



Norwegian University of  
Science and Technology

# Subcontractor Selection in the Construction Industry

Development of a research approach to  
investigate selection criteria, methods, value  
creation initiatives and supply chain  
management

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Master in Science of Project Management

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## Preface

This master thesis was written as the final semester assignment to achieve the Master of Science in Project Management, with the Department of Industrial Economics and Technology Management (IØT) at the Norwegian University of Science and Technology (NTNU). The topic was selected as it is of personal interest to my future endeavors in maximizing value and understanding the most effective frameworks and methodologies in the subcontractor selection process. This thesis has been completed in collaboration with an analysis of the main concepts learnt across the relevant course literature in the Masters in Science (in Project Management) at NTNU.

Thanks to my supervisor, Associate Professor Bjørn Otto Elvenes, for his guidance in writing this thesis. He has provided invaluable knowledge throughout the process. Also, thank you to Professor Luitzen de Boer for his guidance and recommendations in relation to the supply wheel model analysis.

A handwritten signature in black ink, appearing to read 'J. Bailey', enclosed within a faint rectangular border.

John Bailey

Trondheim, 20 June 2016

## Abstract

The primary goals of the subcontractor selection process in construction projects is to reduce project risk, optimize quality and build and maintain good relations between project parties. Some general contractors regard price as the most significant criteria in the subcontractor selection process, however following an in depth analysis of theoretical research, it is recommended that a multi-parameter approach incorporating a number of criteria should be considered in the selection process. A prequalification process is recommended to produce a short-list of potential subcontractors for a work package, based on the subcontractor's relationship management skills, technical expertise in comparison to project specific criteria, financial stability and current workload. The primary criteria identified as the most relevant for award selection include price, quality, safety, and timing. Along with this, value creation initiatives is essential in establishing an environment of awareness, improvement and value. A suggested way a general contractor can create value and gain a competitive advantage, by gaining both value and cost advantages, is through effective supply chain management, and forming high-involvement strategic partnerships with selected subcontractors. Other approaches and theories that are presented in relation to the process include web-based subcontracting, case-based reasoning, bid shopping, principle-agent theory, and statistical evaluation methods.

The purpose of this thesis is to develop a research approach to investigate subcontractor selection criteria and methods, value creation initiatives and supply chain management within the construction industry. This is achieved through the production of a subcontractor selection process model developed from theory. Also, a semi-structured format interview guide has been developed to be applied in a case study context to further understand the methods and value creation initiatives in a general construction contractor organization, whilst simultaneously validating or falsifying the proposed process model. This has been accomplished by way of observations and analysis of the key ideas and themes emerging from theory on purchasing, subcontractor selection, value creation and supply chain management. The developed model and interview guide provide the reader with a good research platform to further analyze a general contractor in relation to their subcontractor selection function.

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## List of Abbreviations

<b>ANOVA</b>	Analysis of Variance
<b>BA</b>	Bespoke approaches
<b>CA</b>	Cluster Analysis
<b>CDF</b>	Composite Decision Factor
<b>CSC</b>	Contractor Selection Criteria
<b>FST</b>	Fuzzy Set Theory
<b>GC</b>	General Contractor
<b>MAA</b>	Multi-Attribute Analysis
<b>MAUT</b>	Multi-Attribute Utility Theory
<b>MDA</b>	Multivariate Discriminate Analysis
<b>MR</b>	Multiple Regression
<b>PSF</b>	Project Success Factor
<b>SC</b>	Subcontractor
<b>SCM</b>	Supply Chain Management
<b>SSCM</b>	Strategic Supply Chain Management
<b>TCO</b>	Total Cost of Ownership

# 1 Introduction

Selection of the most suitable subcontractor for a particular work package or task is paramount to the success of a construction project. *“More than ever, supply strategists are under pressure to select the ‘right’ supplier the first time, in order to maximize value creation”* (Cousins et al., 2008). The concept of supply as applicable to this thesis exists in the form of a construction service, namely the process of subcontracting. All construction experts agree on the importance of subcontracting. The high impact of subcontractors on the construction process exemplifies that the selection of subcontractors is an important and sensitive activity. A common method by which to measure construction project results is in terms of time, cost and quality achieved. Perhaps, the general contractor’s decision most impacting these superlative 'value' criteria, is that of selecting the appropriate subcontractors to complete the work tasks involved in the overall construction product.

