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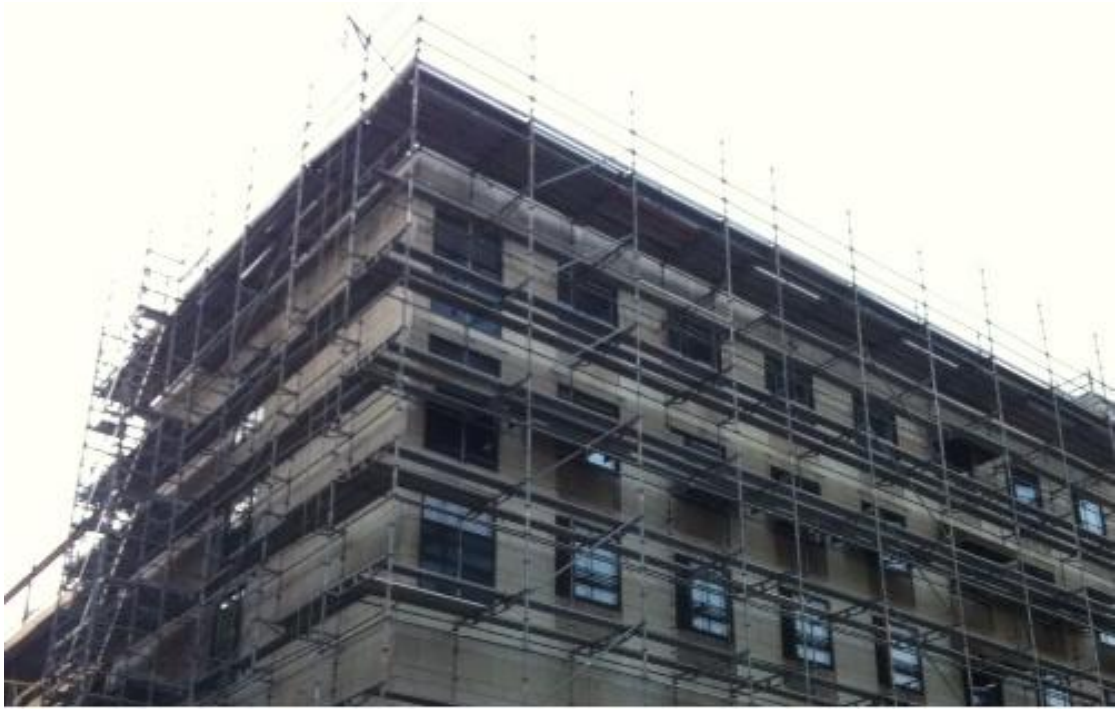

Uncertainties in Subcontractor Procurement

- The case of Scaffolding

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

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Göteborg, Sweden, 2013
Report No. 2013-1

MASTER'S THESIS 2013:1

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Cover:
A figure of scaffolding on a project related to the thesis

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Göteborg, Sweden 2013

Acknowledgements

This master thesis could not have been completed without the help and support from several individuals that have spent their valuable time and experience in order to help us. We would therefore like to direct our gratitude to:

- Per-Erik Josephson, supervisor
- Our supervisors at “CC”
- Julian Siering and Adam Svensson, peer reviewers
- All interviewees

With gratitude!

Gothenburg, March 2013

Christian Legnerot and Christian Lyckell

CONTENTS

1 – Introduction

This thesis began as an inquiry to the authors made by a Swedish contractor. The contractor had found that the actual costs tended to deviate in some accounts, in comparison to the initial calculations. This subject was found interesting, which in the end led to this thesis which investigates the process of subcontractor procurement, as a few of these accounts was explained to be especially difficult to predict.

The use of subcontractors in construction projects entails that the project specific organizations continuously has to work with new external members. As a result, the contractor may not have previous experience of certain subcontractors that they will work with, which creates uncertainty in the process. The temporary organization is also continuously dealing with unique projects. Consequently, uncertainties in the construction processes may exist, due to the limited ability of using previous knowledge in order to predict the future of certain events. Therefore, uncertainty is often found to a large degree in construction projects.

The concept of uncertainty affecting organizational processes has a long history in the study of organizations. Most organizations and individuals in general are sooner or later faced with uncertainty. Thus it is of great interest to understand its nature and origin, and to develop reducing mechanisms. While the term uncertainty is mentioned in much academic literature, there seems to be surprisingly little research on how it exists in and affects the construction industry.

While uncertainty commonly is accepted as inherent in the construction industry as explained by Johnson et.al. (2011), it is certainly more common in some parts of the construction process than in others. As the information available is less in the early processes, such as tendering and procurement, these should be among the processes most influenced by uncertainty.

The main purpose of this thesis is to identify and provide an understanding of the uncertainty areas affecting the process of procuring subcontractors in the construction industry. It is based on data from procurement of scaffolding subcontractors.

The main research questions are: What types of uncertainty exist in the process of subcontractor procurement? How do they affect the construction process? How could they be managed?

The thesis is divided into two parts. The first part describes the background, the literature review and the methodological aspects. In order to answer the research questions and the purpose of the article, uncertainty, uncertainty types, and the ways of managing uncertainty is reviewed and described in the literature chapter of the paper. The literature study is built from a variety of academic journals, books, encyclopedias, and reports that are related to uncertainty. The literature study begins with a compilation of various definitions of the term uncertainty, followed by uncertainty types connected to the process of tendering and procurement. Lastly, under the heading of Uncertainty Management, different ways of managing uncertainty in organizations are described. The second part of the thesis is written in the form of a research paper aimed for publication in conference proceedings.

2 – Literature study

Definitions of uncertainty

Uncertainty is commonly described as a key process in regard to several organizational areas, and has a long history in the study of organizations. It is based on the theory that it is difficult or even impossible to completely predict the future of certain events or choices. Clegg et.al. (2010) defines uncertainty as:

> *"…the inability to know how to continue some action, a lack of a rule or decidability about which rule to apply".*

Maylor (2010) does not define uncertainty per se, instead risk is defined as:

> *"Uncertainty inherit in plans and the possibility of something happening (i.e. a contingency) that can affect the prospect of achieving business or project goals".*

According to Maylor, this definition considers the fundamental idea that when you look into the future, as you do in project planning, there will always exist a degree of uncertainty. He further explains that uncertainty is inherent in projects as the future is impossible to predict with certainty. It exists in all of the environmental conditions in which the project operates. There could for example be uncertainty about the cost of staff, time, and materials, or an uncertainty whether the activity is actually achievable (Maylor, 2010).

Milleken (1987) defines uncertainty as:

> *"An individual's perceived inability to predict something accurately."*

Uncertainty is according to Milleken (1987) experienced when individuals perceive themselves to be lacking sufficient information, and are not able to distinguish between relevant and irrelevant data.

Mann (2011) provides two more definitions for uncertainty:

> *"When a person confronts an inability to predict the future"*

> *"An incompatibility between different cognitions, between cognitions and experiences, or between cognitions and behavior"*

While uncertainty often is a cause for problems in projects, it is commonly accepted as inherent (Johnson, et al., 2011). To which extent uncertainty is found problematic and stressful is however dependent on several things such as culture (Hofstede, 1983). Different cultures may either accept the uncertainty, or seek to avoid it (Hofstede, 1980). The preference for avoiding uncertainty is for example relatively low in Sweden compared to most Asian countries (Hofstede, 2001). Furthermore, individuals with a higher tolerance for ambiguity tend to perceive situations as less uncertain than individuals with lower tolerance (Downey et.al., 1977).

Uncertainty may also be seen as a source of individual power when a person has organizational skills that may reduce it (Clegg, et al., 2010). If a person has control over the uncertainty or has the necessary knowledge needed in order to reduce it, this person will be able to exert power (Hickson, et al., 1971). While there can be no doubt that power can be derived from the control over or knowledge of uncertainty, this is highly context-dependent.

In "Risk, Uncertainty, and Profit" (1921), Frank Knight emphasizes that there is a distinct difference between risk and uncertainty, which is important to keep in mind. He argues that the bearings of a certain phenomenon may have a measurable uncertainty factor that in effect is so far from an unmeasurable one that it is not really an uncertainty at all. Therefore, he argues

that uncertainty and risk should be separated, where uncertainty applies to cases of non-quantifiable types (Knight, 1921), and risk applies to known probabilities and outcomes (McAuliffe, 1998).

