is a lack of systematic risk management (Simu, 2006). In that study, it was also found that the lack of a systematic approach was not always limited to the construction site. In smaller companies, the lack of a

systematic approach characterised the entire organisation. In accordance with other researchers' findings, this is a prevailing picture; there is a great deal of reliance on individuals and their experience and not merely in smaller projects.

The focus when applying risk management is on the early stages of the IARC (Identification-Assessment-Response-Control) process. The identification and assessment are often made simultaneously. The response and control are used more vaguely. In this study there were cases in which risk was identified and assessed, without any subsequent response or control, despite the fact that the assessments called for this. It it was also found that risks end up in plans for response and control without any prior identification and assessment (Simu, 2006).

Another finding in the licentiate study (Simu, 2006) was that the reliance on time schedules and detailed working plans was high and that this way of working was the practical way of managing risks and uncertainty in a project.

It was also found that, even though management systems were available in the companies, they were used only marginally on site. Examples were found in which the demands imposed by the management systems were met. Certain risks were identified and assessed, but they were not the ones with a serious impact on either the project or the company. Instead, the serious risks were handled parallel to the formal management system. The site managers used both their own project-specific control and the management system proposed by the company, which resulted in the duplication of work. The formal risk management system did not produce the desired effects and was not sufficient for the needs on site.

One conclusion that was drawn and is illustrated by this example is that the use of risk management systems does not ensure that the risks in construction projects are managed. It is up to the individuals on site to use the available tools and methods. Since the individuals, in this case, construction site managers, do not see the benefits of applying the methods, they use their experience, draw their own conclusions and use their own management system.

There are, however, differences between small companies and larger ones. In larger companies, more resources are invested in applying uniform management systems and also in educating employees on the objectives of these systems. In smaller companies, fewer staff is employed in developing and implementing adjusted management systems for the construction site to use.

One consequence working in this traditional way is that focus is on tactical risks and the strategic risks that go beyond the scope of the project are lost. The ability to work with continuous learning between employees and projects is also lost.

5.2 The impact of individuals on risk management

In this thesis, individual impact is related to two main areas, first education and experience and then also to personality traits.

5.2.1 Education and experience

The reliance on and practical application of experience and education as a means of implementing and using risk management is extensive in the construction sector and this indicates that there is a belief that this will have a positive impact on the risk management performance in organisations. **The second research question** therefore focuses on these background parameters that might be important for the effects of risk management.

In this thesis, the concept of experience is highlighted in the theoretical framework with the aim of showing that experience as such is neither commonly defined nor has an uncomplicated relationship with the dimensions of personal behaviour. The theories (Brehmer, 1980; Maytorena et al., 2007) reveal that experience may not be appropriate to use to such a large extent as might be supposed, especially when estimating probabilities in connection with uncertainty.

Various researchers in the field of psychology and behavioural science have found that different heuristics have a major influence when using experience, heuristics that bias judgements in relation to what is true and correct. These judgements are adjusted to take account of what could be expected, what first comes to someone's mind or the common belief about what is to be expected. These judgements are rarely based on pure probability, although individuals might think that they are. In spite of this, reliance on experience is high and it is also regarded as valuable. Due to the complexities involved in experience, there is no single, straightforward way of measuring it. The normal way to proceed is simply to relate it to age or time in some sense and this is also what has been done in this study where age has been the indicator of experience.

The results show that there is a positive relationship, albeit not significant, between the people who are certified site managers and two of the chosen

indicators; insurance cases and economic results. A significant difference was found between samples 1 and 2 and the number of insurance cases. In sample 1, there are fewer insurance cases than in sample 2. It was, however, not possible to relate the difference to any of the studied variables. There is an over-representation of certified site managers in sample 1, but this does not explain the difference. There are also differences in educational level and complementary education, but neither of these variables explains the difference that was found. One suggestion is that the difference could be related to the way in which sample 1 was collected. The collection of information for sample 1 was originally based on a validity study in which site managers at NCC had the opportunity to perform personality tests and obtain feedback, without any further implications. It might be that the differences found in the indicators for insurance cases and contribution ratio are related to the managers who chose to take part in this test. If those who chose to take part in the test are 1) more secure in their working situation, i.e. do not feel threatened by exposing themselves through a personality test, 2) feel that they actually have time available to fill in the forms involved in a personality test, 3) are interested in personal growth that might be achieved through a test and 4) feel that it is important to contribute to the development that is taking place in the company, it is also possible that this will have implications for the difference found in these indicators. This suggestion is beyond the scope of this research, but it is still important to put it forward as a possible explanation of the results that were found.

Nor has it been possible to define the specific characteristics of certified site managers that make the difference and, in all probability, this is the result of several factors. One probable influence is, however, that certified site managers have participated in a variety of complementary educational courses, one of which is risk management. Complementary education and training courses have also been found to have a positive influence on the ability to identify risks, according to findings in the UK (Maytorena et al., 2007). Another probable reason is that the people who have been promoted to be certified site managers have also demonstrated their ability to manage projects with positive economic results, which is also shown to be the case in this study. Further, certified site managers have a higher mean age than the others (54 compared with 46). The difference in mean age does not necessarily have a major impact, however. Most site managers, regardless of whether or not they are certified, have an engineering degree as their basic education. That means that, at the age of 46 (mean age for site managers), their likely work experience is more than 25 years, which has to be regarded as fairly long. It is worth asking whether the

additional eight years, to 54 (mean age of certified site managers), have that much impact.

The basic education, which is completed prior to entering the labour market, has also been included as a background variable, but no proof has been found to indicate that this is an important variable in terms of improved risk management performance. There is research that shows that basic formal education has an impact on the ability to identify risk (Maytorena et al., 2007). The same study also shows that experience as such is less important, which has not been validated in this study. The differences in results could, however, be related to some extent to the different research methods used in the two studies. In this study, authentic historical data have been used to measure performance. In the other study, the risk identification performance, RIP, was evaluated from one project that had been reviewed by several middle level project managers. Although that study aimed to be as unbiased as possible, it is possible that people who are comfortable working in fictitious projects, i.e. those used to problem solving with a higher education, benefit from this and therefore produce a better RIP.

5.2.2 Personality traits

The personality traits that have been measured in this study using the scales and factors in PAPI have been measured in a work-related situation. **The third and fourth research questions** address this issue, with the emphasis on identifying the personality traits that could indicate and be related to the effects of risk management at individual level. This study also aimed to determine whether there are traits that dominate and differ between managers from construction and those from the general labour market.

In PAPI, there are certain traits, scales, that indicate risk-prone or risk-averse behaviour and they are related to the economic deliveries at project level. Due to the available empirical data, the economic indicator, CR, has been used as the main indicator of risk management. The results show that neither of the suggested traits that could be related to either risk-prone or risk-averse behaviour correlated to a better economic result. Instead, it is traits indicating a positive attitude to change, sociability and the ability to get things done and act powerfully in negotiations that are found to correlate to a better economic performance. The implication of this is that the suggested, tested and used indicator, economic result, is not such a strong indicator of effective risk management as was initially thought. Instead, the effects of risk management are more complex and cannot simply be reduced to profit. The ability to deliver

good economic results appears to be a question of other parameters than the ability to merely manage risk.

There are assumptions, not always scientifically stated, that individuals who work as site managers in construction differ from individuals in the general labour market. Due to the many errors and the increased costs in the sector, the prevailing and perhaps prejudiced picture that is put forward is that site managers in construction are more risk prone and behave in a different way than those in the labour market in general. The results, however, reveal that this is not the case. Compared with managers in general, construction site managers only differ to a small extent in terms of their ease in making quick decisions, a trait that could indicate more risk-prone behaviour, according to the theories. The other trait, measuring perceived work pace, as an indicator of risk-prone or risk-averse behaviour, shows that site managers from construction are less risk prone, or possibly even risk averse, compared with the group of managers representing the general labour market. The scale showing a lower working pace is also an indicator of an individual who is more stress tolerant, which has been shown to be an important attribute for construction site managers who are constantly affected by stress as a result of a tight time schedule or a lack of resources, for example.

When it comes to the need to be noticed, the site managers from construction also differ from the norm group of managers. Construction site managers have less need for attention in their work performance compared with the norm groups. These results could further confirm the picture of the site managers participating in this study as being fairly confident in their working role.

These construction site managers differ from the norm group of managers in terms of their attention to detail and their need for rules and supervision, which in both cases are greater for the construction site managers, indicating that construction site managers pay more attention to detail and have a greater need for rules and supervision. This is somewhat surprising in view of the reports of increasing errors in construction and the general picture of construction as a decentralised industrial sector in which site managers are strong, independent individuals.

The findings also show that construction site managers have less need for change than managers from the general labour market. Moreover, construction site managers have a greater need for rules and supervision than other managers. The interpretation of these findings is that construction site managers have a higher threshold for working at the knowledge-based level.

Relying on their experience, they stay at the rule-based level of problem solving. In most cases, this is probably the correct choice, as this decision process is far faster than the process at the knowledge-based level. The speed of decision making is prioritised due to the stressful situation on site, but this also opens the door to the errors known as "strong but wrong". The ability to take in new information is lacking and the decision that is made is based on the wrong information, which is based on experience unrelated to the new situation. The importance of being able to take in new information and change one's way of working is also found in the correlation between economic results and the need for change, where it is found that the site managers who have a positive attitude to change also achieve a better economic result. This finding also supports the findings of Maytorena et al. (2007) showing that the ability to seek new information in the risk identification process results in a better risk identification performance (RIP). The frequently stressful situation at construction sites also forces site managers to work at the rule-based level and also rewards this behaviour through the focus on time schedules as a way of controlling the construction process.

Should the differences between site mangers and certified site managers actually have been even larger? The economic results that are generated in the projects are naturally dependent on the site managers, but they also depend on the prerequisites specified during the bidding process during the early planning of the project. The organisation for the project is often chosen in the early stages by the contracting managers (see also Figure 1.4) and the site manager is put in a situation in which many decisions that have an impact on the project performance have already been taken. One such decision that is taken during the bidding process is the decision relating the choice of the site manager. It is not difficult to understand that, for the more complex, difficult projects or for the projects that are valuable for future client relations, the best or at least one of the best site managers is chosen. This means that the performance measured in terms of economic results, for example, is not a complete measure of individual performance. If site managers could be given the same identical prerequisites, larger differences might be revealed. This is obviously a theoretical discussion, as it is not possible to have identical projects in a real-life environment, but it is still important to remember that the differences that were found could easily have been greater.

5.2.3 Conclusion about relations between individuals and effects of risk management performance

There are two different traits that have been found to indicate that construction site managers may have difficulty switching from working at the rule-based level of problem solving to the more demanding knowledge-based level. At the rule-based level, reliance on and the use of experience and instructions are high and, as a result, the decision-making process is rapid. This finding shows that the lower values for trait Z (need for change) and the higher values for trait W (need for rules and supervision) may preserve the way people work in projects and make it harder to break old habits.

Construction site managers have a high threshold when it comes to working at the knowledge-based level and they tend to stay with the more routine problem solving at the rule-based level.

which is the same as

Construction site managers are stuck in the same old rut of problem solving.

The individual impact on the effects of risk management is difficult to establish. With these findings, it is clear that the problems occurring in the construction sector – delays, defects and increased cost – should not be attributed to site managers as individuals, even though they are a vital part of the construction sector and its culture. It is also interesting to note that the dominant reliance on individuals ought to be questioned. Managing risks are far more extensive than leaving it to be blamed on individual judgements. Construction companies need to face the complexities of proactive risk management and stop hiding behind the concepts of individual judgements.