## 1.1 Background

Most subcontracting activities deal with construction work tasks and thus, it has a direct influence on the quality and costs of projects. Selection is the process of aggregating the results of evaluation to identify optimum choice (Holt, 1998). For a general contractor, having the ability to select the most suitable subcontractor for a particular task, is an important attribute to achieving competitive advantage, which may lead to both value and cost advantages, in relation to other competitors. Selecting high quality subcontractors promotes the overall quality of projects and improves the reputation and qualification of the general contractor in future projects. There is a growing realisation that value achieved is as much a function of the quality of contractor employed, as of project cost (Holt, 1998). Establishing an effective framework to select subcontractors via the most effective methods is essential. Employing value creation incentives in the selection process extending from major stakeholders through all major project functions of the construction organization is essential in establishing an environment of awareness, improvement and value.

The original plan for this thesis was to conduct a qualitative analysis through the results of the semi-structured interview, in conjunction with the developed process model, of one major construction company. The results from the interview would be used to confirm, highlight and compare to the main ideas emerging from the theory, and also to validate or falsify the process

model. Firstly, Australian personnel were contacted. When that proved to be difficult and not practical to pursue from Norway, a number of NTNU professors were consulted to help with providing Norwegian construction industry contacts. When this failed, cold calling and emailing of Norwegian construction companies commenced for approximately one month, with little response.

Due to the short time frame to write the thesis and lack of industry personnel to interview, it was decided that with two months to go before delivery date, an extended focus and emphasis was to be placed on the theoretical background to further develop the process model and interview guide to be used in future research. Thus, through the process of a theoretical literature review, a research based approach was developed for the study of subcontractor selection in the construction industry. The results of this thesis provides the reader with a good base to be able to apply a qualitative analysis, in the form of a semi-structured interview divided into key research questions, and analyse the appropriateness of the process model. The model developed and questions contained in the interview guide were developed from the main trends and ideas observed in the theory.

Furthermore, as there are many aliases for different construction terms, for the purpose of this thesis, customers and clients can be considered the same. Also, the term decision maker or procurement officer entails contracts administrators, project managers, quantity surveyors or any similar person who is involved in selecting subcontractors for a construction project. Furthermore, value creation will be viewed as an objective to be met, with supply chain management detailing a process that contributes to the achievement of value creation. In relation to supply chain management, a few criterion have been adapted from each area of the supply wheel model to the subcontractor selection process. The questions that result attempt to provide an analysis platform in assessing if a general contractor has adopted a value creation and supply chain management perspective in their subcontractor selection framework.

## 1.2 Scope and Goal

The scope of this thesis includes published theory on the core focus areas of purchasing, subcontracting, subcontractor selection, value creation and supply chain management. The scope of the study lies in the area between when it is decided that a subcontractor is required to conduct a particular task and the point where the subcontractor is awarded the contract. Thus,

make-or-buy theory and outsourcing vs insourcing are not heavily focused on, as this study assumes that the decision to subcontract a task or tasks has already been made. The intended respondents of the interview guide result is targeted at project managers, contract administrators, quantity surveyors, procurement officers or any similar position, currently employed at a general construction contractor organization.

The scope of the theory has been selected on the relevance to the study, and covers theoretical concepts related to purchasing, subcontracting, subcontractor selection, prequalification criteria, award selection criteria, methods of subcontractor selection, statistical contractor evaluation and selection methodologies, partnering approaches, web-based subcontracting, case-based reasoning, bid-shopping, principle-agent theory, value creation, value chains, supply chain management, and the supply wheel model.

The goal of the study is to produce a high quality semi-structured format interview guide to be applied in a case study context, and a subcontractor selection process model. This is achieved by way of observations and analysis of the key ideas and themes emerging from theory on subcontractor selection, value creation and supply chain management. From the results of this study, the reader has the ability to conduct a qualitative analysis through the use of the interview guide, and validate or falsify the proposed process model. From the answers and feedback provided from the respondents of the interview guide, the reader may understand the basis for the ways in which construction companies are selecting subcontractors in construction projects and whether they have adopted a value creation perspective during the process.