While a situation may be considered as uncertain when involving a risk, it can usually be converted into reasonable certainty by quantifying it. This is plausible, as most cases become predictable in accordance with the laws of chance when the number of cases is increased, as this reduces the error in predictions to a number approaching zero (Knight, 1921). Situations involving uncertainties as defined by Knight are usually more difficult for decision making than situations with quantifiable uncertainty, or as he describes it, a risk.

Based on the previous definitions of uncertainty, this paper will use the following definition as it also comprehends the separation of risk and uncertainty as defined by Knight (1921), where uncertainty applies to situations of the non-quantifiable type, and vice versa.

> *"A situation where an entity is phased with an inability to predict the future or the consequences of a certain decision or event based on quantifiable information"*

Types of uncertainty

As uncertainty is a very general term, all definitions and theories of uncertainty are of course not applicable to the construction industry with procurement of subcontractors as a main focus. In the literature research, the authors of this article found 22 types of uncertainty. Eight types of uncertainty were found to be relevant for the subject of subcontractor procurement; process, time, effect, option, information, bidding, contractual, and cost.

Process uncertainty

In the construction industry projects are commonly carried out by several cooperating organizations. As each project is unique, and so also the temporary project organization, there is always an amount of uncertainty regarding the process in the specific project but also regarding the temporary organization. Maylor (2010) mentions the possibility of for example uncovering an archeologically significant building when excavating which might cause months of delays in the project, and also the possibility of finding out that different teams or individuals does not function well together. When a process is uncertain there is a risk that this uncertainty will affect the time and cost calculations that has been made earlier in the project.

Time uncertainty

Construction projects are commonly characterized as having a high complexity, with several factors determining this feature. A large number of activities generally have to be performed in the correct order if project completion is to be achieved successfully. Consequently, time is of the essence and an efficient scheduling phase is crucial in order to ensure that the project follows the estimated time, and within the budget (Bruni, et al., 2011).

Furthermore, the construction industry exists in a complex and dynamic environment, which highlights the need for effective planning and scheduling. However it is hard to predict the future, and if the time for each project activity is uncertain, the project faces a risk of delayed activities affecting other activities, or the project as a whole, with unknown consequences (Bruni, et al., 2011). As the time for a specific activity is a major cost factor, an increased activity time will affect the cost for the involved subcontractor to a large extent.

Yeo and Ning (2004) argue that better management of time uncertainty in projects may contribute significantly to the project. They discuss the concept of implementing time buffers to

deal with this, which they however believe is often not done correctly or at least done ineffectively.

Effect uncertainty

Milliken (1987) describes effect uncertainty as the relation between cause and effect, which is unknown. A certain event may be likely to occur, but the effect on the organization is uncertain due to a lack of knowledge of the cause and effect relationship for this event. Hence, uncertainty also exists in the predicament on how to respond to it.

One example is strikes issued by labor unions. A strike could overthrow the whole time plan for the construction project leading to cost overruns due to delays etc. Even though the strike takes place the outcome of the strike could as well be limited to other projects. In this situation the effect uncertainty is high from the beginning until it is clear which projects that will be affected. Therefore it is important to consider the effects of each decision or procurement in the project.

Option uncertainty

Options available at the point of decision might be too limited due to a lack of imagination from the persons who compiled the set of alternatives. Due to this there may exist a number of unknown options that might be superior to the selected one. The sample of options in a decision situation might also contain options that are not feasible in practice (Lovell, 1995). Thus there exists a degree of uncertainty in decision-making processes.

An example of option uncertainty is the process of sub-contracting. Appropriate subcontractor relationships are essential for the project performance, and usually selected from two criteria: price and trust. According to Hartmann and Caerteling (2010), neither can be downplayed as an important mechanism. While the lowest price often is seen as the most important factor, trust is after all a result of successful dealings with this subcontractor in the past. As they have proven to provide good results in the past, they might actually be preferable over a new subcontractor even if their price is higher. This scenario could also be seen as a gamble (Lovell, 1995), where the probability of the "known" subcontractor meeting their terms to some extent is predictable, but not of the "unknown" subcontractor.

Informational uncertainty

In order to form social judgments and to be able to make decisions from the options available, proper information is needed. If there is a lack of proper information to base the decision on, informational uncertainty exists (Mann, 2011). It can be described simply by a decision made at a point when there was not enough information available to really support the decision.

Tendering is a process that tends to have problems with informational uncertainty. Studies have shown that the quality of tender documents is a major problem (Laryea, 2010). The tendering process requires extensive information and documents exchange. If the project information is unclear or inconsistent this may lead to poor tender documents which are common causes for inaccurate estimates, claims and contractual disputes (Laryea, 2010).

Bidding uncertainty

A contractor's project life cycle begins with a need for work and an invitation to bid on the project by a client, followed by an assessment of the bidding opportunity and a decision whether to submit a bid or not (Naert & Weverbergh, 1978). In most projects, the contractor submitting the lowest bid receives the contract (Hartmann & Caerteling, 2010). The client's decision on which contractor to use is thus quite straight-forward, while the contractor's deci-

sion on what price to bid is more complicated. Bidding low increases the chances of being awarded the project, but also reduces the profitability. Thus, the problem is estimating the probability of winning the bidding process as well as the uncertainty of costs involved in the project (Chapman, et al., 2000). Lowering the bid however also decreases the profitability margin and the tolerance for uncertainty. Quantifying the cost uncertainty in terms of a distribution of possible costs is essential if this uncertainty is to be taken into account (Chapman, et al., 2000)

Contractual uncertainty

Contractual uncertainty may exist when it is not clearly regulated in the contract who will take the consequences when an unforeseeable event occurs (Lonsdale, 2005).This might be problematic if the power distribution is in favor of either party. This occurs when there is a need to interpret a clause in the contract. When the contract is produced there are several things that cannot be known at that time, and therefore the contract does not directly regulate them (Lonsdale, 2005). The specifications of the contract with subcontractors are often also a source of uncertainty. Traditionally, lump sum is the method preferred even if alternative procurement forms could be considered. However, these types of procurement forms are often dependent on the organization's resources and experience (Love, et al., 2008).

Omran and Hussin (2011) argue that contractual claims are one of the most common causes of unwanted costs at a construction site. As such, it is important that both parties properly understand all terms of the contract, and that all duties and obligations within the scope of the contract is understood.

Cost uncertainty

Cost estimation is a fundamental task in construction projects (Ökmen & Öztas, 2010). However, as many risk factors affect the construction process, these estimations tend to deviate from the actual costs in a favorable direction (Ökmen & Öztas, 2010). Thus, analyses of the uncertainty affecting the estimation of costs are required. An example that may create risks of cost deviations is uncertain weather conditions.

Naert and Weverberg (1978) mention that cost uncertainty generally decreases the optimal expected profit and that the distribution ratio between estimated costs and actual costs varies with the markup.

According to Omran and Hussin (2011), there are numerous cases of unwanted costs at each project site. These are often also camouflaged as claims, or due to cost overruns following an extended project time.

Hartmann and Caerteling (2010), argue that the conceptualization of price and cost actually is quite straightforward. In proper subcontractor contracts it describes the cost for the work as well as surplus covering overhead costs and profit. However, they also argue that uncertainty does exist and is associated with the tenders, due to the uncertainty of estimating costs for a "tailor-made" product that previously did not exist.

Consequential costs may also occur due to uncertain project and site conditions, by ambiguity in contract clauses, due to the fault of other parties, or by other costs that are not covered in the contract price (Cao, et al., 2008). According to Cao et.al. (2008) these costs are often the result of loose contract agreements. In order to reveal and minimize the cost uncertainty, tender documents should be as accurate and detailed as possible.

Uncertainty management

As the uncertainty of future events is a common problem source in construction projects, the possibility of reducing or avoiding uncertainty is much sought for. By the previous definition made by Knight (1921), uncertainty, which can be reduced and calculated into quantifiable numbers, is per definition not an uncertainty, but rather a risk. Thus, one possible solution to reduce or eliminate uncertainty is to transform the uncertainty into quantifiable risks which the organization then can manage. Maylor (2010) claims that there are two approaches to reduce uncertainty; either you deal with the cause, or you deal with the effect. Furthermore, he argues that management should be deliberately structured in a way that takes advantage of both approaches. The causes of uncertainty should be analyzed and minimalized, and options on how to respond to the effects of the uncertainty should be researched. Managerial strategies introducing organizational flexibility is another way of dealing with project uncertainty (Blacud et.al., 2009) (Oyegoke et.al., 2008).