The individuals are merely a part of a context, influenced by situation, culture and organisational structure and strategy. It is, however, easier to point the finger at the individuals as the cause rather than being forced to change the culture of an organisation or even an industrial sector.

The individual impact only explains a small part of project performance.

Maintaining the prevailing picture of construction site managers instead serves as an excuse for failure when the adoption of new management ideas takes place, especially as these findings indicate that this might not be true. Construction site managers instead represent managers who are good at planning and paying attention to detail. It is therefore vital to let go of the prejudiced picture of construction site managers being risk-prone individuals, at least when they are regarded as a group. Focusing on each individual separately in relation to economic performance reveals that the relationship to risk-related behaviour is even further removed. The individuals who produce a better economic performance appear to be sociable, open minded, with the potential to act forcefully, characteristics that are not related to either risk-prone or risk-averse behaviour.

Construction site managers are not more risk prone than other managers from the general labour market.

Both education and experience appear to have a positive effect on project performance in terms of contribution ratio and number of insurance cases. This is related to the indication that certified site managers appear to perform better. It is, however, difficult to correlate this directly to the performance related to risk management. The difficulty involved in distinguishing the effects of risk management from the contribution made by general project management remains. It is, however, clear that caring about the skills of the employees, in this case the site mangers, produces a positive return on investment; they achieve better results. These findings stress the importance of working in an organisation capable of learning from experience.

Education and experience probably pay off in producing better effects of risk management.

5.3 Risk management performance

This study started with the aim of finding a reliable way to measure a somewhat vague and diffuse concept – the effect of risk management in a Swedish construction company – and then relating it to individual impact. The **first research question** therefore addresses the issue of finding the possible indicators of effective risk management. The first part of the question is whether there are theories that support the idea of finding a way of measuring the effects of risk management. The second part focuses on determining whether there are indicators that are already being used in companies and comparing them with indicators found in the theoretical framework. The third part of this research question involves actually testing the model using the available data to see whether it works in practice.

The theoretical model consists of four indicators and there are five indicators found to be used in practice, for measuring the effects of risk management at construction site level. These indicators are as follows;

Indicators found in theory	Indicators in practice
– *Quality performance in terms of defects in the delivered product*	– *Contribution ratio*
– *Safety in terms of accidents*	– *Number of accidents*
– *Predictability in terms of the relationship between plan and delivery*	– *Number of insurance cases*
– *Profit on bottom line at project level*	– *Results of internal audits*
	– *Precision of economic delivery*

These indicators are based on the theoretical framework where they originated from a number of key performance indicators. Finding almost the same indicators in practice confirms that risk management and its effects are an important issue for the construction industry. It is interesting that the indicators that were found only focus on what is defined as tactical risks. For an organisation to work with risks in a more integrated or proactive way, it is essential also to include the strategic risks. Strategic risks include matters related to the common objective for the company rather than project-specific targets. This could be related to the concepts of effective or efficient risk management. These measures indicate whether the risk management process is effective, i.e. measuring to ensure that things are done in the right way. The measures do not provide information about the efficiency of the risk management process, i.e. if the right things are being done. Merely focusing on

tactical risks might produce an effective result but not necessarily an efficient one. To realise an efficient risk management process, the approach needs to be more proactive than that currently found.

The common indicator for measuring the effects of risk management is the economic performance in terms of profit measured by contribution ratio. This is an important measurement, but the influences from general project management in contrast to risk management are difficult to define. There is, moreover, no question that risk management is part of project management, but the extent is difficult to establish. A public limited company is measured by the market on its ability to deliver profit and one of the main reasons for CEO management to use risk management in organisations is to avoid uncertainty in these financial deliveries. There are many contributors to project profit and there is no doubt that effective risk management is one of the important. Using this indicator as the main contributor to measure the effects of risk management is however questionable since it could not solely represent effects of risk management.

The theory includes the indicator of quality performance with the emphasis on product delivery. This is not measured in practice as an indicator of risk management performance. Instead, another indicator focusing on the quality of the process is used in practice – the results of internal audits. Internal audits aim to assure the process of realising the product and are an important part of quality management systems. Using internal audits in an organisation is a way of working proactively to eliminate defects and, used correctly, it is also a way to improve the progress of the work. It is somewhat surprising to find that this is not an indicator of risk management performance in the theories. Focusing on the product delivery ought to be interesting in practice, even if it is not used today. In this thesis, defects have been defined as being a consequence of poor risk management and they should therefore also be used as an indicator for measuring the effects of risk management. Using defects in products as an indicator would, however, require the systematic reporting of data from final inspections. In any collection of data, there must also be a reflection of the added value the data would contribute in relation to the effort involved in collection. Not having a purpose for data collection is a sound excuse for not doing it. However, if there is information that could work as an indicator of an issue that is apparently important for an organisation, it ought to be valuable. Measuring defects in the product that is going to be delivered could serve two purposes in an organisation; it could indicate the ability to manage risks that are related to defects and it could also function as a means of improvement by learning from mistakes.

Insurance cases are measured in the company as an indicator of the way risk management is working. This measurement has not been found in the theories as such, but it could be related to the aims included in the indicator of quality performance related to the product. This "insurance case" indicator probably has some information hidden in it, as the only damage that is reported is that exceeding the excess. The other damage is not reported and there are signals from both other researchers and practitioners that there is a large amount of damage in this category that is never reported. If all the damage were reported, this would be a valuable source of information that would fulfill two purposes; an indicator of the ability to manage risks that are related to damage and a means of improvement by learning from mistakes, i.e. the same benefits as those produced by measuring defects.

The last indicator that is found both in theories and in practice is the indicator of precision or predictability. In practice, this indicator is used most often in searches for large dips in the forecast late in the construction of a project. The interpretation of this is that a large dip represents a lack of control and thereby also a lack of control of the risks that have occurred. Since one of the aims of risk management for CEOs is delivery precision, the positive fluctuations are also of interest. The "surprise effect" of delivering a good profit is also regarded as lack of control. In the results in this study, no clear relationship has been found between the managers with good to average economic results, contribution ratio, and stable deliveries of results. It has instead been found that there are large fluctuations (more than 5%) in close to half the projects that were studied and for the entire group of site managers who were studied. As in the case with measuring profit, the fluctuation in this indicator could also have different origins and there might be reasons other than the lack of control of risks that caused the effects. In spite of this, it still serves as a signal that there are problems in the predictability of financial deliveries. This indicator has unfortunately not been possible to measure in a way that enabled it to be used in the statistical processing.

The indicators that are used in practice have been found to fit in the theoretical model for measuring the effects of risk management. The test of the model using indicators from data made available by NCC does not, however, reveal the statistically significant correlations that were expected. The conclusion is that there were not enough empirical data. What has been found is a more vague relationship between the economic result and the number of insurance cases reported and this supports the suggested relationship between a small number of insurance cases and a better economic result.

5.3.1 Conclusion about measures for risk management performance

According to the model, there is a concept of effective risk management that can be measured using the suggested indicators. There are, however, not enough empirical data in this study to establish this statistically. Quality performance are constituted by three parts in this model; defects, project performance and insurance cases. This means that there are four main areas for measures and actually six measures to be used.

Indicators suitable for measuring the effects of risk management at project site level are:

- ***Quality performance*** *in terms of*
  - *defects in delivered product*
  - *process performance*
  - *insurance cases*
- ***Safety*** *in terms of accidents*
- ***Predictability*** *in terms of the relationship between plan and delivery*
- ***Profit*** *on bottom line at project level*

5.4 Organisational context of risk management performance

This sub-section is a discussion that attempts to return to the complex reality of construction projects presented in the introduction. From the start, this study focused on the individuals' impact on the risk management performance and this is the loop back to the contextual framework.

In the interviews, in this study and in the previous licentiate study (Simu, 2006), the individuals and their ability to make sound judgements regarding risk and uncertainty are regarded as playing a very important role in the outcome, i.e. the effects of risk management. In spite of this, the interviewees or other respondents expressed no reflections on issues associated with or relationships to the organisational or corporate-culture impact on the effects of risk management. As this study progressed, the important interaction between individuals and organisations became too obvious to ignore. For this reason, it is included in the discussion in spite of a lack of empirical data collected with the aim of focusing on organisational impact. The empirical data were collected with the aim of describing the construction site context in order to obtain a wider understanding.

Working in any organisation, people quickly realise that there are rarely single dependencies for any action, behaviour or result and this also applies in the field of project risk management in construction. Most probably, things are knitted together in a complex manner. In the previous licentiate study, interest focused on determining how risks are managed, i.e. what tools and methods are applied. The results revealed that the use of systematic risk management was weak and the reliance on individuals was high. One conclusion in this study is that risk management does not simply comprise the influence of individuals. Organisation, culture and attitude are put forward as important ingredients in the way risk management is applied and also when it comes to the effects of using these systems. One further conclusion that can be drawn from this study is that construction site managers have difficulty changing their way of working, they easily get stuck in the same old rut of problem solving. Putting these conclusions in the context of construction projects at site level, it is obvious that the culture and structures prevailing in the construction industry further feed this way of managing projects and solving problems. Problem solving most often remains at the rule-based level, due to the situation on site, and site managers misjudge when it is necessary to collect new information and knowledge due to changing circumstances, i.e. working at the knowledge-based level. Working at the knowledge-based level of problem solving is more time consuming and demanding. With intensive time pressure and limited resources at the construction site level, the individuals are not urged to step up to the knowledge-based level. They are instead encouraged and also forced by the context and situation to stay at the rule-based level.

According to Reason (1990), errors at the rule-based performance level occur as a result of deficiencies in the application of rules. This in turn means that rules could be wrongly applied or merely awkward or not advisable and the implication of this is that the rules, i.e. routines, are not fit for purpose. The system is not adjusted for practical use and so the results of the interviews indicating that the system is perceived as being too complicated could be related to errors and risk outbreaks in the organisation.

Hollnagel (2004) also presents some different sources of accidents, which could just as well have implications for risks and errors and, from these sources, most of them could be related to a wider perspective than just individual influence. In the interviews the importance of communication and collaboration to achieve a more risk-efficient organisation was pointed out, which is also one of the sources identified by Hollnagel.

The sought and much desired precision in deliveries also appears to be difficult to achieve. There is awareness that it is important to follow the dips in the economic forecast and this is also measured. The root cause of the uncertainty in deliveries is dealt with in a more inconsistent manner. Some of this work and analysis is done. In other parts, only the knowledge of fluctuations relating to the number and size of dips in forecasts is applied. Moreover, only the dips in forecasts are followed and not the total deviation. According to the CEOs, the uncertainty is devastating, no matter whether it is positive or negative; it is the uncertainty as such that matters. To be able actually do something about the uncertainty, it ought to be obvious that more knowledge is needed about the root cause, in order to learn from previous experience. This leads us to the concept of learning organisations.

Practitioners in the construction industry emphasise the importance of experience, which is only valuable if one is able to learn from it, according to the theories. To be able to learn from experience, there needs to be an environment that encourages learning and the sharing of experience. The results of this study, the previous licentiate study and other researchers' studies in the field of construction show that the construction industry as it works today is far from being a learning organisation. Instead, it is a "blaming" culture that is revealed when defects and errors are mainly investigated with the aim of finding out "who is responsible and who will pay?" rather than "what we can learn so we do not do this again?".

The results of other studies also reveal a way of working with risks that focuses on events in projects, often through defined risk checklists. It is rare for the focus to be extended with the aim of including strategic risks for the organisation. Risk management also appears to be applied as a matter for the projects rather than for the organisation as such.

Another phenomenon that emerges in the results is the common acceptability of retention of risks. It appears that, by having a culture that generally retains the risk by adding contingencies either in the tender or through insurance, work on avoidance, reduction or prevention suffers. The common process in the construction sector of transferring risks between project participants also acts as an obstacle to a more proactive approach.