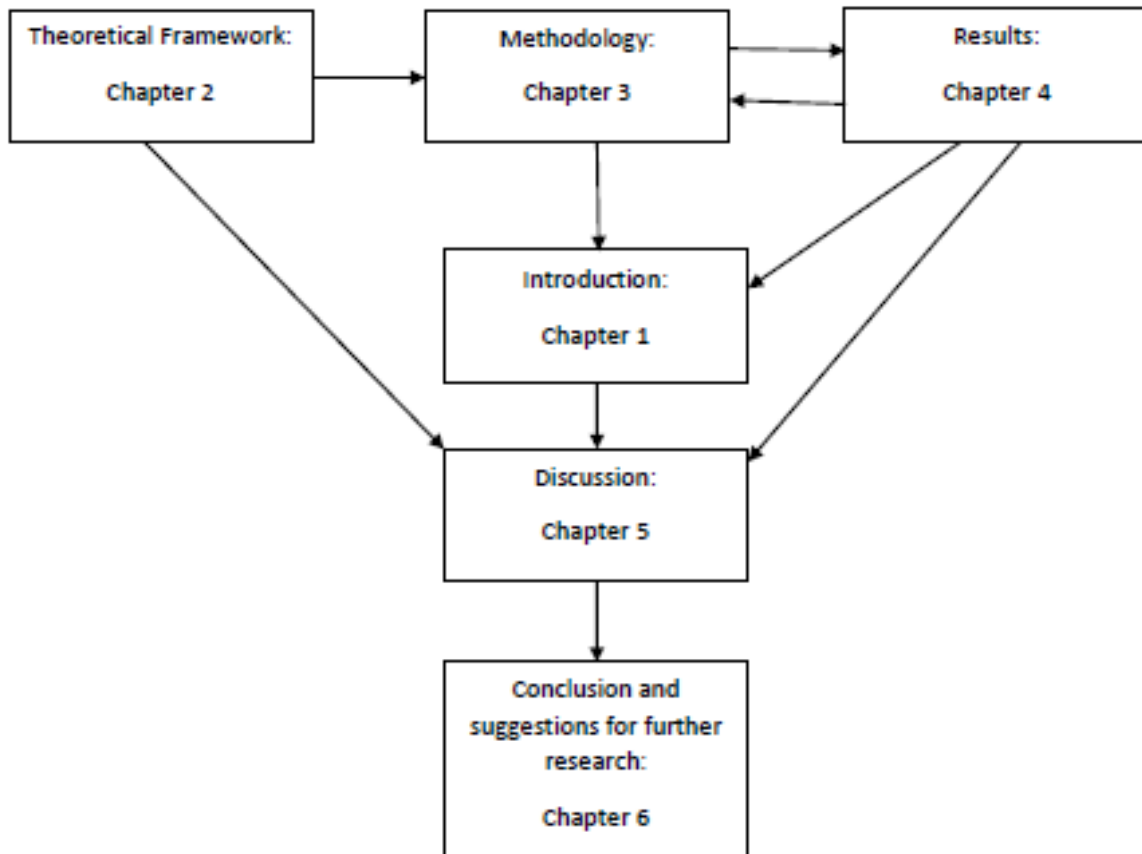
The theory selected for inclusion is based directly on its applicability to the problem statement and key research questions, presented in the methodology chapter. After establishing the key research questions, sub-questions within each key research question were developed from the main trends and ideas observed in the theory.

### 1.3 Structure of Thesis

The structure of this thesis is founded upon systems thinking, in which the thesis in its entirety is considered to be the main system, incorporating different sub-systems and components that are interrelated. The process of writing this thesis and the interrelated relationships between the different chapters or sub-systems is shown in Figure 1.

Chapter 1 outlines an introduction which presents the background of the study, scope and goal, thesis structure, challenges, and major assumptions and delimitations. Chapter 2 incorporates the methodology including the course learning outcomes methodologies applied, systems thinking, literature review, comments on validity and reliability, and limitations of the study. Chapter 3 provides the theoretical framework for the study and consists of key concepts integral to the understanding of the research conducted including purchasing, subcontracting, subcontractor selection, prequalification criteria, award selection criteria, methods of subcontractor selection, statistical contractor evaluation and selection methodologies, partnering approaches, web-based subcontracting, case-based reasoning, bid-shopping, principle-agent theory, value creation, value chains, supply chain management, and the supply wheel model. Chapter 4 presents the result of the literature review, namely, the theoretical process model and interview guide. Chapter 5 discusses the reasoning behind the conclusions drawn from the theoretical review to produce the results and some implications and elements for the use of the results. Chapter 6 concludes the thesis and provides some suggestions for further research.

The thesis has evolved from a process of deductive reasoning, a “top-down” approach, in which theory was firstly consulted on the interest topics of subcontractor selection and value creation in the construction industry. Following this, the focus was narrowed down to a specific hypothesis, displayed through the key research questions. The process model and questions for the interview guide were developed through observations and analysis of the theory on key selection methods and criteria, value creation and supply chain management. This was performed in consultation with the methodology selected. A discussion of the results was then carried out referring back to the theory and introduction chapters to validate the use of the interview guide and for reasoning behind the elements selected to be included in the process model. Finally, from the discussion, a conclusion was drawn and suggestions for further development of the results and for the continuation of the study offered. Thus, Figure 1 displays the relationships between the different sub-systems or chapters, and the method by which the study progressed.