Knight (1921) further contends that the possibility of reducing risks depends on two sets of conditions that are fundamental; that uncertainty in groups is less than in single instances, and the differences among individuals in regard to the uncertainty. He mentions *priori probability theory* as an example of how uncertainty actually tends to disappear altogether when grouped with an increased number of similar situations. With statistical probabilities, the uncertainty tends to manifest in a less degree limited by defectiveness of classification. He also argues that the *true uncertainties* may show some extent of regularity when grouped together with other uncertainties, of almost any similarity or common elements.

With the two methods just mentioned, the reduction by grouping (consolidation) and the reduction of selecting individuals to "bear the responsibility" (specialization), Knight (1921) also adds two more methods of reducing uncertainty: the method of controlling the future, and the method of increasing the power of prediction. Both additional methods are closely interrelated to control and identifiable by the progress of civilization, technology and knowledge. According to Knight (1921) all these methods of dealing with uncertainty leads to a common goal which is to secure better knowledge of the future while at the same time gaining control over it.

Naert and Weverberg (1978) write about the problem with uncertainty involving cost estimates, and argue that while their paper is not actually about uncertainty in general; their approach of reducing uncertainty may still be applicable to other sources of uncertainty as well. They argue that the options available in decision making must be identified, as a lack of clarity contributes to uncertainty and if there are different choices, this creates further uncertainty. The uncertainty should be specified, its existence highlighted, and if possible quantified. While there will always exist an amount of uncertainty, it should be transparent when used in calculations and quantified as much as possible (Naert & Weverbergh, 1978).

Johnson et.al (2011) mention another approach of reducing uncertainty, and the effects of the uncertainty, *the real options approach*. The profitability analyses often carried out by managers require them to make possible non-realistic assumptions of the future. The real options approach is a way of using scenario analyses in order to analyze uncertain future activities and events. The idea is that this approach will defer decisions as far as possible, as the passage of time will clarify the expected results. Johnson et.al (2011) also argue that this might even lead to the possibility that apparently unfavorable and costly strategies may actually prove to be the best strategy in the end.

3 – Methodology

The main purpose of this thesis is to identify how uncertainty exists and affects the process of subcontractor procurement in the construction industry. The main research questions are: What types of uncertainty exist in the process of subcontractor procurement? How do they affect the construction process? How could they be managed? In order to answer these questions, a literature framework is composed where uncertainty is described. Then, a case study with a Swedish construction contractor concerning scaffolding subcontractor procurement is used in order to exemplify how this uncertainty exists and affects the procurement processes in practicality. As a way of determining how uncertainty exists in practical construction, e.g. to what extent uncertainty affects the processes of tendering and procurement as well as the possible consequences from this uncertainty, a case study involving a large Swedish construction contractor has been made. This construction contractor will further on be referred to as CC. The choice of using a case study was made as it is argued to be appropriate when investigating issues in a real-life context (Bryman, 2004).

At first to collect information, six interviews were conducted at CC. These included two site managers, one project manager, the head of the calculation office, the head of the procurement office, and a head of construction. The interviews were semi-structured in order to get a broader perspective on the interviewees opinions and let them mention what they believe is relevant for the paper's subject, and the possibility of asking follow-up questions. They took place at either CC's main office or at construction site offices, lasted for approximately one and a half hour each, and were focused on the interviewees' opinion on uncertainties in tendering and production.

Furthermore, tendering and procurement documents regarding four recently finished projects were examined in order to find actual differences and proofs of uncertainty between the tendering documents, procurement documents, and the actual results. In order to limit the information to a researchable amount, we chose to focus the research into tendering and procurement documents mainly on scaffolding subcontractors, who early on came up as one of the areas with the largest amount of uncertainty according to the interviewees.

In order to complement the results from the study of tendering and procurement documents, four interviews were held with the respective site managers for each project. These were more structured than the previous interviews, and focused on explanations for the results, and clarification of the circumstantial factors affecting each project.

Finally, the concept of uncertainty in tendering and procurement processes is analyzed and discussed based on the findings and the theoretical framework. Also, the eight types of uncertainty are quantified for sub-processes within subcontractor procurement.

4 – References

Blacud, N. A., Bogus, S. M., Diekmann, J. E. & Molenaar, K. R., 2009. Sensitivity of Construction Activities under Design Uncertainty. *Journal of Construction Engineering and Management,* pp. 199-206.

Bruni, M. E., Beraldi, P., Guerriero, F. & Pinto, E., 2011. A scheduling methodology for dealing with uncertainty in construction projects. *Engineering Computations, Vol 28 Iss:8,* pp. 1064-1078.

Bryman, A., 2004. *Social research methods.* Second ed. Oxford: Oxford university press.

Cao, D. T., Wang, S. Q. & Tiong, R., 2008. Management of uncertainties and consequential costs for construction projects in China. *Cost engineering, Aug, 50,8,* pp. 26-37.

Chapman, C., Ward, S. & Bennell, J., 2000. Incorporating uncertainty in competetive bidding. *International Journal of Project Management 18,* pp. 337-347.

Clegg, S., Kornberger, M. & Pitsis, T., 2010. *Managing & Organizations, second edition.* London: SAGE publications Ltd.

Downey, H. K., Hellriegel, D. & Slocum, Jr., J. W., 1977. Individual Characteristics as Sources of Perceived Uncertainty Variability. *Human Relations, Volume 30, Number 2,* pp. 161-174.

Hartmann, A. & Caerteling, J., 2010. Subcontractor procurement in construction: the interplay of price and trust. *Supply Chain Management: An International Journal 15/5,* pp. 354-362.

Hickson, D. J. et al., 1971. A strategic contingency theory of intraorganizational power. *Administrative Science Quarterly, 16, (2),* pp. 216-229.

Hofstede, G., 1980. *Culture's consequences: International differences in work-related values.,* Beverly Hills, CA: Sage.

Hofstede, G., 1983. National cultures in four dimensions - A Research-based Theory of Cultural Differences among Nations. *Int. Studies of Man. & Org., Vol. XIII, No 1-2,* pp. 46-74.

Hofstede, G., 2001. *Culture's Consequences: Comparing Values, Behaviors, Institutions, and Organizations Across Nations.* Second ed. Thousand Oaks CA: Sage Publications.

Johnson, G., Whittington, R. & Scholes, K., 2011. *Exploring Strategy, ninth edition.* Harlow: Financial Times Prentice Hall.

Knight, F. H., 1921. *Risk, Uncertainty, and Profit.* Cambridge: Hart, Schaffner & Marx; Boston: Houghton Mifflin Company, The Riverside Press, Cambridge.

Laryea, S., 2010. *Quality of tender documents: case studies from the UK,* Reading: School of Construction Management and Engineering, University of Reading.

Lonsdale, C., 2005. Contractual Uncertainty, Power and Public Contracting. *Jnl Publ. Pol., 25, 2,* pp. 219-240.

Love, P. E. D., Davis, P. R., Edwards, D. J. & Baccarini, D., 2008. Uncertainty avoidance: public sector clients and procurement selection. *The International Journal of Public Sector Management 21.7,* pp. 753-776.

Lovell, B. E., 1995. *A taxonomy of types of uncertainty,* Portland State University: Proquest Dissertation & Theses (PQDT).

Mann, A., 2011. *Managing Uncertainty During Organization Design Decision-Making Processes: The Moderating Effects of Different Types of Uncertainty,* Columbia University: UMI 3453258.

Maylor, H., 2010. *Project Management, fourth edition.* Harlow: Pearson Education Limited.

McAuliffe, R. E., 1998. Uncertainty (economics). In: *Encyclopedia of Management.* Malden: Blackwell Publishers ltd., p. 670.