A reactive approach is characterised by an organisation that relates instructions and routines to previous events, content in checklists, and always tries to find "who is responsible" and transfer risks and errors, which also adds to liability. In a reactive organisation, there is a formal way of working and the

organisation reacts to the information that is presented, such as statistics and discrepancies in audits. Moreover, the acceptance and retention of risks is part of the management culture, where one example of this kind of retention is the common procedure of adding contingencies to the tender, just in case. In the reactive approach, there is also a clear focus on either retaining the risks or transferring them to someone else. The results of previous research (Simu, 2006) show that there is a way of allocating money at the start of a project, just to be on the safe side, that can be used if something goes wrong. This way of working implies that the project has to bear the cost of an error, if an error occurs. This means that risks are retained but are hopefully never realised. There are also results (Simu, 2006) that show that the risks are transferred between parties in accordance with the legal contracts and this is a way of playing "Old maid", as it is always important to identify the person who failed and the person who is responsible for errors occurring. This is a further indication of a "blaming" culture, as described in the definitions of reactive risk management.

It is argued that the organisational approach to risk management, as addressed in the theoretical framework of this thesis, has an important impact on the final results of risk management. In the theoretical framework, the concept of proactive, holistic, generative or best practice risk management is presented. Using Smallman's (1996) three factors to help describe the prevailing approach to risk management, it emerges that it is dominated by a reactive approach.

Structure

- Decisions about risks and risk management are decentralised close to the construction site.
- Managers think that risk management is vital, although there are differences in the way this is done, either with specialists or with managers.

Strategy

- Risk management systems are based on formal routines and checklists that focus on tactical risks related to project performance, focusing on technical or health and safety issues, for example.
- Insurance is used and premiums are based on the outcome from previous years.

Culture

- The view that it is always someone else's (individuals or circumstances) fault if an error occurs.

- Statistics and experience in the organisation are not used to make improvements in any systematic way. There is no sign of a learning organisation.
- The liabilities are important and are defined in the contracts between clients and contractors in projects. Most often, this is done in accordance with the General Conditions of Contracts (AB) implying that risks are transferred to the most suitable party.

5.4.1 Conclusion of discussion about organisational context for risk management performance

There are issues at organisational level that most probably have an important impact on the effect of risk management. In this study, the research questions have focused on individuals, regardless of their individual context in terms of organisation, corporate culture and group dynamics, issues that most probably have a major impact on the effects produced by risk management. These are issues that need to be focused on in future work on risk management in construction projects.

The concepts of proactive and reactive organisations are found in the theoretical framework. Taking these concepts and applying them to the contextual descriptions in this study reveals that there are arguments that support the conclusion that the present-day construction industry applies a reactive approach to the application of risk management.

5.5 Strengths and weaknesses of this study

Generalisations from this study must be made with the delimitations of the study fresh in one's mind. The limitation of merely collecting data from one construction company in Sweden is a result of the exclusivity of the data that were made available. The data should, however, be regarded as one of the strengths of this study. Not only are the data exclusive, due to the close relationship between the researcher and NCC, resources were also made available in the company to help find the data from various internal systems and support the researcher in the work on empirical data. Increasing the generalisability of the study with data from other companies would have resulted in less detailed information and the validity of the results would therefore have been reduced.

The reference group has played an important role in increasing the generalisability and validity of this study. The reference group consists of people representing a variety of organisations and stakeholders in construction, including one of NCC's competitors, Skanska. Throughout this research study, there has been continuous contact and meetings with the reference group to discuss aims, problem formulation, research questions and preliminary results. This process has extended the focus of the study to cover parts of the construction industry that have not been covered by empirical data and this has increased the trustworthiness of this thesis. Further support for the generalisability of the thesis is provided by the homogeneity of the construction sector described by researchers and governmental reports. To a large extent, the context, problems and challenges described nationally are also found in research internationally.

The reliability of this study, i.e. whether it answers the research questions in a satisfactory matter by using a reliable method, has been secured by using established methods with detailed and thorough data collection.

The data in this study are genuine and the opportunity to control the input in an experimental manner is therefore limited. This should naturally be regarded as a strength in the sense that the results are not biased by the researcher's aim with the study. The weakness of the data is the other side of the coin; the available data have not been registered for use in the way in which they have been used in this study. The original purpose was to use the data as dependent variables for financial accounting, the settlement of insurance cases and statistics for the work environment and process development. The data that were made available from the personality inventory for the first sample were collected for a purpose other than that in this study. The respondents in the first sample chose to participate in a validity study and they decided whether they had time and whether they felt it was valuable for them personally. Feedback from this sample was promised via mail. The individuals in the second sample were asked to participate specifically in this study and they were not promised any personal feedback. However, personal feedback was given to those who requested it.

Another issue that needs to be highlighted is that the people who chose to respond to the first request to take part in the PAPI test are the same group that formed the basis of the first sample in this study. More certified site managers chose to participate and there could be several reasons for this and they could also be related to each individual separately. It could also be that, as a result of experience and training courses in various parts of project management, they

perceive themselves as having time and interest in participating. These respondents probably regard themselves as being fairly confident in their role as site managers and they do not therefore feel threatened by participating in such an exposed study as a personality test. The implication of this is that there might be site managers "out there" with a different profile and background who would also give other answers to the research questions formulated in this study.

Despite the available data, not all the variables are available for or distributed to the same individual. In sample 1, there are only nine individuals with available data for three of four variables, see Figure 5.1. For sample 2, the picture is more complicated, as there were fewer individuals in the second sample who took part in the PAPI test and there was also a lack of complete data for each individual. Due to the complexity of visualising sample 2, the outline in Figure 5.1 is not complete for the second sample.

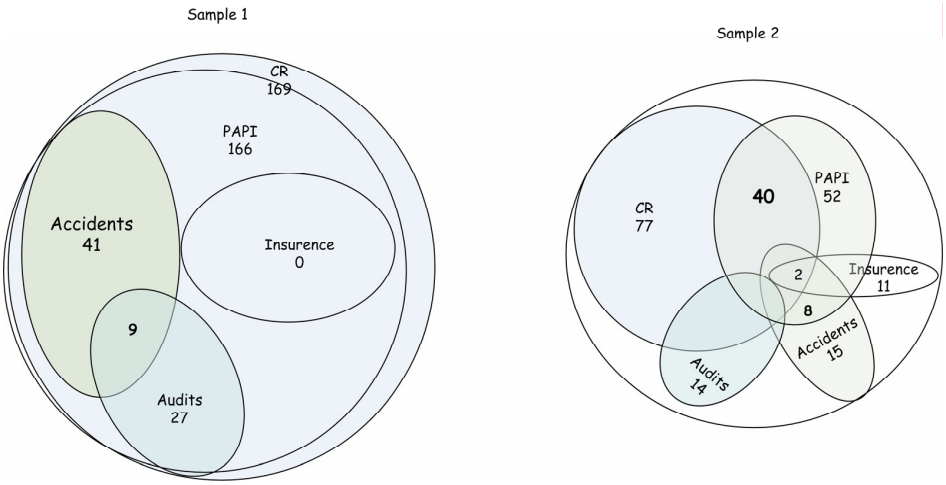


Figure 5.1 The number of individuals contributing to each variable, where the lowest common denominator for sample 1 is 9, meaning that, for nine individuals, there are data for three of four variables.

When interdisciplinary studies like this are conducted, criticism may be levelled at the depth of each discipline that is considered. This is a balance between digging deeper holes of knowledge or wider openings of understanding. The choice in this study was based on the researcher's belief that life is more a question of wider understanding in a larger context than separate knowledge in specific fields. The work of connecting this specific

knowledge from different fields of science to a new and wider knowledge is the scientific contribution of this thesis.

5.5.1 What could have been done in a different way

There is always more than one way to proceed when performing a task, no matter whether it is a construction project or a research study. The best way to proceed is also clearest at the end of such a process when all the mistakes have already been made. This study could also have been conducted in a variety of ways which could have improved the results. Some reflections on possible alternatives that might have been appropriate now follow.

To find out more about individual judgements and individual impact, it also would have been possible to conduct a qualitative survey with interviews and detailed studies of a few selected projects. A study of this kind would have been able to analyse in more detail the actual causes of things going wrong and it would also have made it possible to find incidents as well as accidents and defects. It would not, however, have been possible to search for significant correlations between different information. On the other hand, the results from this study show that it was difficult to find correlations, despite the large amount of data.

It would also have been possible to conduct questionnaire surveys to collect information about indicators of the effects of risk management, instead of relying on reported data in the company. This was also discussed and rejected, as the aim was to see whether it was possible to use the existing data.

The choice of the samples could also have been made differently. Basing the sample on the managers with insurance cases might have led to slightly different information. It would have meant that there was more information about the relationships between economic performance and damage covered by insurance, but there could possibly also have been less information from personality tests. Since this study aimed to find relationships associated with the effects of risk management and personality, it was decided to begin with the personality test.

5.6 Implications for industry

The results and findings have some specific implications for the construction industry when it comes to improving performance. It might not be possible to take this as a textbook formula for ensuring higher profit, but most players in the construction industry would probably be able to use the ideas and suggestions for improvements, provided that they were able to adapt them to their own organisational context.

5.6.1 Measuring effects from risk management

The concept of measuring the effects of risk management using different indicators, not only economic results, is most probably a good idea, considering the importance of risk management in construction. However, to be able to find proper correlations, the amount of data needs to be increased for all the indicators apart from the contribution ratio, which is well reported in all projects. One way to increase the data relating to accidents is to include near-accidents and not just accidents. In a similar way, more data would be reported if all the cases of damage, failure and defects were reported and not just those exceeding the excess.

Further, the assessments in internal audits could be coded in a structured way, giving ratings in relation to how well the project is going. Audits are a powerful tool for an organisation that wants to improve, but only if they are properly used. Audits with reports that no one cares about or learns from are merely a waste of time and money.

The most difficult indicator to use in relation to the other indicators appears to be the one focusing on delivery precision, even if this is an important issue. As it is used today, interest appears to focus on the negative outcomes, but the results in this study show that there are fluctuations and uncertainty in both directions and they should be addressed if greater precision is desired. It is, however, important for any collection of data that its eventual use is specified. Vast collections of data that do not fulfil a purpose are merely a waste of time and resources. So organisations that want to increase the amount of data need to have a clear picture of what they are going to do with the results, i.e. how to learn from the increased amount of information. It is also important when collecting data related to tactical risks at projects that there are analyses made at management level about the strategic risks, as a consequence of the information received from the measures.

5.6.2 Reliance to education and experience

The results in this study show that there is most probably a positive effect in risk management performance related to education and possibly also to experience. The relations are however not strong but the concept of certified site managers seems to be positive. This concept would probably be suitable for other key roles in the organisation. Paying attention to key roles in the organisation also clarifies the achievements that are expected and the skills that are needed and this should then have a positive impact on collaboration within the organisation.

5.6.3 The character of the construction site manager

There is no such thing as site managers from construction being more risk prone or more reckless than managers from other industries, rather the opposite. However, construction site managers appear to be more conservative and, as a result, they find themselves more easily caught up in old habits. This is, however, not solely an individual matter as the context of construction projects also has a preserving effect in the sense that there is rarely the time or resources to encourage problem solving at the knowledge-based level. The implication of this is that the prevailing picture of construction site managers as being unique is not completely true. It could therefore not be used as an excuse for not adopting management influences from other industrial sectors. Instead, the site managers who are open to change have a positive influence on the economic performance in projects and these individuals ought to be encouraged.