*Figure 1- Structure of Thesis*

## 1.4 Challenges

This study had a number of challenges that were encountered. The main one as previously mentioned, was the difficulty in following the original plan for this thesis in conducting a qualitative analysis through the semi-structured interview result, as a result of a lack of response from industry personnel. This was overcome by restructuring the thesis to focus on a research based approach for the study of subcontractor selection in the construction industry via an extended focus on the theory to further develop the results of the process model and interview guide. Another challenge was found in the development of the questions in the interview guide that were going to deliver the right responses to answer the key research questions. This was solved by consulting Bryman (2015) and Walliman (2006), and with the help of the supervisor, ensuring questions were targeting the right response fields.

## 1.5 Major Assumptions and Delimitations

The study will focus on the time period between when a decision is made to subcontract a project work task until the actual selection of the subcontractor. It assumes rational, profit maximizing actors in a construction company have already made the decision to subcontract a work task. Consequently, the research does not investigate the time period before the decision to subcontract has been made or the period after the subcontractor has been selected.

Furthermore, it is assumed that it is uncommon for subcontractors to perform superior on all selection criteria for a project, and that general contractors make decisions based on selection criteria they nominate as superior. There is therefore a trade-off assumption, with a risk of measuring intentions of the general contractor rather than actual practices.

Also, as the topic of value creation is so broad in scope, it will be looked at predominately through the lens of supply chain management. In other words, supply chain management is assumed to be a process to achieve value, and thus, a key value creation incentive in the subcontractor selection process. An analysis through the supply wheel model is also assumed to be an effective measure of an organization's application of supply chain management. The supply wheel model's main application appears to be for a manufacturing supply chain, in which a product is produced. This thesis makes the assumption that it is possible to apply this model to a service based industry and the subcontractor selection process. Its purpose is to give an indication of whether supply chain management incentives and perspectives have been adopted in the selection process. Value creation is assumed to be a goal or target to be met, covering a wide range of meanings and applications and is therefore left open for interpretation.

## 2 Methodology

### 2.1 Course Learning Outcomes

The learning outcomes for this course as presented in the course curriculum for the subject TIØ4920- Project Management, Master's Thesis at the Norwegian University of Science and Technology (NTNU) specifies:

- Knowledge developed in the course:
  - Specific and detailed knowledge about one particular area within the main profile area of the student.
  - Knowledge about how to do scientific research, including knowledge about research design and methodology.
  
- Skills developed in this course:
  - Practical use of research methodology
  - Ability to understand what literature is relevant to a scientific problem, and to search for and employ this literature in a reasonable way
  - Ability to write a scientific report.

### 2.2 Methodologies Applied

With these learning outcomes in mind, the philosophies and methodologies that have been applied in this study include systems thinking and a literature review with the result presented providing the reader with the ability to apply a qualitative analysis, in the form of a semi-structured interview method in a case study context; along with a subcontractor selection process model. The process model and interview guide were developed by analysing the main and consistent trends observed in the theory. The validity and the reliability of the theoretical research is also examined with the main types of validity identified in the study being face validity and concurrent validity, and the main types of reliability identified being internal reliability and external reliability.

As mentioned, the thesis has developed from a process of deductive reasoning, in which theory has been firstly consulted on the interest topics of subcontractor selection and value creation in the construction industry. Following this, the focus is narrowed down to a specific hypothesis through observations and analysis of the theory to key selection methods and criteria and value creation initiatives. This approach was selected as it was originally unclear what was to be the



focus in combining the topics of subcontractor selection and value creation. Also, due to the the time available, and following the unavailability of contacted construction personnel to interview, the main resource identified was theory. The process was developed from the main ideas and thoughts that emerged from the analysis of previous publications. The study was tapered down to focus on the development of a research approach to investigate subcontractor selection criteria and methods for construction organizations, along with value creation initiatives in the selection process, encompassing a heightened focus on supply chain management.

## 2.3 Systems Thinking

Systems thinking can be defined as a management discipline that concerns an understanding of a system by examining the linkages and interactions between the components that comprise the entirety of that defined system (Bryman, 2015). It is a philosophy that attempts to balance both holistic and reductionist styles of thinking and has been used in this study as a structural framework in researching and analyzing the existing literature publications on subcontractor selection in the construction industry.