Miller, S., 1995. Uncertainty. In: *Encyclopedic dictionary of organizational behavior.* Cambridge: Blackwell Publishers ltd., p. 592.
Miller, S., 1998. Uncertainty. In: *Encyclopedia of Management.* Malden: Blackwell Publishers ltd., p. 670.
Milliken, F. J., 1987. Three types of Perceived Uncertainty About the Environment: State, Effect, and Response Uncertainty. *Academy of Management Review, Vol. 12, No. 1,* pp. 133-143.
Naert, P. & Weverbergh, M., 1978. Cost Uncertainty in Competetive Bidding Models. *The journal of the Operational Research Society, Vol. 29, No 4,* pp. 361-372.
Omran, A. & Hussin, A. A., 2011. Minimizing the unnecessary costs on site. *Annals of faculty engineering Hunedoara - International Journal of Engineering, Tome IX, Fascicule 3,* pp. 69-78.
Oyegoke, A. S., Khalfan, M. M., McDermott, P. & Dickinson, M., 2008. Managing risk and uncertainty in an agile construction environment: application of agile building specialist model. *Int. J. Agile Systems and Management, Vol. 3, Nos. 3/4,* pp. 248-262.
Yeo, K. & Ning, J., 2004. Managing uncertainty in major equipment procurement in engineering projects. *European Journal of Operational Research 171,* pp. 123-134.
Ökmen, Ö. & Öztas, A., 2010. Construction cost analysis under uncertainty with correlated cost. *Construction Management and Economics, 28:2,* pp. 203-212.

Appendix 1 - Research Paper:

Uncertainties in subcontractor procurement
- The case of scaffolding

Christian Legnerot and Christian Lyckell

Abstract
The construction industry continuously deals with unique circumstances. Projects are commonly assembled by temporary organizations, often consisting of both internal staff and external staff, such as subcontractors. As each project is unique and so the temporary organization, uncertainty is often found to a large extent in construction projects. The purpose of this paper is to identify and provide an understanding on how uncertainty affects the process of procuring subcontractors in the construction industry. In order to do this, a literature study describing uncertainty, what types of uncertainty that exists in construction projects and how these could be managed, is composed. Furthermore, a case study involving a construction contractor in Sweden is used as a way of investigating how uncertainty affects construction processes.

The article identifies eight key types of uncertainty that affect the process of subcontractor procurement. The findings also show that uncertainty does play an important role in projects, manifesting in e.g. cost deviations and time delays. Finally, the paper presents a quantification of uncertainty types dependent on subcontractor procurement processes as a way of managing uncertainty, along with other recommendations.

Keywords: uncertainty, tendering, procurement, subcontractors, construction industry, scaffolding, managing uncertainty, project organizations

Introduction
How uncertainty affects organizational processes has for long been studied (Miller, 1995). Most organizations and individuals in general are sooner or later faced with uncertainty and the pressure to understand its nature and origin. Consequently, the development of uncertainty reducing activities has always been of great interest in order to cope with it (Miller, 1998).

While the term uncertainty is mentioned in much academic literature, there seems to be surprisingly little research on how it exists in and affects the construction industry. As construction continuously deals with unique circumstances, which can be difficult to predict, it could therefore be argued that uncertainty has a major effect on construction processes.

While uncertainty commonly is accepted as inherent in construction activities as explained by Johnson et.al. (2011) and Maylor (2010), it is certainly more common in some parts of the construction process. As the information available is less in the early processes, such as tendering and procurement, these are among the processes that are most influenced.

The main purpose of this paper is to identify and provide an understanding of the uncertainty areas affecting the process of procuring subcontractors in the construction industry. The main research questions are: What types of uncertainties exist in the process of subcontractor procurement? How do they affect the construction process? How could they be managed?

In order to answer these questions, a literature framework is composed where uncertainty is described. Then, a case study with a Swedish construction contractor concerning scaffolding subcontractor procurement is conducted in order to exemplify how this uncertainty exists and affects the procurement processes in practicality.

Literature framework

Definition of uncertainty

Uncertainty is commonly described as a key process in regard to several organizational areas, and has a long history in the study of organizations (Miller, 1998) (Miller, 1995). It is based on the theory that it is difficult or even impossible to completely predict the future of certain events or choices. Clegg et.al. (2010) defines uncertainty as:

> *"…the inability to know how to continue some action, a lack of a rule or decidability about which rule to apply".*

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Mann (2011) provides another definition for uncertainty:

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While uncertainty often is a cause for problems in projects, it is commonly accepted as inherent (Johnson, et al., 2011). To which extent uncertainty is found problematic and stressful is however dependent on several things such as culture (Hofstede, 1983). Different cultures may either accept the uncertainty, or seek to avoid it (Hofstede, 1980). The preference for avoiding uncertainty is for example relatively low in Sweden compared to most Asian countries (Hofstede, 2001). Furthermore, individuals with a higher tolerance for ambiguity tend to perceive situations as less uncertain than individuals with lower tolerance (Downey et.al., 1977).

Knight (1921) emphasizes that there is a distinct difference between risk and uncertainty, which is important to keep in mind. He argues that the bearings of a certain phenomenon may have a measurable uncertainty factor that in effect is so far from an unmeasurable one that it is not really an uncertainty at all. Therefore, he argues that uncertainty and risk should be separated, where uncertainty applies to cases of non-quantifiable types (Knight, 1921), and risk applies to known probabilities and outcomes (McAuliffe, 1998).

While a situation may be considered as uncertain when involving a risk, it can usually be converted into reasonable certainty by quantifying it. This is plausible, as most cases become predictable in accordance with the laws of chance when the number of cases is increased, as this reduces the error in predictions to a number approaching zero (Knight, 1921). Situations involving uncertainties as defined by Knight are usually more difficult for decision making than situations with quantifiable uncertainty, or as he describes it, a risk.

Based on previous definitions, this paper will use the following definition, which also comprehends the separation of risk and uncertainty as defined by Knight, where uncertainty applies to situations of the non-quantifiable type, and vice versa.

> *"A situation where an entity is phased with an inability to predict the future or the consequences of a certain decision or event based on quantifiable information"*

Types of uncertainty

As uncertainty is a very general term, all definitions and theories of uncertainty are not applicable to the construction industry with procurement of subcontractors as a main focus. In the literature research, 22 types of uncertainty were found, out of which eight were deemed relevant for the subject of subcontractor procurement. This decision was based on information from the case study. Each type of uncertainty that was considered to have a large possible effect on the project was chosen.

Process uncertainty

In the construction industry projects are commonly carried out by several cooperating organizations. As each project is unique, and so also the temporary project organization, there is always an amount of uncertainty regarding the process in the specific project but also regarding the temporary organization. Maylor (2010) mentions the possibility of for example uncovering an archeologically significant building when excavating which might cause months of delays in the project, and also the possibility of finding out that different teams or individuals does not function well together. When a process is uncertain there is a risk that this uncertainty will affect the time and cost calculations that has been made earlier in the project.

Time uncertainty

Construction projects are commonly characterized as having a high complexity, with several factors determining this feature. A large number of activities generally have to be performed in the correct order if project completion is to be achieved successfully. As such, time is of the essence and an efficient scheduling phase is crucial in order to ensure that the project follows the estimated time, and within the budget (Bruni, et al., 2011) (Yeo & Ning, 2004). However it is hard to predict the future, and if the time for each project activity is uncertain, the project faces a risk of delayed activities affecting other activities, or the project as a whole, with unknown consequences (Bruni, et al., 2011). As the time for a specific activity is a major cost factor, an increased activity time will affect the cost for the specific subcontractor to a large extent.

Effect uncertainty

Frances J. Milliken (1987) describes effect uncertainty as the relation between cause and effect, which is unknown. A certain event may be likely to occur, but the effect on the organization is uncertain due to a lack of knowledge of the cause and effect relationship for this event. Hence, uncertainty also exists in the predicament on how to respond to it. An example is strikes issued by labor unions. Even though the strike takes place, the outcome of it could as well be limited. In this situation the effect uncertainty is high from the beginning until it is clear to which extent projects will be affected. Therefore it is important to consider the effects of each decision or procurement in the project.

Option uncertainty

Options available at the point of decision might be too limited due to a lack of imagination from the persons who compiled the set of alternatives. Due to this there may exist a number of unknown options that might be superior to the selected one. The sample of options in a decision situation might also contain options that are not feasible in practice (Lovell, 1995). Thus there exists a degree of uncertainty in decision-making processes. An example of option uncertainty is the process of sub-contracting. Appropriate subcontractor relationships are essential for the project performance, and usually selected from two criteria: price and trust. While the lowest price often is seen as the most important factor, trust is often a result of successful dealings with the subcontractor in the past. This scenario could also be seen as a gamble

(Lovell, 1995), where the probability of the known subcontractor meeting their terms to some extent is predictable, but not of the unknown subcontractor.