5.6.4 Change from reactive to proactive approach to risk management

These findings call for changes in the organisation of construction projects. In this study, the focal point is the construction site, but the changes need to relate to a larger context. It is not possible for either individuals or construction sites to implement new ways of managing risk. This needs to be done at higher organisational levels and possibly even at sector level for the construction industry as such. The challenge facing the construction industry is to start the process of getting closer to the proactive approach to risk management instead of preserving the prevailing reactive approach. The proactive approach to risk management implies that the concept of a learning organisation is working, that interest is not only focusing on event-driven risks at project level and the focus must include strategic risks for the organisation, as well as opportunities. A

proactive approach also focuses on avoiding, preventing and reducing risks rather than transferring or retaining them.

5.7 Future research

The individual impact is important but not to such a large extent as might be expected when listening to practitioners and reading previous research. It would therefore be interesting to conduct more research on the contextual situation on site.

One area on which interest should focus is the relationship between individuals and the organisational impact on risk management. The individuals are part of organisations, but the interaction between the two still needs to be examined in construction projects. There are signals of sub-cultures as well as corporate and sector cultures within construction. Finding out how this affects risk management performance would help to make risk management more efficient.

Another area that would be interesting for further research is the measurement of effects of risk management performance. With more data, it would be possible to demonstrate the validity of the model. This could possibly be done using incidents, defects reported at final inspections and reports of damage, including those below the excess level. Another issue important for measures of effect is to relate the indicators of tactical risks to indicators of strategic risks. Finding such a relation enable the senior management in construction to control the core of construction and not only being reliant to individuals in the projects.

It would be valuable to determine and evaluate the degree to which an organisation uses a reactive or proactive approach. Comparable measurements within or as a comparison between companies would also make it possible to follow an ongoing change. This could also work as a means of improvement and a driver for change. One approach would be to use the three factors, *structure, strategy* and *culture*, defined by Smallman (1996), and make an qualitative evaluation of the status of organisations in terms of each of these factors. A study like this would provide more details about the next steps for organisations that are interested in getting closer to a proactive approach to risk management.

A qualitative study based on information relating to situations in which things have gone wrong, such as cases for insurance, would enable findings about the reasons for risk outbreak and not simply information that it has occurred. Due

to liabilities, there are investigations relating to insurance cases. These investigations could work as a basis for a qualitative study of this kind in which interviews with project participants could shed light on the more underlying causes of events.

References

Akintoye, A. S. & MacLeod, M. J. (1997). Risk analysis and management in construction. *International Journal of Project Management, 15*(1), 31.

Anheim, F. (2001). *Entreprenörens lärande.* Luleå University of Technology, Luleå.

Ashby, S. & Diacon, S. (1996). The value of corporate risk management: empirical evidence from large UK companies. *Risk Decision and Policy, 1*, 203-215.

Aven, T. (2003). *Foundations of risk analysis*. Chichester: John Wiley & Sons Ltd.

Azinim, M. & Edum-Fotwe, F. T. (2006, 18-20 October). *Risk management practices of construction project staff: Preliminary lessons.* Paper presented at the Construction in the XXI Century- Local and global challenges, Rome.

Berggren, K. (2005, 13-16 June). *Risk management in small sized projects.* Paper presented at the CIB 2005 Helsinki Joint Symposium, Helsinki.

Borgbrant, J. (2003). *Byggprocessen i ett strategiskt perspektiv*. Stockholm: Byggkommissionen.

Brehmer, B. (1980). In one word: Not from experience. *Acta Psychologica, 45*(223-241).

Bresnen, M. & Marshall, N. (2001). Understanding the diffusion and application of new management ideas in construction. *Engineering, Construction and Architectual Management, 8*(5/6), 335-345.

Brody, N. & Ehrlichman, H. I. (1998). *Personality Psychology, the science of individuality*. Upper Saddle River: Prentice-Hall Inc.

Bull, R. (2005). *Financial ratios: Building a Model of Success for your business* London: Sapiro Press.

Butler, R. (1995, May). *Risk and strategic planning in organisations.* Paper presented at the ESRC Risk and Human Behaviour Programme, Risk in Organisational Settings Conference, London.

Cervone, D. & Pervin, A. L. (2008). *Personality, theory and research* (10th ed.). Hoboken: John Wiley & Sons, Inc.

Cettner, A. (2008). *Kvinna i byggbranchen- civilingenjörers erfarenheter ur genusperspektiv.* Luleå University of Technology, Luleå.

Chapman, C. & Ward, S. (2003). *Project risk management : processes, techniques and insights* (second ed.). Chichester: Wiley.

Chapman, C. & Ward, S. (2004). Why risk efficiency is a key aspect of best practice projects. *International Journal of Project Management, 22*(8), 619.

Chuvin, B., Hermand, D. & Mullet, E. (2007). Risk Perception and Personality Facets. *Risk Analysis, 27*(1), 171-185.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hllsdale, New Jersey: Lawrenece Erlbaum Associates, Publishers.

Cohen, J. (1992). A power primer. *Psychological bulletin, 112*(1), 155-159.

Crane, A. (2002). *Rethinking Construction : 2002*. London: Rethinking Construction Ltd.

Cubiks. (2006). *Investigating the relationship between PAPI-N and the lexical Big Five personality factors*. London.

Davidson, M. & Sutherland, V. (1992). Stress and the Construction Site Managers: Issues for Europe 1992. *Employee Relations*(2), 25-38.

Djebarni, R. (1996). The impact of stress in site management effectiveness. *Construction Management and Economics, 14*(4), 281-293.

Egan, J. (1998). *Rethinking Construction*. London.

Fernie, S., Leiringer, R. & Thorpe, T. (2006). Change in construction: a critical perspective. *Building Research and Information, 34*(2), 91-103.

Flanagan, R. & Norman, G. (1993). *Risk Management and construction*. Oxford: Blackwell Scientific Publications.

Goldberg, R. L. (1992). The development of markers for the big five factor structure. *Psychological assessment, 4*(1), 26-42.

Grey, S. (1995). *Risk assessment for project management*. Chichester: John Wiley & Sons Ltd.

Hair, J. F. J., Andersson, R. E., Tatham, R. L. & Black, W. C. (1998). *Multivariate data anlysis* (5th ed.). New Jersey: Prentice-Hall PTR.

Hansson, S. O. (1994). *Decision theory, a brief introduction*. Uppsala: Departement of philosophy, Uppsala University.

Hartzell, M., Leineweber, C., Hansson, M. L., Theorell, T. & Westerlund, H. (2008). *Hållbart ledarskap i byggsektorn*. Stockholm: Stressforskningsinstitutet, Stockholms universitet.

Hillson, D. (2004). *Effective opportunity management for projects : exploiting positive risk*. New York, N.Y.: M. Dekker.

Hillson, D. (2006). *Integrated Risk Management As A Framework For Organisational Success.* Paper presented at the PMI Global Congress Proceedings, Seattle, Washington.

Hillson, D. & Murray-Webster, R. (2005). *Understanding and managing risk attitude*. Hampshire: Gower Publishing Limited.

Hintze, S., Håkansson, U. & Täljsten, B. (2004). Delhi Metro- risker och riskhantering i miljonformat. *Bygg & Teknik*(1), 41-48.

Hollnagel, E. (2004). *Barriers and Accident Prevention* Hampshire: Ashgate.

IEC62198:2001. (2001). *International Standard IEC 62198:2001*: International Electrotechnical Commission.

Jaafari, A. (2001). Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International Journal of Project Management, 19*(2), 89-101.

Jonsson, B. (2008). *Analys av utveckling av dödsfall till följd av olyckor på arbetsplatsen* (No. AIHÄ 2008/22164).

Josephson, P.-E. & Hammarlund, Y. (1999). The causes and costs of defects in construction A study of seven building projects. *Automation in Construction*(8), 681-687.

Kahneman, D. & Tversky, A. (1979). Prospect theory: an analysis of decision under risk. *Econometrica, 47*, 263-269.

Katz, D. & Kahn, R. L. (1978). *The social psychology of organizations* (2nd ed.). New York: Wiley.

Khalaf, F. (2008). The risk management Process - An overview. *Society of Petroleum Engineers - 9th International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2008 - "In Search of Sustainable Excellence", 1*, 556-565.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction* (No. 72): Center for Integrated Facility Engineering, Stanford University.

KPMG. (2005). *Global Construction Survey 2005, Risk Taker, Profit Maker?*

KPMG. (2008). *Global Construction Survey 2008, Embracing Change?* .

Kuhn, T. S. (1996). *The Structure of Scientific Revolution* (3rd ed.). Chicago: The University of Chicago Press.

Kähkönen, K. (2007, 14-15 June). *Quantitative risk management for construction- model of elements for workable solutions.* Paper presented at the 4th Nordic Conference on Construction Economics and Organisation, Luleå.

Laryea, S. & Hughes, W. (2008). How contractors price risk in bids: Theory and practice. *Construction Management and Economics, 26*(9), 911-924.

Lazarus, R. & Folkman, S. (1994). *Stress, appraisal and coping*. New York: Springer.

Lewis, C. & Andersson, P. (1998). *PAPI Technical manual*. London: Cubiks.

Lindfors, C. (2003). *Process oriented information management in construction* Royal Institute of Technology, Stockholm.

Love, P. E. D. & Josephson, P.-E. (2004). Role of Error-Recovery Process in Projects. *Journal of management in engineering, 20*(2), 70-79.

Lyons, T. & Skitmore, M. (2004). Project risk management in the Queensland engineering construction industry: a survey. *International journal of project management*(22), 51-61.

March, J. G. & Shapira, Z. (1987). Managerial perspectives on risk and risk taking. *Management Science, 33*(11), 1404-1418.

Maytorena, E., Winch, G. M., Freeman, J. & Kiely, T. (2007). The influence of experience and information search styles on project risk identification performance. *IEEE Transactions on Engineering Management, 54*(2), 315-326.

McCrae, R. R. & Costa, T. P. (1989). More reasons to adopt the five-factor model. *American psychologist, 44*(2), 451-452.

Merriam, S. B. (1998). *Qualitative research and case study applications in education* (2nd ed.). San Francisco: Jossey-Bass inc.

Murray, H., A. (1938). *Explorations in personality*. New york: Oxford U.P.

Nylén, K.-O. (1999). *Civil Works- Unique projects or repeatable process?* . The Royal Institute of Technology, Stockholm.

Ones, S. D., Dilchert, S., Viswesvaran, C. & Judge, A. T. (2007). In support of personality assessment in organizational settings *Personnel psychology*(60), 995-1027.

Osipova, E. (2007, 14-15 June). *Risk management in the different phases of a construction project-a study of actors´ involvement* Paper presented at the 4th Nordic Conference on Construction Economics and Organisation, Luleå University of Technology, Sweden.

Osipova, E. & Atkin, B. (2008, 11-15 February). *From project-oriented to process-oriented risk management in construction.* Paper presented at the Conference proceedings BEAR 2008 : Building Resilience, Kandalama, Sri Lanka.

PMBOK. (2000). *A guide to the project management body of knowledge*. Newton Square: Project Management Institute.

Raz, T. & Michael, E. (2001). Use and benefits of tools for project risk management. *International Journal of Project Management, 19*(1), 9.

Reason, J. (1990). *Human Error*. Cambridge: Cambridge University Press.

Reason, J. (1997). *Managing the risks of organizational accidents*: Ashgate.

Rhodin, A. (2002). *Interaktionsprocesser i byggprojekt: en studie i partnering som kraft för förändring.* Luleå University of Technology, Luleå.

Robson, C. (2002). *Real world research* (2nd ed.). Oxford: Blackwell publishing

Rundmo, T., Tharaldsen, J. E. & Olsen, E. (2007). Associations between risk perception and risk-taking behaviour. In A. Vinnem (Ed.), *Risk reliability and societal safety: proceedings of the European Safety and Reliability Conference ESREL 2007* (Vol. 2, pp. 1631-1637). London: Taylor and Francis Group.

Sanz, J., Gil, F., Garcia-Vera, M. P. & Barrasa, A. (2008). Needs and Cognitive/Behavior Patterns at Work and the Big Five: An assessment of the Personality and Preference Inventory-Normative (PAPI-N) from the perspective of the five-factor model. *International Journal of Selection and Assessment, 16*(1).

SCB, S. S. (2008). *Yearbook of Housing and Building Statistics 2008*.

Senge, P. M. (1995). *Den femte disciplinen*: Nerenius & Santérus.

Simu, K. (2006). *Risk management in small construction projects* Luleå University of Technology.

Sjöberg, L. (1999). Consequences of percieved risk: Demand for mitigation. *Journal of risk research, 2*, 129-149.

Sjöberg, L. (2000a). Consequence Matter, "Risk" is Marginal. *Journal of risk research, 3*, 287-295.

Sjöberg, L. (2000b). New Age and Risk Perception. *Risk Analysis, 22*, 751-764.

Sjöberg, L. (2003a). Distal factors in risk perception *Journal of risk research 6*, 187-211.

Sjöberg, L. (2003b). Riskperception och attityder. *Ekonomisk debatt*(6), 22-31.

Skitmore, R. M., Stradling, S. G. & Tuohy, A. P. (1989). Project management under uncertainty. *Construction Management and Economics*(7), 103-113.

Slovic, P. (1987). Perception of risk. *Science*(236), 280-285.

Smallman, C. (1996). Risk and organizational behaviour: a research model. *Disaster prevention and management, 5*(2), 12-26.

Smith, J. N., Merna, T. & Jobling, P. (2006). *Managing risk in construction projects* (2nd ed.): Blackwell Science.

SOU. (2000). *SOU 2000:44 Från byggsekt till byggsektor* (No. 2000:44): Fritzes offentliga publikationer.

SOU. (2002). *SOU 2002:115 Skärpning gubbar! Om konkurrensen, kvaliteten, kostnaderna och kompetensen i byggsektorn. Byggkommissionens betänkande* (No. SOU_2002:115): Norstedts.

Stahl, B. C., Lichtenstein, Y. & Mangan, A. (2003). The limits of risk management- a social construction approach. *Communications of the International Information Management Association, 3*(3), 15-22.

Styhre, A. & Josephson, P.-E. (2006). Revisiting site manager work: stuck in the middle? *Construction Management and Economics, 24*(5), 521-528.

Sweden PAPI-N Norms. (2006).): Cubiks.

Sveriges Byggindustrier. (2008). Retrieved 2008-11-14

Theorell, T. (2006). *I spåren av 90-talet*. Stockholm: Karolinska Institutet University Press.

Thompson, M. K., Deisler, F. P. J. & Schwing, C. R. (2005). Interdisciplinary Vision: The First 25 Years of the Society for Risk Analysis (SRA), 1980-2005. *Risk Analysis, 25*(6).

Tichy, N. M. (1983). *Managing strategic change*. New York: John Wiley & Sons.

Tupes, E. C. & Christal, R. E. (1992). Recurrent Personality Factors Based on Trait Ratings. *Journal of Personality, 60*(2), 225-251.

Tversky, A. & Kahneman, D. (1974). Judgement under uncertainty: Heuristics and biases. *Science*(185), 1124-1131.

van Wyk, R. R. (2008). Project risk management practice: The case of a South African utility company. *International journal of project management, 26*(2), 149-163.

Ward, S. & Chapman, C. (2003). Transforming project risk management into project uncertainty management. *International Journal of Project Management, 21*(2), 97-105.

Vennström, A. (2008). *The Construction Client as a Change Agent.* Luleå University of Technology, Luleå.

Wickens, C. D. & Hollands, J. G. (2000). *Engineering psychology and human performance* (3rd ed.). New Jersey: Prentice-Hall Inc.

Wiguna, I. P. A. & Scott, S. (2006). Relating risk to project performance in Indonesian building contracts. *Construction Management and Economics, 24*(11), 1125-1135.

Yeung, J. F. Y., Chan, A. P. C., Chan, D. W. M. & Li, L. K. (2007). Development of a partnering performance index (PPI) for construction projects in Hong Kong: a Delphi study. *Construction Management and Economics, 25*(12), 1219-1237.

Yin, R. K. (1994). *Case Study Research, Design and methods* (Second ed. Vol. 5). Thousand Oaks: Sage publications, Inc.

Zeng, J., An, M. & Smith, J. N. (2007). Application of a fuzzy based decision making methodology to construction project risk assessment. *International journal of project management, 25*(6), 589-600.

Personal communication and support for data collection

Claes Andrén, Controller, Business control, NCC Construction Sweden AB
Mikael Hellström, Risk Manager, NCC Risk Management Group, NCC AB
Ulrika Mehrotra, Specialist, Human resources, NCC Construction Sweden AB
Kristina Lager, Professional Training Manager, NCC Construction Sweden AB
Anne-Marie Pettersson, Professional Training Officer, NCC Construction Sweden AB
Sören Pettersson, Manager of Organisation and Process Development, NCC Construction Sweden AB
Dan Wiklund, Risk Manager, Quality manager, NCC Construction Sweden AB

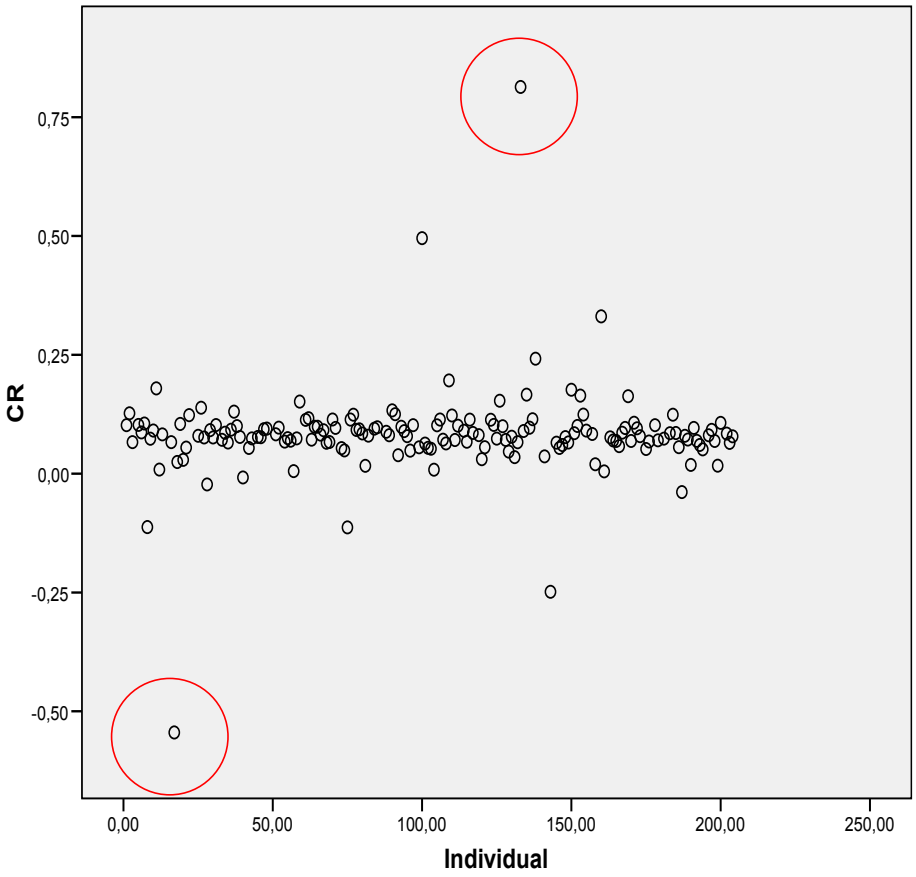
Monica Grundström, ecretary, Region Norrland, NCC Construction Sweden AB
Bo Hedén, Engineer Work Environment, Region Väst, NCC Construction Sweden AB
Jan Hedälv, Engineer Work Environment, Region Stockholm/Mälardalen, NCC Construction Sweden AB
Stig Hogebrandt, Engineer Work Environment, Region Norrland, NCC Construction Sweden AB
Lars-Gunnar Larsson, Manager Work Environment, NCC Construction Sweden AB
Rolf Svensson, Engineer Work Environment, Region Syd, NCC Construction Sweden AB
Rolf Tegner, Engineer Work Environment, Region Stockhom/Mälardalen, NCC Construction Sweden AB
Per Thörnblad, Engineer Work Environment, Region Öst, NCC Construction Sweden AB

David Morgenstern, Cubiks
Marika Vayrynen, Cubiks
Kate Young, Cubiks

Internal NCC Documents

Guidelines for certified site managers
Contents of Management system available at intra network within NCC AB

Appendix A- Identification of outliers



Appendix B Descriptions of PAPI scales

Those descriptions are taken from Cubiks technical manual of PAPI (Lewis & Andersson, 1998).

P Need to control other

This scale assesses the need to exert influence on the behaviour of others. It indicates the tendency to strive for a leadership position within the organisation. *High values* could either stand for that someone likes to influence and persuade others and that this person often will be a group leader *or* that this person do not like other to be in control and is a poor team member when not in control. *Low values* could either indicate that this person does not object others to take the lead and is prepared to cooperate with the leader's efforts *or* that this person stays in the background and relies on other to take control and seeks to avoid taking responsibility for the outcome of a group task.

L Leadership role

This scale measures how well a person perceives they perform in a managerial role. The focus is on the individual's confidence in themselves as manager and how they perceive the reactions of others in this respect. The traditional controlling and directing management functions are not emphasised in this scale. *High values* indicate that this person is confident that they are good managers and that they are prepared to be dominant *or* they are overly concerned about their status rather then the content of the job and can appear pompous and overconfident. *Low values* indicate that this person see themselves as technical specialists who want to develop in this direction and will let others take the leadership role *or* it indicates that this person is not confident in their management role and they may avoid leadership roles.

C Organised type

This scale measures the extent to which an individual perceives the importance of personal practical organisation. *High values* imply a person that gives the impression of being on top of their job, is neat and orderly and is in control of their present work load *or* it implies a person that may hide the inability to prioritise their work by using surface neatness/tidiness, that can be rigid and inflexible and may not cope with enforced disorder in their workplace. *Low values* indicate a person that is able to work in an untidy and disordered workplace and tends to be adaptable and flexible *or* indicates a person that appears disorganised and untidy, sees workspace efficiency as low priority and they may describe themselves as unmethodical.

H Integrative planner

This scale measures the extent to which an individual perceives themselves as planning their work in an integrative way. Here, planning refers to behaviour underpinned by a complex cognitive process involving several simultaneously occurring activities such as mentally holding and evaluating several ideas and possibilities, considering the consequences of each idea, thinking of contingencies and seeing the overall picture change as these are integrated – hence the Integrative Planner. The scale is at its most sensitive when considered in conjunction with other PAPI scales (eg 'R' and 'D') especially in relation to the 'integrative' dimension. For example, an Integrative Planner who has little future focus in terms of thinking about concepts and ideas (R-) may be systematic, but less prone to thinking about contingencies. They may respond to events more by organising rather than planning ahead for the future. *High values* imply a person who is able to see the overall picture of what is ahead and plans effectively for it and a person who is internally driven, setting their own schedules and deadlines *or* a person who is over confident that future events can be predicted accurately and may not be tolerant of alternative plans. *Low values* implies a person that has the ability to deal with unexpected events effectively and possesses a high level of spontaneity *or* a

person that expects others to give warnings of problems ahead and relies on deadlines to provide the impetus for delivery.