Informational uncertainty

In order to form social judgments and to be able to make decisions from the options available, proper information is needed. If there is a lack of proper information to base the decisions on, informational uncertainty exist (Mann, 2011). It can be described simply by decisions made at a point when there was not enough information available to really support the decision. Tendering is a process that tends to have problems with informational uncertainty. Studies have shown that the quality of tender documents is a major problem (Laryea, 2010). The tendering process requires extensive information and documents exchange. If the project information then is unclear or inconsistent this may lead to poor tender documents which are common causes for inaccurate estimates, claims and contractual disputes (Laryea, 2010).

Bidding uncertainty

A contractor's project life cycle begins with a need for work and an invitation to bid on the project by a client, followed by an assessment of the bidding opportunity and a decision whether to submit a bid or not (Naert & Weverbergh, 1978). In most projects, the contractor submitting the lowest bid receives the contract (Hartmann & Caerteling, 2010). The client's decision on which contractor to use is thus quite straight-forward, while the contractor's decision on what price to bid is more complicated. Bidding low increases the chances of being awarded the project, but also reduces the profitability margin and the tolerance for uncertainty. Thus, the problem is estimating the probability of winning the bidding process as well as the uncertainty of costs involved in the project (Chapman, et al., 2000). Quantifying the cost uncertainty in terms of a distribution of possible costs is essential if this uncertainty is to be taken into account (Chapman, et al., 2000).

Contractual uncertainty

Contractual uncertainty may exist when it is not clearly regulated in the contract who will take the consequences when an unforeseeable event occurs (Lonsdale, 2005).This might be problematic if the power distribution is in favor of either party. This occurs when there is a need to interpret a clause in the contract. When the contract is produced there are several things that cannot be known in that time, and because of this the contract does not directly regulate these things (Lonsdale, 2005). Omran and Hussin (2011) argue that contractual claims are one of the most common causes of unwanted costs at a construction site. As such, it is important that both parties properly understand all terms of the contract, and that all duties and obligations within the scope of the contract is understood.

Cost uncertainty

Cost estimation is a fundamental task in construction projects (Ökmen & Öztas, 2010). However, as many risk factors affect the construction process, these estimations tend to deviate from the actual costs in a favorable direction (Ökmen & Öztas, 2010). Thus, analyses of the uncertainty affecting the estimation of costs are required. An example that may create risks of costs increasing is uncertain weather conditions. According to Omran and Hussin (2011), there are numerous cases of unwanted costs at each project site. These are often camouflaged as claims, or as cost overruns following an extended project time. Consequential costs may also occur due to uncertain project and site conditions, by ambiguity in contract clauses, due to the fault of other parties, or by other costs that are not covered in the contract price (Cao, et al., 2008). These costs are often the result of loose contract agreements. In order to reveal and

minimize the cost uncertainty, tender documents should be as accurate and detailed as possible (Cao, et al., 2008).

Uncertainty management

As the uncertainty of future events is a common problem source in construction projects, the possibility of reducing or avoiding uncertainty is much sought for. By the previous definition made by Knight (1921), uncertainty which can be reduced and calculated into quantifiable numbers is per definition not an uncertainty, but rather a risk. Thus, the actual solution to reducing or eliminating uncertainty is to transform the uncertainty into a quantifiable risk which the organization then can manage.

Knight (1921) further contends that the possibility of reducing risks depends on two sets of conditions that are fundamental; that uncertainty in groups is less than in single instances, and the differences among individuals in regard to the uncertainty. These two conditions lead to two methods of reducing uncertainty; the reduction by grouping (consolidation), and the reduction by selecting individuals to "bear the responsibility" (specialization).

Knight (1921) also mentions *priori probability theory* as an example of how uncertainty actually tends to disappear altogether when grouped with an increased number of similar situations. With statistical probabilities, the uncertainty tends to manifest in a less degree limited by defectiveness of classification. He also argues that the *true uncertainties* may show some extent of regularity when grouped together with other uncertainties, of almost any similarity or common elements.

Naert and Weverberg (1978) write about the problem with uncertainties regarding cost estimates but also argue that their approach of reducing uncertainty may be applicable to other sources of uncertainty as well. They state that the options available in decision making must be identified, as a lack of clarity contributes to uncertainty and if there are different choices, this creates further uncertainty of which alternative to choose. The uncertainty should be specified, its existence highlighted, and if possible quantified. While there will always exist an amount of uncertainty, it should be transparent when used in calculations and quantified as much as possible (Naert & Weverbergh, 1978).

Johnson et.al. (2011) mentions another approach of reducing uncertainty, and the effects of the uncertainty, *the real options approach*. The profitability analyses often carried out by managers require them to make possible non-realistic assumptions of the future. The real options approach is a way of using scenario analyses in order to analyze uncertain future activities and events. The idea is that this approach will defer decisions as far as possible, as the passage of time will clarify the expected results. Johnson et.al. (2011) also argues that this might even lead to the possibility that apparently unfavorable and costly strategies may actually prove to be the best strategy in the end.

Method

With the purpose of studying how uncertainty exists in practical construction, e.g. to which extent uncertainty exists and affects the processes of tendering and procurement and the possible consequences from this uncertainty, a case study involving a Swedish construction contractor has been made. This construction contractor will further on be referred to as CC.

At first to collect information, six interviews were conducted at CC. These included three site managers, a project manager, the head of the calculation office, the head of the procurement office, and a head of construction. The interviews were semi-structured in order to get a broader perspective on the interviewees opinions and let them mention what they believe is relevant for the paper's subject, and for the possibility of asking follow-up questions. They

took place at either CC's main office or at construction site offices, lasted for approximately one and a half hour each, and were focused on the interviewees' opinion on uncertainty in tendering and production.

Furthermore, tendering and procurement documents regarding four recently finished projects were examined in order to research actual differences and proofs of uncertainty between the tendering documents, procurement documents, and the actual costs. In order to limit the information to a researchable amount, this paper has chosen to focus the research on scaffolding subcontractors, who early on came up as one of the areas with the largest amount of uncertainty according to the interviewees.

To complement the results from the study of tendering and procurement documents, four interviews were held with the respective site managers for each project. These were more structured than the previous interviews, and focused on explanations for the results, and clarification of the circumstantial factors affecting each project. They were chosen to be more structured as these interviews were mainly consisting of clarification issues regarding the documentation from the four projects.

Finally, the concept of uncertainty in tendering and procurement processes is analyzed and discussed based on the findings and the theoretical framework. Also, the eight types of uncertainties are quantified for sub-process within subcontractor procurement.

Case description

CC is a construction contractor in Sweden. Their main clients are municipalities, municipal organizations, industrial and commercial companies, and real estate companies. Their vision is to develop into one of the leading construction companies in Sweden, and position themselves as one of the leading actors on the market.

The project process

To gain further insight to why CC experience uncertainty in their tendering and procurement processes, this paper will look into the actual project process in the organization. CC's idea of the project process and the model they work after is described in Figure 1, where the main processes can be seen from the start of the project.

Figure 1. Main processes in CC

The construction market is continually monitored by the head of the calculation office, by e.g. checking advertisements where public clients put inquiries, or by direct inquires made by private clients. When a suitable project is found, senior management, in consultation with the heads of procurement and calculations, consider if they have the required resources needed and if the project is worth to pursue. If so, a head of construction is assigned with the overall responsibility for the project. Usually a period of four weeks goes by until the tender is handed in, during which inquiries are sent to different subcontractors from the head of the procurement office. The calculation office calculates a construction budget where the project is broken down in order to determine the prime production cost for the project.

The prime production cost is then compiled with the results of the procurement office's work and re-evaluated in order to do necessary corrections. An overall assessment of the tender is also made with the help of "experience ratios", where CC goes through previous tenders and make double-checks in order to make sure that the cost is reasonable. The head of construc-

tion, who is partly involved during the whole process, then does a thorough presentation of the project together with the CEO and project manager once the compilation is done.

Later the strategic choices concerning the final tender are made and the tender is sent to the client. Examples affecting the strategic choices made are the current employment situation in the organization, the risk level, how many competing companies that are involved, and if there are other gains to be made with the project such as prestige or marketing opportunities.

If the project is assigned to CC, a shorter phase of procurement follows, in which CC can handle amendments, memos, and additions. In contract negotiations, this could for example be concerning price issues. The head of construction then has the responsibility of establishing a project organization. If the project is a design-build project, the organization begins to go through the documents and plan the construction. If it is a design-bid-build project, the work consists mostly of familiarizing themselves with the existing documents and plans. At this point, the tender is considered history and thus less interesting. Instead, the appointed site manager and the head of construction are responsible for creating a construction spreadsheet. In approximately half of the projects, they also work in cooperation with the calculation department, as they possess valuable economic knowledge about the project. The construction budget is the important calculation to consider. It is almost exclusively lower than the tender, as it is extremely more detailed, thus making the different accounts more easily quantifiable and decreases the amount of risk factors to consider.

A construction schedule is made, after which the construction budget is updated based on it. All accounts are adjusted and CC does new cost inquiries and enter final price negotiations with its subcontractors.

Depending on which type of contract that is used, the construction budget is finished at different stages of the project. In a design-bid-build contract all documents should already be available and the project should be fully planned, at least in theory. It is then in principle possible to do a complete construction budget from the beginning. In a design-build contract the planning is often finalized parallel to the construction, which decreases the possibilities of having a complete construction budget ahead of the construction phase, as it needs to be developed as the project proceeds. The procurement department then does continuous procurements depending on the construction budget in order to be able to directly follow up on how the current cost level is compared to the budgeted and does planning adjustments if the construction budget does not meet the budgeted costs.

The site manager is responsible for most of the work, even if more critical decisions for the project as a whole often are taken in concert with the project manager or the head of construction. At the end of construction, the building is transferred to the client, defined as an inspection phase and an occupation phase. This is followed by a management phase or a guarantee period if the project is not owned by CC. Once the guarantee period is over, the project is fully “closed”.

Results from the interviews

As the information available usually is less in the early processes, such as tendering and procurement, these are among the processes that are most influenced by uncertainties. This statement also gains approval from the head of the calculation office at CC and one of the site managers, who explains the problem of there being parts of a construction project where the estimated costs in the initial stage for subcontractors may differ significantly from the actual outcome. While this in most cases is a problem that can be managed in the end, it does involve an amount of risk where the contractor may experience less control of the budget, especially if there are several areas influenced by this uncertainty.

Two of the site managers believed that part of the problem with uncertainty in the tendering and procurement processes lay in a lack of production experience at the calculation office. If the site managers would participate in the early processes, they might contribute by their experience. However, they feel like there simply is not enough time for actually doing it. The head of the calculation office explained that from his point of view the main problem was:

> *"…how to spend the limited time and resources available during the tendering of a project."*

The most common uncertainty areas mentioned in the interviews were: additional metalwork, work related to establishment of the construction site, fire sealing, logistics, and scaffolding.

Additional metalwork was according to one of the site managers a problem because the conditions and environmental factors affecting these are almost exclusively unknown in the beginning of a project, and therefore problematic to study in detail. Most of the decisions concerning additional metalwork are also taken in a later phase of the project, after the budget is set. The same problems apply to fire sealing, the conditions are simply not known in advance.

While establishment of the construction site previously have been known as a problem area for CC, a major review of the routines has recently been made, making the existing statistics in this area obsolete.

The project manager explained that logistics is a potential area related to uncertainty and the problems along with it. However this area has not been measured at all so far at CC, and is therefore not available for a full investigation in the current state.

One area that all the interviewees mentioned as problematic and uncertain was scaffolding. In most projects scaffolding cost overruns were experienced, which had a quite large impact on the project. While the assembly, transport and disassembly of scaffolding are included in the tendering documents, there is still a lack of predicting how the scaffolding is actually going to be used or changed during the project. Due to this, the scaffolding account often experience a big cost increase for changes made during the rental time of scaffolding, as well as for extended rental time.

Scaffolding

Clearly, CC experiences uncertainty in many areas during the early phases of a project, a problem quite well-spread throughout the construction industry. In order to better understand what the actual uncertainties are, and why they exist, this paper focuses on one of the areas that came forward as uncertain and problematic while still researchable; scaffolding.

The usual approach when procuring a scaffolding contractor at CC is to begin by sending out tender document containing specifications on what should be priced. Attached to this document is necessary information like façade drawings. These are sent to a number of companies that have declared their interest in the project. From this information each scaffolding contractor puts together a tender, specifying the cost for delivery, assembly- and disassembly work, as well as the rental cost. Usually a list of extra options is included in the price as well as a pricelist of selectable options. The tenders are weighted against each other and chosen based on different criteria such as price, trustworthiness and earlier experience of the company. A negotiation about the final terms follows before the contract is signed. Since the rent time is a bit uncertain and dependent on external factors, it is most often priced as an ongoing cost. The whole procurement process is illustrated in Figure 2.

Figure 2. Procurement process in CC.

Case study – Scaffolding, four recent projects in CC

As scaffolding was explained to be an account with large cost deviations which were hard to predict and thus influenced with uncertainty, four recent projects performed by CC were studied. In Table 1, the estimated cost made by the calculation office in the tendering phase, the procurement cost and the actual outcome of the accounts of scaffolding is presented.

Table 1. Estimated cost, procurement cost, and outcome for 4 recent projects in CC.

Project	*Type of project*	*Estimated cost (kSEK)*	*Contract price (kSEK)*	*Contract price / Est. cost (%)*	*Actual cost (kSEK)*	*Actual cost / Est. cost (%)*	*Actual cost / Contract price (%)*
1	Retirement homes	1 125	721	-36	1 845	64	156
2	Housing	1 284	1 204	-6	2 250	75	87
3	School	207	207	0	383	85	85
4	Pre-School	273	117	-57	370	35	217

Why do the costs increase?

The site manager for project 1 explained the increased scaffolding costs divided into four different causes. First, there was a lot of additional scaffolding ordered during the project, and changes made to the scaffolding due to demands from the different professions working on the scaffolding such as painters, carpenters and metal workers. Second, the total rental time for the scaffolding was increased due to a delay in the project because of difficult ground conditions. Third, scaffolding inside the house needed to be built. Fourth, weather protections for the scaffolding were needed, as well as temperature protection due to the delay of the project, which pushed the façade work into the winter season.

The site manager for project 2 experienced different problems. More scaffolding was necessary compared to what was calculated, as they needed to build around the balconies which had not been predicted in the budget phase. This also led to an increase of loading towers. Just like in project 1, weather protection for the scaffolding also needed to be added. Furthermore, there was a major time issue due to several causes. The construction order was changed, which led to scaffolding being necessary from a much earlier stage than was calculated. Also, the façade works were delayed for a number of months due to the mason not working according to schedule.

Project 3 was explained to have four causes to the increase. Additional scaffolding was procured compared to the estimated amount, which increased both the contract sum and the rental cost. In addition, the total rental time was increased with almost fifty percent. Several changes to the scaffolding were also made, as well as additional orders of scaffolding inside the house.

In project 4, the causes for the increase were slightly different from the other projects. Here, the main cause for the increase was that CC did not really understand what type of scaffolding that was procured. While they thought they had procured an ordinary and adjustable type of scaffolding, the subcontractor delivered a type that was extremely difficult to change and adjust due to the needs of different professions, which led to a large increase of cost for the adjustments. Like the other projects, scaffolding inside the house was also needed in a larger degree.

According to the site managers for the studied projects, additional scaffolding, either due to a larger order from the beginning or by changes during the construction phase, is probably the major reason for an increase of costs. Another large area of increasing costs according to the site managers are increased rent time, due to for example a delay in the project or by a delay by other subcontractors.

The last area that by the site managers was explained to experience cost increases in many projects was weather protection. While this is budgeted for in a separate account, it is important to consider the risk of project delays leading to other types of weather protection, if scaffolding is still used close to the winter season. However the site managers agree that this should be included in the tender from the subcontractors, as they are the ones who ultimately are scaffolding professionals and possess the knowledge and experience related to this. However, the tenders tend to vary a lot, both in price but also in specifications and options. One example that showed significant variation between different tenders was "free rental time", where some tenders had no free rent included, while others had up to eight weeks. The site managers was also in agreement when explaining that contracts and inquires often are too vague, and occasionally refer to oral agreements, which might lead to contractual disputes.

One site manager mentioned that it in general is very hard to follow up and evaluate the scaffolding account, as the invoices sent by the subcontractors often do not contain enough information to trace the costs and compile them accordingly.