D Attention to detail

This scale measures the extent to which an individual perceives themselves to be conscious of detail. *High values* indicates a person that tend to be good at activities requiring precision and accuracy, they emphasises quality in their work, are good at fine tuning plans and ideas by detecting inconsistencies and deficiencies or it indicates a person that will not be satisfied with anything other then the highest quality, might be overly critical and may lose sight of the main objectives. Persons with high values may also tend to be perfectionists. *Low values* indicates that a person is willing to delegate detail to others and is able to ignore detail to produce the broad picture more quickly or it indicates that a person may act with insufficient or inaccurate information, may cut corners or may deliver things of quantity at the expense of quality.

W Need for rules and supervision

The W scale assesses the extent to which someone needs clear instructions and guidance when doing their job. *High values* indicate a person who conforms to policies, performs the job in the prescribed manner and the quality of the performance is likely to be predictable *or* it indicates a person that may lack flexibility, lack creativity in addressing work problems and expects to be 'spoon fed' instructions. *Low values* indicates a person that is more likely to use own initiatives and do not depend on supervision *or* a person that is unreliable and undependable in performing the job as specified, establishes own rules which may be in conflict with those of the organisation.

R Conceptual thinker

This scale measures the extent to which an individual perceives themselves to have a creative future focus for thinking about concepts, ideas and the general global picture. *High values* implies a person that can see problems from different angels, is intrinsically interested in ideas and comes up with novel solutions to problems *or* a person that appears to be unconcerned with daily events, is seen as impractical an unrealistic and are described as having their 'head in the clouds'. *Low values* implies a person that is resourceful rather then creative and can perform well on a day to day trouble shooting basis *or* a person that possibly finds it hard to visualise future events and has problems with discussing hypothetical issues.

Z Need for change

This scale measures the individual's need to try new thing and experience new situations. It essentially homes in on how easily bored someone can get when faced with routine tasks. *High values* indicates a person that is willing to try new things, welcomes the changing nature of work and organisations and does not value familiarity for its own sake *or* a person that is easily bored, can become restless if change is not frequent enough and finds routine jobs difficult to perform. *Low values* indicates a person that is happy to stay with tries and tested and adapts to routine easily *or* a person that tends to resist change and is possibly unable to adapt quickly to changes in work patterns.

N Need to finish a task

This scale assesses the extent to which individuals feel the need for closure; to finish what has been started. It gives some idea as to whether a person is inclined to leave things dangling in mid air or not.

(Note: 'N' is in some ways counterintuitive as a PAPI scale. Empirically, it loads more onto the 'Openness to Experience' factor rather than the 'Conscientious Persistence' factor as one might expect. From an interpretative point of view, 'N' functions to direct the individual's response to new experience, ie it establishes whether in searching for new experience, the individual is likely to have a need for closure. In a work context, it may be important to

establish whether a conceptual thinker with a high need for change is able to 'deliver' key task requirements).
High values indicate a person that take responsibility to finish the task they have begun regardless of how they have undertaken it and are prepared to exhibit self-discipline or a person for whom the completion of a task may be more important then its content and may indicate a narrow view of how to perform the job most effectively. *Low values* indicate a person who is prepared to start up a number of projects at the same time and is not obsessed with finishing the task personally *or* a person with poor insight into the practical implications of new and innovative ideas and has a low commitment to the task.

X Need to be noticed

This scale measures an individual's desire to be the centre of attention. It shows an inclination to behave in an unambiguously outgoing way in order to be noticed by others. *High values* indicates a person that seeks to be in the spotlight and welcome the acclaim of others *or* a person whose maintaining satisfactory job performance may depend on being the centre of attention and does thing for effect rather then to be effective. *Low values* indicate a person that does not seek to upstage others and does not need public recognition to motivate them *or* a person that may lack self assuredness and is unwilling to allow themselves to stand out in a group.

B Need to belong to groups

This scale indicates the extent to which an individual needs to be part of a group. *High values* indicates a person that enjoys the company of others and who prefers to work in a supportive team as a member *or* a person that is overly dependent of the group, that may focus on the group as an end itself rather then the task at hand and may find it difficult to work alone. *Low values* indicates a person that is self reliant and independent, and is able to resist group pressure *or* a person that tends to be a loner, avoids social stimulations and is insensitive to group needs.

S Social harmonizer

This scale measures the extent to which a person sees themselves as someone who is sociable, outgoing and friendly and as a consequence prevents tension and promotes harmony in the work place. *High values* indicates a person that is able to utilise superficial warmth to create and harmonious workplace, gets to know most people quickly, exhibits cordiality and avoids unpleasantness and sees people positively or a person for whom the creating the right atmosphere in the workplace takes priority over doing the job and spend work time on social interaction. *Low values* indicates a person that can possibly work in an atmosphere of unpleasantness, are more able to display assertive behaviours, does not have high expectations of other people's pleasantness and may be task focused *or* it indicates a person that may lack exuberance, may appear aloof, may possibly lack interactive skills e.g. tactfulness and is unconcerned about their impact on others.

O Need to relate closely to others

This scale measures the extent to which an individual feels a need to be close to other individuals in the work setting. It also assesses whether the individual is able and willing to give something of themselves to others, ie to share feelings and 'open up' to people in order to develop empathy and rapport with them. *High values* indicates a person that tends to be affectionate and friendly, who genuinely likes people, is sensitive to the feelings of others and who forms close attachments easily *or* a person that is easily hurt, is not sufficiently aware of the shortcomings of others and is subjective in the judgements. *Low values* indicate a person that is objective and impartial in their assessment of others and is emotionally self-sufficient *or* a person that tends to be formal and distant and might appear unfriendly and secretive.

I Ease in decision making

This scale measures the extent to which an individual perceives themselves to be a rapid decision maker. The emphasis is on the individual responding quickly to the decision-making process regardless of whether that is what the situation demands. In this sense, decision making may not be just a response behaviour but may reflect a striving to make decisions as quickly as possible and move on to the next issue *High values* indicates a person that is comfortable with making quick decision, sees speed to be of the essence, is prepared to, and enjoys taking risks and may be opportunistic *or* it indicates a person that may be impulsive, for whom decision may not be based on informed judgements and for whom speed is more important then accuracy (See also scale D) Low values indicates a person that makes well-considered decisions and tend to be cautious or a person that suffers from indecisiveness, someone who tends to ponder too long and who may miss opportunities.

T Work pace

This scale measures a person's perceived work pace and energy output. It gives insight into a person's likely work throughput and response to external demands such as deadlines imposed by others or by events. *High values* indicates a person that has a fast and enthusiastic work style, someone who responds well to external demands and has a strong sense of urgency *or* it indicates a person that may become careless and error prone and who believes that all work demands can be met effectively (gets lulled into a false sense of security). *Low values* indicates a person that can control external urgency during times of stress, who prevents thoughtless, reactive work activity, someone that will not be hurried into mistakes and is easy going *or* a person that is too relaxed to deal with the changing demands of the job, has little concern for time and pace and can be a slow worker.

K Need to be forceful

This scale measures the extent to which someone is prepared to aggressively push for what they want. This may include dealing with people 'head on'. *High values* indicates a person that is prepared to be honest about how they fell, is willing to face conflict, can be powerful in negotiations and often get their way and gets thing done *or* it indicates a person that will often choose to compete rather then cooperate, someone who tends to be aggressive and is prone to confrontations. *Low values* indicates a person that takes a considered approach when handling conflict, is seen as pleasant and who is prepared to listen *or* it indicates a person that is seen as self-effacing with low self-esteem and someone who turns away from conflicts and confrontations.

E Emotional restraint

This scale measures the extent to which an individual perceives that they can keep their emotions under control, presenting a calm, controlled exterior. *High values* indicates a person that tends to keep emotions under control, someone who prevents disharmony by not exhibiting feelings of anger or aggression and who appears to forgive and forget or it indicates a person who can be source of stress to keep emotions 'bottled up', may be seen as unconcerned and others may suspect there is a discrepancy between behaviour and feelings, causing apprehension. *Low values* indicates a person whom other people know where they stand, some one who is seen as open and direct and someone able to show positive emotions can raise the level of enthusiasm of the work team *or* it indicates a person who has little reluctance to express anger when necessary, who may lose respect of other s by showing emotions too openly and may be seen as a bully (possibly uses emotions to 'lean' on people).

A Need to achieve

This scale indicates how important it is for someone to be successful in their job or career. It indicates those who are really striving to get on. *High values* indicates a person who sets their sights on achieving difficult tasks to enhance job/ career success, someone who will achieve more then is expected of them and who may work harder to achieve goals *or* it indicates a person who may invest too much in their work at the expense of other aspects of their life,

who could become a 'workaholic' and may experience high levels of stress. *Low values* indicates a person who has a balanced view of work in relation to other aspects of their lives and who remains motivated even though career progression is not available *or* it indicates a person who could be lackadaisical or even lazy, someone who requires constant supervision to keep their performance at satisfactory level and who may appear to lack ambition and be seen as aimless.

F Need to be supportive

This scale measures the extent to which someone wants to help and be seen to help their boss and the organisation. It often indicates someone's awareness of the political subtleties of the organisation. *High values* indicate a person that is loyal to their employers, is a good team member, is aware of the political subtleties of the organisation and will protect those to whom they report *or* it indicates a person who may indulge in political manoeuvring to protect own interest, who will not protect their staff against those more senior in the organisation and may be overly deferential. *Low values* indicates a person who works well without praise from those in authority, is less likely to manipulate the organisation to gain advancement *or* it indicates a person who questions the authority of those above them, may foster discontentment and may lack commitment to the aims of the organisation.

G Role of the hard worker

This scale measures the extent to which a person perceives the notion of hard work to be a motivational influence, i.e. work for the sake of it rather than as a result of external forces. *High values* indicates a person that sees the values of hard work and is motivated by hard work in itself *or* indicates a person who may not channel the hard work effectively, who sees hard work as the major element of doing a job well and creates unnecessary work to keep busy. *Low values* indicates a person that is inclined to focus on efficiency rather then effort and has a balanced view of what is necessary for effective job performance *or* it indicates a person who may be feeling demotivated at work, it can indicate the desire to avoid hard work and might indicate they are underemployed.

Social desire

This scale may give an indication as to whether someone is attempting to present themselves in the best possible way, that is they are offering a socially desirable rather than an accurate self-perception. *High values* indicate a person who might refuse to admit to any personal negative behaviour, is anxious to be seen in a positive light by others, may have a poor self-knowledge and insight and who may simply set themselves very high personal moral standards. *Low values* indicate a person who may be honest enough to admit to negative behaviour and may indicate that they have responded to the questionnaire by expressing their view of themselves accurately.