Discussion

Quantifying uncertainty

Uncertainty clearly is a common problem source in construction projects. In order to predict the future as far and well as possible, and reduce or avoid the uncertainty, both Naert & Weverbergh (1978) and Knight (1921) explain that quantification of the uncertainty areas is the first step. In order to better understand uncertainty in procurement processes, we have quantified the uncertainty areas affecting the processes between and including inquires sent to the subcontractors and the actual building process. The quantification is based on how we perceived the interviewees opinions on the probability of each uncertainty to affect the process and also on the consequences if the uncertainties happened to affect he processes, see Table 2.

Table 2. Uncertainty/Impact chart for types of uncertainty in project sub-processes (0=low level, 3=high level)

Uncertainty /Impact	*Bidding*	*Time*	*Effect*	*Information*	*Process*	*Contractual*	*Cost*	*Option*	
Inquiry 1	3*3	3*2	3*1	3*2	2*1	0*0	3*1	3*3	38
Tenders 1	2*3	3*2	3*1	2*2	2*2	1*0	2*2	2*1	29
Budget	2*3	2*3	3*2	2*3	2*2	1*1	2*3	2*3	47
Inquiry 2	2*2	1*3	2*2	2*3	1*2	1*1	2*2	2*2	28
Tenders 2	1*2	1*3	2*2	2*3	1*2	1*1	2*2	1*2	24
Contract	1*2	1*3	1*3	1*3	2*2	2*3	2*3	1*3	30
Construction	0*0	1*3	1*3	1*3	1*3	2*3	1*2	1*2	22
	29	30	26	34	21	15	29	28	

While this information is a highly contextual and only shows the perceived uncertainty, it still may provide an understanding on how it exists in construction. Furthermore, the possible impact of each uncertainty type in each process is demonstrated, e.g. the impact of informational uncertainty in the inquiry process on this particular process. As such, the informational uncertainty in the inquiry process will have impact on only the inquiry decisions and not in decisions made in other processes and so forth.

The sum of uncertainty multiplied by the impact, for each process and uncertainty type is also demonstrated as a way of quantifying uncertainty into risk. The process of quantifying uncertainty into risk is as described in the literature review one way of managing uncertainty.

While it is clear that the level of uncertainty in general tend to decrease as the project progresses, with the exception of contractual uncertainty, the impact tend to deviate more. As Table 2 demonstrates, the sum of uncertainty multiplied by impact (i.e. risk) is highest in the processes of inquiry 1, budget and contract. The high risk in inquiry 1 can be explained by the high amount of uncertainty that exists in the early processes, as the amount of specifications and information still is relatively low. The budget and contract phase however show both high uncertainty and impact, since they are the processes in the project where the most decisions are to be made. This is further indicated by the fact that the option uncertainty and impact is highest in the inquiry phases, the budget phase, and the contract phase, whereas it is relatively low in the tender phases. This is due to the fact that option uncertainty exists in decision making processes, and where different options with unknown consequences exist.

As illustrated, the risk for each respective uncertainty types for the whole process is quite similar, with the exception of informational and contractual uncertainty. The low level of risk for the contractual uncertainty may be explained by the simple conclusion that there exists no major uncertainty until the actual signing of the contract, where the contractor to some extent is locked to the chosen option, and if something goes wrong, it might have major consequences. The high level of risk for the informational uncertainty can be explained by the reasoning that a lack of proper information obviously will have a major impact on the project. As this to some extent is known, it will also add to the sum of informational uncertainty that exists due to the relatively low amount of specifications and information in the early processes of a project. Hence, uncertainty and impact are interrelated; if an individual knows that the wrong information will cause major problems in the project, the perceived uncertainty regarding the information will increase.

Bidding uncertainty and time uncertainty is high in the early processes and significantly lower in the later. That bidding uncertainty is relatively high in these processes are due to the fact that the contractor has begun looking for the best subcontractor, but still only gets quite a low amount of information from the actors. However they still need to figure out which subcontractor is the best for this particular project, and what terms such as cost or trust that should be considered. Time uncertainty is high in the early processes as the frames for how long i.e. the scaffolding is needed, is still relatively uncertain, and can be changed due to a large number of factors.

In the construction phase, the amount of uncertainty is relatively low, as can be seen in Table 2. This is natural, as the project has progressed and the amount of information increased. There are also no more actual options to choose between, reducing the option uncertainty to zero. This is also true for the bidding uncertainty, which no longer exists. However, the impact of each uncertainty that still exists is quite large, as it is more expensive and time-consuming to deal with the consequences of a wrong decision. One exception however is the contractual uncertainty which is still at its highest. The contractor needs to trust that the contract has considered everything that might happen, and each area forgotten in the contract may have a large financial impact on the project.

Uncertainty in practice

As explained in the previous chapter, we have chosen to look further into the process of procuring scaffolding subcontractors in a Swedish construction contractor (CC) in order to identify uncertainty areas in procurement processes. As can be seen in Table 1, the actual cost for

four studied projects is between 35 and 85 percent higher than the estimated cost in the budget.

While cost increases certainly could be hypothesized prior to the case study, such high increases were quite surprising. Interviews with the involved site managers indicated that it is often quite easy to explain these increases post project, but more difficult to predict them pre project. After studying the results for the project, we identified five key causes generally responsible for the increase:

- Extended rental period
- Scaffolding inside the building
- Covers and weather protection
- Additional orders of scaffolding
- Changes made to the scaffolding during the project

While there was no information available on the increase distribution of these areas for the project, every site manager agreed to them being significant problem areas. While some of these areas actually should be able to predict, others are more difficult. Changes made to the scaffolding during the rental time should have been predictable to some extent, as they are frequently occurring during projects. For example, carpenters, painters and metalworkers each have different ergonomic demands for their respective work, which requires the scaffolding levels to be changed in order for the next profession to work.

Another interesting point made in Table 1 is that the largest as well as smallest amount of cost increase was found in the school project (project 3) and preschool project (4), which generally would be considered as quite straight-forward projects. Such projects would in our opinion usually have quite low cost variations, as they are similar in type of project and complexity. However this emphasizes that uncertainty does exist to a large extent between the processes of calculating the budgets in the tender phases and the actual outcome of the projects, as illustrated earlier in Table 2.

Furthermore, it was quite surprising to see the significant differences between the tenders submitted by the potential scaffolding subcontractors. Not only were there significant cost differences between the tenders, but also differences in both dispositions and content which made it harder to compare them on an equal basis. This leads to a high amount of uncertainty and work for the contractor when trying to compare the tenders in order to find the most suitable tender. If connected to the theory of uncertainty presented in the literature study, several of the uncertainty types can be identified in this retrospect, such as informational, bidding, cost, option, and effect uncertainty. Also there may be a risk of subcontractors “hiding costs” in certain contractual terms. This could for example mean that the “free rental period” instead is included in the cost for establishment of the scaffolding, with an actual higher increase for the rent than what it elsewise would have cost.

Further increasing the uncertainty concerning scaffolding subcontractor procurement is the nature of the invoices received. The site managers explained that often these do not contain specifications for each cost, such as establishment of the scaffolding, transport, additional cost for changes made, additional costs for workers etcetera, but rather contain only a lump sum. This leads to difficulties tracing and quantifying the actual expenses regarding the scaffolding account, and thus creates a knowledge barrier which makes it more difficult to use the experiences from previous projects when estimating the budget in other projects. While the knowledge may be kept in the head of the site manager responsible for that specific project,

there are barriers for sharing this knowledge both to other individuals and the organization. If extensive common frameworks for inquiries, contracts, and invoices were created, this may help centralize the knowledge from the site managers and the specific projects to the organization, which would decrease the amount of uncertainty in these areas. If the inquiries for example would require the tenders to be well commented, explaining each cost and why it is needed or profitable, this would help decrease many uncertainties for the contractor as well as take advantage of the professional knowledge each subcontractor possess.

Another problem is ongoing costs, which can easily increase rapidly in the project, for example when changes must be made. One way of decreasing the uncertainty regarding this might be to ask for certain fixed price areas in the tenders, such as the cost for changing the heights for the floor levels of the scaffolding.

Another idea in order to quantify the cost specifications for scaffolding is to create "sub-accounts" for each area that has a large amount of uncertainty, such as the five common causes previously mentioned in this paper. While this might require more administration in a field where time is already limited, this would however be a good way of quantifying each uncertainty area and lead to more knowledge and less uncertainty, as this enables both the analysis of the uncertainty areas as well as the minimization of them, which both Maylor (2010) and Knight (1921) claims is one of the ways of reducing uncertainty. If analyzed for a long period of time, it might even reduce the uncertainty to an extent where it would rather be seen as a quantifiable risk that can be assessed and dealt with, as Knight (1921) argues. In a smaller extent, it might also help create key indicators for each area which helps improve the estimation of the budget.

Furthermore, there does seem to exist a process uncertainty in CC, where the actual processes seem to differ between projects. One example of this process uncertainty is that the interviewees mentioned that in some projects the construction budget is derived from the budget made in the tender phase and calculated by the calculation office, while in other projects it could be built from scratch totally disregarding the previous budget, and made by the site manager. While the process uncertainty may not be the largest uncertainty it could to some extent affect the other uncertainty types and increase them. Further increasing the process uncertainty, and to some extent also every other uncertainty is the limited practical construction experience in the calculation office. While this may lead to for example less cost uncertainty due to their knowledge in this area, it may increase other uncertainties such as contractual uncertainty, as it might be harder for them to predict the future events that can occur in the construction phase. However there is also a continuous balancing act whether or not to calculate the budget in the early phases too specific, as this will most probably increase the tender price and thus reducing the chance of being awarded the project.

Related to the process uncertainty is also Hofstede's (1983) explanation that there is a cultural difference in how uncertainty is perceived; the calculation department as an example will perceive the uncertainty in a different manner than the site managers. As each uncertainty is perceived in different ways by different individuals, there is also a variation of which uncertainties that are perceived as most important by different parts of the organization.

Yet another way of decreasing uncertainties is the real options approach which is mentioned in the literature study. This is basically a way of using scenarios in order to make sensitivity analyses of possible events that may occur and affect the outcome of the project. It is also related to the specialization method by Knight (1921), which is mentioned in the literature study. This will decrease many uncertainties in the project, and in particular the effect uncertainty. However, this is a time-consuming activity which may also require individuals with an

extremely high expertise and experience of the construction industry, making it a less desirable alternative.

While decreasing uncertainty in the procurement phase certainly is a possibility, we believe it is impossible to eliminate it, due to the unique nature of each construction project. Also, factors such as the client ordering additional work certainly increase the level of uncertainty. As these changes occur in the production phase, they are naturally impossible to predict in the earlier phases of a project, as when creating the budget. These are examples of the true uncertainties mentioned in the literature study. However, changes ordered from the client are also paid by the client, and will therefore not burden the contractor's results, which is important to keep in mind. They may however increase the total cost for the project and the involved accounts, which might make the accounting more difficult and explain many overdrafts in the project accounts.

Concluding remarks

The purpose of this article was to study if and how uncertainty exists in the process of subcontractor procurement in the construction industry. Also it meant to identify key uncertainty areas as well as how these affect the process. We found that uncertainty both according to literature and a case study done with a Swedish construction contractor does exist and affect the process of subcontractor procurement to a large degree. We also identified eight key uncertainty types that affect this process.

Five common subcontractor areas that are often influenced by uncertainty were identified. The case study is centralized on one of these; the procurement of scaffolding subcontractors. According to each interviewee at the company as well as four projects studied in detail, the actual total cost for scaffolding subcontractors tended to substantially exceed the estimations made in the budget. While the cost distribution for the reasons behind the increases was not possible to fully trace, we found five key causes that explained most of cost overruns.

The paper also presents a quantification of uncertainty types in each subcontractor procurement process where the amount of uncertainty and its possible impact on the project is specified. Furthermore, several uncertainty reducing activities, supported by literature, which could be possible ways of addressing the problem are presented.

While the paper provides an understanding and identification on what kinds of uncertainties that exist and affect the process of scaffolding subcontractor procurement, it may also provide a basis for future studies where uncertainty regarding subcontractor procurement may be studied, since this field of study seems to be limited.

References

Bruni, M. E., Beraldi, P., Guerriero, F. & Pinto, E., 2011. A scheduling methodology for dealing with uncertainty in construction projects. *Engineering Computations, Vol 28 Iss:8,* pp. 1064-1078.

Cao, D. T., Wang, S. Q. & Tiong, R., 2008. Management of uncertainties and consequential costs for construction projects in China. *Cost engineering, Aug, 50,8,* pp. 26-37.

Chapman, C., Ward, S. & Bennell, J., 2000. Incorporating uncertainty in competetive bidding. *International Journal of Project Management 18,* pp. 337-347.

Clegg, S., Kornberger, M. & Pitsis, T., 2010. *Managing & Organizations, second edition.* London: SAGE publications Ltd.

Downey, H. K., Hellriegel, D. & Slocum, Jr., J. W., 1977. Individual Characteristics as Sources of Perceived Uncertainty Variability. *Human Relations, Volume 30, Number 2,* pp. 161-174.

Hartmann, A. & Caerteling, J., 2010. Subcontractor procurement in construction: the interplay of price and trust. *Supply Chain Management: An International Journal 15/5*, pp. 354-362.

Hofstede, G., 1980. *Culture's consequences: International differences in work-related values.,* Beverly Hills, CA: Sage.

Hofstede, G., 1983. National cultures in four dimensions - A Research-based Theory of Cultural Differences among Nations. *Int. Studies of Man. & Org., Vol. XIII, No 1-2,* pp. 46-74.

Hofstede, G., 2001. *Culture's Consequences: Comparing Values, Behaviors, Institutions, and Organizations Across Nations.* Second ed. Thousand Oaks CA: Sage Publications.

Johnson, G., Whittington, R. & Scholes, K., 2011. *Exploring Strategy, ninth edition.* Harlow: Financial Times Prentice Hall.

Knight, F. H., 1921. *Risk, Uncertainty, and Profit.* Cambridge: Hart, Schaffner & Marx; Boston: Houghton Mifflin Company, The Riverside Press, Cambridge.

Laryea, S., 2010. *Quality of tender documents: case studies from the UK,* Reading: School of Construction Management and Engineering, University of Reading.

Lonsdale, C., 2005. Contractual Uncertainty, Power and Public Contracting. *Jnl Publ. Pol., 25, 2,* pp. 219-240.

Love, P. E. D., Davis, P. R., Edwards, D. J. & Baccarini, D., 2008. Uncertainty avoidance: public sector clients and procurement selection. *The International Journal of Public Sector Management 21.7,* pp. 753-776.

Lovell, B. E., 1995. *A taxonomy of types of uncertainty,* Portland State University: Proquest Dissertation & Theses (PQDT).

Mann, A., 2011. *Managing Uncertainty During Organization Design Decision-Making Processes: The Moderating Effects of Different Types of Uncertainty,* Columbia University: UMI 3453258.

Maylor, H., 2010. *Project Management, fourth edition.* Harlow: Pearson Education Limited.

McAuliffe, R. E., 1998. Uncertainty (economics). In: *Encyclopedia of Management.* Malden: Blackwell Publishers ltd., p. 670.

Miller, S., 1995. Uncertainty. In: *Encyclopedic dictionary of organizational behavior.* Cambridge: Blackwell Publishers ltd., p. 592.

Miller, S., 1998. Uncertainty. In: *Encyclopedia of Management.* Malden: Blackwell Publishers ltd., p. 670.

Milliken, F. J., 1987. Three types of Perceived Uncertainty About the Environment: State, Effect, and Response Uncertainty. *Academy of Management Review, Vol. 12, No. 1,* pp. 133-143.

Naert, P. & Weverbergh, M., 1978. Cost Uncertainty in Competetive Bidding Models. *The journal of the Operational Research Society, Vol. 29, No 4,* pp. 361-372.

Omran, A. & Hussin, A. A., 2011. Minimizing the unnecessary costs on site. *Annals of faculty engineering Hunedoara - International Journal of Engineering, Tome IX, Fascicule 3,* pp. 69-78.

Yeo, K. & Ning, J., 2004. Managing uncertainty in major equipment procurement in engineering projects. *European Journal of Operational Research 171,* pp. 123-134.

Ökmen, Ö. & Öztas, A., 2010. Construction cost analysis under uncertainty with correlated cost. *Construction Management and Economics, 28:2,* pp. 203-212.