Appendix C-

Regression analyses on joint sample

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	D Attention to detail, H Integrative planner(a)	.	Enter

a All requested variables entered.
b Dependent Variable: CR

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,020(a)	,000	-,011	,061939	,000	,038	2	182	,963

a Predictors: (Constant), D Attention to detail, H Integrative planner

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations		
		B	Std. Error	Beta	Lower Bound	Upper Bound	Zero-order	Partial	Part	B	Std. Error
1	(Constant)	,089	,036		2,495	,013	,019	,159			
	H Integrative planner	2,03E-005	,001	,001	,015	,988	-,003	,003	-,011	,001	,001
	D Attention to detail	,000	,001	-,021	-,234	,815	-,002	,002	-,020	-,017	-,017

a Dependent Variable: Total CR

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	T Work pace, I Ease in decision making(a)	.	Enter

a All requested variables entered.
b Dependent Variable: Total CR

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,107(a)	,011	,001	,061598	,011	1,049	2	182	,353

a Predictors: (Constant), T Work pace, I Ease in decision making

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations		
		B	Std. Error	Beta	Lower Bound	Upper Bound	Zero-order	Partial	Part	B	Std. Error
1	(Constant)	,031	,036		,882	,379	-,039	,102			
	I Ease in decision making	,001	,001	,061	,673	,502	-,001	,003	,096	,050	,050
	T Work pace	,001	,001	,059	,647	,519	-,002	,004	,095	,048	,048

a Dependent Variable: Total CR

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	K Need to be forceful	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a Dependent Variable: Total CR

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,191(a)	,037	,031	,060644	,037	6,936	1	183	,009

a Predictors: (Constant), K Need to be forceful

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations		
		B	Std. Error	Beta	Lower Bound	Upper Bound	Zero-order	Partial	Part	B	Std. Error
1	(Constant)	,004	,030		,146	,884	-,054	,063			
	K Need to be forceful	,003	,001	,191	2,634	,009	,001	,004	,191	,191	,191

a Dependent Variable: Total CR

Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	G Hard worker	-,005(a)	-,065	,949	-,005	,951
	P Need to control others	-,064(a)	-,775	,439	-,057	,781
	L Leadership role	,010(a)	,110	,912	,008	,684
	C Organised type	,040(a)	,499	,618	,037	,824
	H Intergrative planner	-,121(a)	-1,496	,136	-,110	,798
	D Attention to detail	-,100(a)	-1,290	,199	-,095	,877
	W Need for rules and supervision	,039(a)	,538	,592	,040	1,000
	R Conceptual thinker	,019(a)	,230	,819	,017	,794
	Z Need for change	,095(a)	1,138	,257	,084	,753
	N Need to finish a task	-,059(a)	-,740	,460	-,055	,841
	X Need to be noticed	-,006(a)	-,070	,944	-,005	,824
	B Need to belong to groups	-,005(a)	-,066	,948	-,005	,957
	S Social harmonizer	,125(a)	1,653	,100	,122	,905
	O Need to relate closely to others	-,053(a)	-,731	,466	-,054	,994
	I Ease in decision making	,011(a)	,140	,889	,010	,796
	T Work pace	,014(a)	,177	,860	,013	,812
	E Emotional restraint	,124(a)	1,698	,091	,125	,974
	A Need to achieve	,005(a)	,073	,942	,005	,946
	F Need to be supportive	,050(a)	,684	,495	,051	,994
	SD Social desire	-,016(a)	-,215	,830	-,016	,992

a Predictors in the Model: (Constant), K Need to be forceful
b Dependent Variable: Total CR

Appendix D – Correlation analysis between indicators

Correlation analysis for Sample 1 and 2

Sample 1		Contribution ratio, CR	Accidents	Audit result
Contribution ratio, CR	Pearson Correlation	1	,091	-,005
	Sig. (2-tailed)		,570	,982
	N	169	41	27
Accidents	Pearson Correlation	,091	1	,224
	Sig. (2-tailed)	,570		,563
	N	41	41	9
Audit result	Pearson Correlation	-,005	,224	1
	Sig. (2-tailed)	,982	,563	
	N	27	9	27

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Sample 2		Contribution ratio, CR	Audit result	Accidents	Insurance cases
Contribution ratio, CR	Pearson Correlation	1	-,405	-,263	-,426
	Sig. (2-tailed)		,217	,385	,253
	N	77	11	13	9
Audit result	Pearson Correlation	-,405	1	,500	.(a)
	Sig. (2-tailed)	,217		,667	.
	N	11	14	3	0
Accidents	Pearson Correlation	-,263	,500	1	.(a)
	Sig. (2-tailed)	,385	,667		.
	N	13	3	15	2
Insurance cases	Pearson Correlation	-,426	.(a)	.(a)	1
	Sig. (2-tailed)	,253	.	.	
	N	9	0	2	11

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
a Cannot be computed because at least one of the variables is constant.

Joint sample		Contribution ratio, CR	Insurance cases	Accidents	Audit result
Contribution ratio, CR	Pearson Correlation	1	-,426	,030	-,042
	Sig. (2-tailed)		,253	,836	,807
	N	225	9	49	36
Insurance cases	Pearson Correlation	-,426	1	.(a)	.(a)
	Sig. (2-tailed)	,253		.	.
	N	9	11	2	0
Accidents	Pearson Correlation	,030	.(a)	1	,132
	Sig. (2-tailed)	,836	.		,683
	N	49	2	51	12
Audit result	Pearson Correlation	-,042	.(a)	,132	1
	Sig. (2-tailed)	,807	.	,683	
	N	36	0	12	39

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
a Cannot be computed because at least one of the variables is constant.

Factor analysis for Sample 1

Communalities

	Initial	Extraction
Contribution ratio, CR	1,000	,487
Accidents	1,000	,419
Audit result	1,000	,125

Extraction Method: Principal Component Analysis.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,030	34,345	34,345	1,030	34,345	34,345
2	,997	33,239	67,584			
3	,972	32,416	100,000			

Extraction Method: Principal Component Analysis.

Appendix E – Cross tabulation Sample 1 & 2 – Fisher's exact test

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Sample * FSK	260	100,0%	0	,0%	260	100,0%

Sample * FSK Crosstabulation

			FSK		Total
			Insurence case	No insurence case	Insurence case
Sample	Sample 1	Count	0	169	169
		Expected Count	7,2	161,9	169,0
		Residual	-7,2	7,2	
	Sample 2	Count	11	80	91
		Expected Count	3,9	87,2	91,0
		Residual	7,2	-7,2	
Total		Count	11	249	260
		Expected Count	11,0	249,0	260,0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	21,331(b)	1	,000	,000	,000	
Continuity Correction(a)	18,452	1	,000			
Likelihood Ratio	24,011	1	,000	,000	,000	
Fisher's Exact Test				,000	,000	
Linear-by-Linear Association	21,249(c)	1	,000	,000	,000	,000
N of Valid Cases	260					

a Computed only for a 2x2 table
b 1 cells (25,0%) have expected count less than 5. The minimum expected count is 3,85.
c The standardized statistic is -4,610.

Appendix F – Certainty in economic deliver

Table.1 Comparisons between budget/forecast at an early stage in projects, 20% of production time, and the final results in per cent

Individual A	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	7	7	0 No correlation found
Project 2	5	-1	-6
Project 3	7	1	-6
Individual B	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	10	9	-1
Project 2	9	-5	-14
Project 3	8	-7	-15
Project 4	9	11	2
Project 5	10	9	-1
Project 6	10	10	0
Project 7	10	10	0
Individual C	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	12	-15	-27
Project 2	8	8	0
Project 3	6	6	0
Project 4	39	40	1
Project 5	8	16	8
Project 6	8	12	4
Individual D	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	9	13	4
Project 2	9	13	4
Project 3	12	21	9
Project 4	8	21	13

Individual E	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	9	18	9
Individual F	**CR at 20% of production time**	**CR at 20% of production time**	**Difference in percentage points**
Project 1	7	14	7
Project 2	8	-7	-15
Individual G	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	10	13	3
Project 2	3	3	0
Project 3	10	15	5
Project 4	11	12	1
Project 5	10	24	14
Project 6	11	23	12
Individual H	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	9	-2	-11
Project 2	8	10	2
Individual I	**CR at 20% of production time**	**CR at 100% of production time**	**Difference in percentage points**
Project 1	8	18	10
Project 2	8	12	4

Appendix G- Descriptions of PAPI scales

The descriptive statistics is used to present the data collected in this study and the data is sorted in three different groups, the total population of site managers in NCC, and the two different samples consisting of 169 and 91 individuals from the total population of 701.

Descriptive statistics for age-distribution in sample 1, sample 2 and for the total population, see Figure 1, Figure 2 and Figure 3.

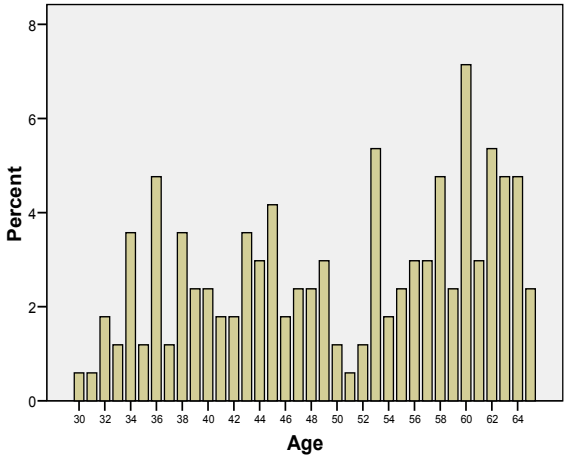


Figure 1. Distribution of age within the first sample.

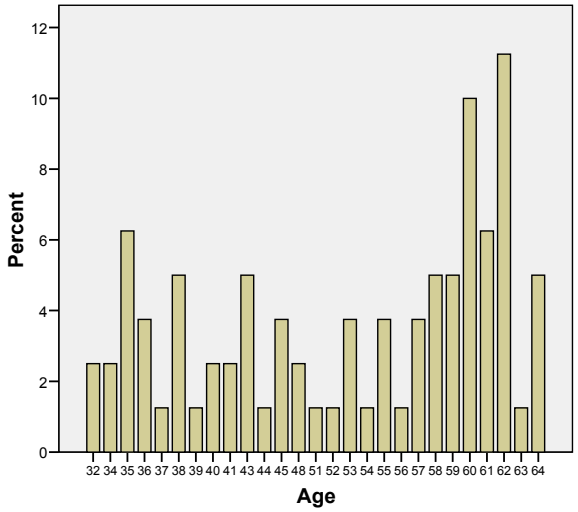


Figure 2. Distribution of age within the second sample.

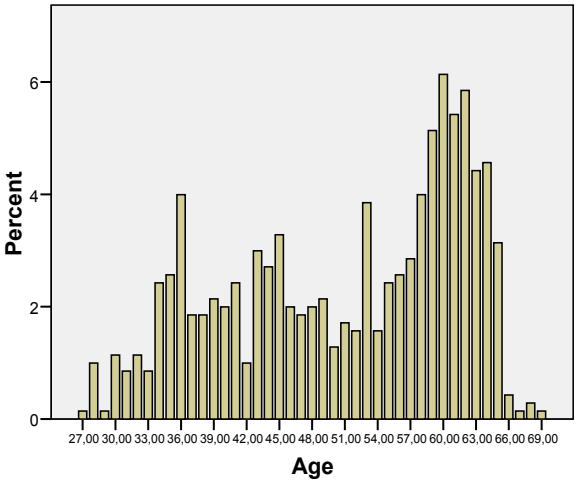


Figure 3. Distribution of age within the total population.

Appendix H - Differences in CR

Differences in CR in relation to basic education

Anova for the joint sample

ANOVA

Total CR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,005	3	,002	,419	,740
Within Groups	,815	211	,004		
Total	,820	214			

T-test, differences in CR in relation to certified site managers

Joint sample

Group Statistics

	Cert PC /PC	N	Mean	Std. Deviation	Std. Error Mean
Total CR	Certified Site manager	125	,08554	,071660	,006409
	Site manager	90	,07232	,044189	,004658

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Total CR	Equal variances assumed	1,737	,189	1,551	213	,122	,013224	,008528	-,003586	,030034
	Equal variances not assumed			1,669	208,528	,097	,013224	,007923	-,002396	,028844

Cross tabulation with Fisher´s exact test for certified and not certified site managers

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Cert PC /PC * FSK	248	95,4%	12	4,6%	260	100,0%

Cert PC /PC * FSK Crosstabulation

			FSK		Total
			Insurence case	No insurence case	Insurence case
Cert PC /PC	Certified Site manager	Count	3	137	140
		Expected Count	5,6	134,4	140,0
		Residual	-2,6	2,6	
	Site manager	Count	7	101	108
		Expected Count	4,4	103,6	108,0
		Residual	2,6	-2,6	
Total		Count	10	238	248
		Expected Count	10,0	238,0	248,0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2,966(b)	1	,085	,108	,082	
Continuity Correction(a)	1,951	1	,163			
Likelihood Ratio	2,971	1	,085	,108	,082	
Fisher's Exact Test				,108	,082	
Linear-by-Linear Association	2,954(c)	1	,086	,108	,082	,062
N of Valid Cases	248					

a Computed only for a 2x2 table
b 1 cells (25,0%) have expected count less than 5. The minimum expected count is 4,35.
c The standardized statistic is -1,719.

Appendix I – Correlations analysis

Pearson correlation sample 1

		Total CR
Total CR	Pearson Correlation	1
	Sig. (2-tailed)	
	N	169
G Hard worker	Pearson Correlation	,035
	Sig. (2-tailed)	,656
	N	166
P Need to control others	Pearson Correlation	,064
	Sig. (2-tailed)	,415
	N	166
L Leadership role	Pearson Correlation	,129
	Sig. (2-tailed)	,096
	N	166
C Organised type	Pearson Correlation	,093
	Sig. (2-tailed)	,231
	N	166
H Intergrative planner	Pearson Correlation	-,007
	Sig. (2-tailed)	,930
	N	166
D Attention to detail	Pearson Correlation	-,030
	Sig. (2-tailed)	,699
	N	166
W Need for rules and supervision	Pearson Correlation	,044
	Sig. (2-tailed)	,571
	N	166
R Conceptual thinker	Pearson Correlation	,087
	Sig. (2-tailed)	,265
	N	166
Z Need for change	Pearson Correlation	,171(*)
	Sig. (2-tailed)	,027
	N	166
N Need to finish a task	Pearson Correlation	,020
	Sig. (2-tailed)	,797
	N	166
X Need to be noticed	Pearson Correlation	,098
	Sig. (2-tailed)	,208
	N	166
B Need to belong to groups	Pearson Correlation	,052
	Sig. (2-tailed)	,502
	N	166
S Social harmonizer	Pearson Correlation	,168(*)
	Sig. (2-tailed)	,030
	N	166
O Need to relate closely to others	Pearson Correlation	-,009

	Sig. (2-tailed)	,911
	N	166
I Ease in decision making	Pearson Correlation	,090
	Sig. (2-tailed)	,247
	N	166
T Work pace	Pearson Correlation	,106
	Sig. (2-tailed)	,173
	N	166
K Need to be forceful	Pearson Correlation	,192(*)
	Sig. (2-tailed)	,013
	N	166
E Emotional restraint	Pearson Correlation	,094
	Sig. (2-tailed)	,230
	N	166
A Need to achieve	Pearson Correlation	,059
	Sig. (2-tailed)	,450
	N	166
F Need to be supportive	Pearson Correlation	,075
	Sig. (2-tailed)	,334
	N	166
SD Social desire	Pearson Correlation	-,023
	Sig. (2-tailed)	,771
	N	166

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Spearman's rho sample 1

Spearman's rho			Number of accidents	Results audits
	Number of accidents	Correlation Coefficient	1,000	,380
		Sig. (2-tailed)	.	,314
		N	41	9
	Results audits	Correlation Coefficient	,380	1,000
		Sig. (2-tailed)	,314	.
		N	9	27
	G Hard worker	Correlation Coefficient	-,037	-,467(*)
		Sig. (2-tailed)	,822	,014
		N	39	27
	P Need to control others	Correlation Coefficient	-,044	,001
		Sig. (2-tailed)	,791	,996
		N	39	27
	L Leadership role	Correlation Coefficient	,025	-,104
		Sig. (2-tailed)	,880	,605
		N	39	27
	C Organised type	Correlation Coefficient	,004	-,254
		Sig. (2-tailed)	,979	,201
		N	39	27
	H Intergrative planner	Correlation Coefficient	-,129	-,263
		Sig. (2-tailed)	,433	,184
		N	39	27
	D Attention to detail	Correlation Coefficient	-,155	-,190
		Sig. (2-tailed)	,347	,343
		N	39	27
	W Need for rules and supervision	Correlation Coefficient	-,263	-,332
		Sig. (2-tailed)	,106	,091
		N	39	27
	R Conceptual thinker	Correlation Coefficient	-,103	-,041
		Sig. (2-tailed)	,534	,839
		N	39	27
	Z Need for change	Correlation Coefficient	-,089	,005
		Sig. (2-tailed)	,592	,982
		N	39	27
	N Need to finish a task	Correlation Coefficient	-,103	-,069
		Sig. (2-tailed)	,533	,731
		N	39	27

	X Need to be noticed	Correlation Coefficient	-,069	-,117
		Sig. (2-tailed)	,674	,560
		N	39	27
	B Need to belong to groups	Correlation Coefficient	,004	,040
		Sig. (2-tailed)	,980	,844
		N	39	27
	S Social harmonizer	Correlation Coefficient	-,151	,201
		Sig. (2-tailed)	,359	,315
		N	39	27
	O Need to relate closely to others	Correlation Coefficient	,013	-,063
		Sig. (2-tailed)	,935	,756
		N	39	27
	I Ease in decision making	Correlation Coefficient	,041	,314
		Sig. (2-tailed)	,803	,110
		N	39	27
	T Work pace	Correlation Coefficient	-,061	-,070
		Sig. (2-tailed)	,711	,728
		N	39	27
	K Need to be forceful	Correlation Coefficient	-,008	-,098
		Sig. (2-tailed)	,960	,628
		N	39	27
	E Emotional restraint	Correlation Coefficient	-,034	,049
		Sig. (2-tailed)	,836	,809
		N	39	27
	A Need to achieve	Correlation Coefficient	,041	-,117
		Sig. (2-tailed)	,802	,561
		N	39	27
	F Need to be supportive	Correlation Coefficient	,011	-,004
		Sig. (2-tailed)	,945	,984
		N	39	27
	SD Social desire	Correlation Coefficient	,309	-,019
		Sig. (2-tailed)	,056	,926
		N	39	27

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Pearson correlation sample 2

		CR
CR	Pearson Correlation	1
	Sig. (2-tailed)	
	N	77
G	Pearson Correlation	,258
	Sig. (2-tailed)	,108
	N	40
P	Pearson Correlation	-,074
	Sig. (2-tailed)	,652
	N	40
L	Pearson Correlation	,035
	Sig. (2-tailed)	,832
	N	40
C	Pearson Correlation	,281
	Sig. (2-tailed)	,079
	N	40
H	Pearson Correlation	,071
	Sig. (2-tailed)	,661
	N	40
D	Pearson Correlation	,108
	Sig. (2-tailed)	,507
	N	40
W	Pearson Correlation	-,009
	Sig. (2-tailed)	,957
	N	40
R	Pearson Correlation	,172
	Sig. (2-tailed)	,289
	N	40
Z	Pearson Correlation	,211
	Sig. (2-tailed)	,190
	N	40
N	Pearson Correlation	,125
	Sig. (2-tailed)	,441
	N	40
X	Pearson Correlation	-,093
	Sig. (2-tailed)	,569
	N	40
B	Pearson Correlation	-,007
	Sig. (2-tailed)	,967
	N	40
S	Pearson Correlation	,119
	Sig. (2-tailed)	,466
	N	40
O	Pearson Correlation	-,183
	Sig. (2-tailed)	,258
	N	40
T	Pearson Correlation	,085
	Sig. (2-tailed)	,603
	N	40

K	Pearson Correlation	,092
	Sig. (2-tailed)	,571
	N	40
E	Pearson Correlation	,087
	Sig. (2-tailed)	,593
	N	40
A	Pearson Correlation	,227
	Sig. (2-tailed)	,159
	N	40
F	Pearson Correlation	,072
	Sig. (2-tailed)	,658
	N	40
SD	Pearson Correlation	,050
	Sig. (2-tailed)	,760
	N	40
I	Pearson Correlation	,182
	Sig. (2-tailed)	,261
	N	40

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Spearman’s rho sample 2

	Spearman's rho	Audit results	Accidents	Insurance cases
CR	Correlation Coefficient	-,371	-,356	-,450
	Sig. (2-tailed)	,262	,232	,224
	N	11	13	9
Audit results	Correlation Coefficient	1,000	,500	.
	Sig. (2-tailed)	.	,667	.
	N	14	3	0
Accidents	Correlation Coefficient	,500	1,000	.
	Sig. (2-tailed)	,667	.	.
	N	3	15	2
Insurance cases	Correlation Coefficient	.	.	1,000
	Sig. (2-tailed)	.	.	.
	N	0	2	11
G	Correlation Coefficient	-,176	-,063	,000
	Sig. (2-tailed)	,650	,881	1,000
	N	9	8	5
P	Correlation Coefficient	-,391	,064	,707
	Sig. (2-tailed)	,298	,881	,182
	N	9	8	5
L	Correlation Coefficient	-,261	-,195	-,250
	Sig. (2-tailed)	,498	,644	,685
	N	9	8	5
C	Correlation Coefficient	-,262	-,255	-,181
	Sig. (2-tailed)	,496	,542	,770
	N	9	8	5
H	Correlation Coefficient	-,442	-,260	,000
	Sig. (2-tailed)	,233	,534	1,000
	N	9	8	5
D	Correlation Coefficient	-,545	-,638	,544
	Sig. (2-tailed)	,129	,089	,343
	N	9	8	5
W	Correlation Coefficient	-,870(**)	,065	,354
	Sig. (2-tailed)	,002	,878	,559
	N	9	8	5
R	Correlation Coefficient	,136	-,577	-,354
	Sig. (2-tailed)	,727	,134	,559
	N	9	8	5
Z	Correlation Coefficient	-,130	,319	-,725
	Sig. (2-tailed)	,738	,442	,165
	N	9	8	5
N	Correlation Coefficient	-,177	-,127	,354

	Sig. (2-tailed)	,649	,765	,559
	N	9	8	5
X	Correlation Coefficient	-,087	,127	-,707
	Sig. (2-tailed)	,823	,765	,182
	N	9	8	5
B	Correlation Coefficient	-,611	,317	-,725
	Sig. (2-tailed)	,080	,444	,165
	N	9	8	5
S	Correlation Coefficient	-,264	-,064	-,725
	Sig. (2-tailed)	,492	,881	,165
	N	9	8	5
O	Correlation Coefficient	-,575	-,390	,707
	Sig. (2-tailed)	,105	,340	,182
	N	9	8	5
T	Correlation Coefficient	,000	,385	,186
	Sig. (2-tailed)	1,000	,346	,764
	N	9	8	5
K	Correlation Coefficient	-,346	,446	-,707
	Sig. (2-tailed)	,361	,268	,182
	N	9	8	5
E	Correlation Coefficient	-,480	-,507	-,354
	Sig. (2-tailed)	,191	,200	,559
	N	9	8	5
A	Correlation Coefficient	,000	,446	,725
	Sig. (2-tailed)	1,000	,268	,165
	N	9	8	5
F	Correlation Coefficient	-,393	,000	,707
	Sig. (2-tailed)	,295	1,000	,182
	N	9	8	5
SD	Correlation Coefficient	,087	,446	-,707
	Sig. (2-tailed)	,823	,268	,182
	N	9	8	5
I	Correlation Coefficient	,478	,064	-,707
	Sig. (2-tailed)	,193	,881	,182
	N	9	8	5

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).