In the context of this thesis, systems thinking makes up the main system, and is the foundation to understanding the relationships between a general contractor and a subcontractor in the selection process. The use of more specific theory to investigate properties and processes associated with these relations, such as selection criteria and methods, value creation initiatives, and supply chain management, makes up the sub-system. Collectively these sub-systems define the subcontractor selection system. This thesis has been structured on the basis of system thinking principles. Figure 1 in Chapter 1 highlights the way this thesis has been produced and organized as a whole system consisting of sub-systems.

## 2.4 Literature Review

The literature review provides an overview of the major concepts related to subcontractor selection and value creation techniques and models applicable to the construction industry. This method has been selected to effectively establish a theoretical framework for the problem statement, highlight key terms and ideas, identify studies that support the topic, and develop a process model and semi-structured interview guide. The main advantage of the literature review approach in this thesis was the time efficiency factor, compared with conducting a qualitative

analysis and analyzing and discussing the results. A supporting advantage is that it provides a more solid conceptual framework for further research by way of a more thorough analysis of the literature.

Information was predominately gathered using three data base search engines, namely Oria (an NTNU database), Google Scholar (an online scholarly literature search engine), and Scopus (a large abstract and citation database). These were selected as the principal vehicles for finding the literature as they have proven to be highly reputable and a very reliable source of information.

Furthermore, it was also important to use literature that was recognized to have a high quality. The use of search engines Google Scholar and Oria were able to provide an extensive range of scientific literature on the topic. However as these search engines alone do not guarantee the highest possible quality, for the scientific literature, additional sources of literature that were consulted include peer-review journals, the impact-factor of said journals and recommended literature from the supervisor. Other factors that contributed to selecting specific literature include how often the author had been cited by others, and if the theories expressed were well within the scientific consensus of the parameters of the study field. Caution was taken when selecting literature from the newly established “public domain” journals, due to fact that their quality hasn’t yet completely been established with the potential ability of the author to pay for the publication and skip the quality assessment processes. As mentioned, supply chain management is considered as a form of value creation with the former providing an effective process to achieve the goal of creating value. The subcontractor should be viewed as part of the project supply chain, offering not a product, but a service.

In locating the literature selected, firstly different searches were placed into the Oria database. This was used as the primary database for gathering information, supported by Scopus and Google Scholar. Key words and phrases were firstly selected as specific terms related to value creation and subcontractor selection in construction projects. Following this, similar and related terms were selected as a singular entity or in combination with other key words. The key words and phrases used in the search for literature as standalone searches or in combination with each other include:

- Construction

- Purchasing
- Subcontractor selection
- Value management
- Contractor logistics
- Value chain
- Project management
- Subcontractor evaluation
- Project purchasing
- Value creation
- Project management
- Supply chain
- Subcontractor procurement
- Supply chain management
- Principal-agent theory
- Transaction-cost theory
- Social research methods

Searches began with a systematic approach in which an attempt was made to find all relevant material. As there was several thousand hits for each search, to narrow it down, a retrospective approach was adopted in which the most recent material was selected first for review working backwards. This was complemented by selecting literature with the highest number of citations. When too many sources were found on a particular search, sometimes a re-focus of the requirements of the problem statement was also performed, followed by a new search. The final selection was made by reading the abstracts and assessing the relevance of each literature's material to the goals of the problem statement.

From a process of observing and analysing the theory, the problem statement was narrowed down and divided into a specific hypothesis that gave rise to the following key research questions:

1. What is the role of the project manager/ procurement officer in subcontractor selection and their general view on the process?
2. What is the nature and details of subcontracting at Company X?

3. What are the key subcontractor prequalification and award selection criteria used at Company X?
4. What is/are the main method(s) by which Company X selects subcontractors? Is partnering, web-based subcontracting, case-based reasoning, bid shopping or principle-agent theory considered and used?
5. Has Company X adopted a value creation and supply chain management perspective to the subcontractor selection process?
6. What is Company X's view on the proposed process selection model?

These were selected as the main research questions as answers for these will contribute to answering the problem statement which focuses on key subcontractor selection criteria and methods used by construction organizations, in combination with value creation and supply chain management initiatives. Each main research question has been subdivided into further questions that highlight key areas and elements that make up that particular research question. Research questions 1 and 2 are suggested to gain a conclusive insight into the background of the case company selected along with information about the interviewee. They can also be used to note any systematic differences in answers across gender, level, education, position, experience etc. in order to understand the potentially different answers provided by different individuals.

Furthermore, as the questionnaire is large, the interview guide result incorporates a priority ranking for questions. Each question is given a ranking in relation to its relevance to the problem statement and also the key topics investigated in the theory chapter. A ranking should be initially selected by the reader, depending upon the depth that the reader would like to go to in analyzing the company selected. Thus, the interview guide can be shortened and lengthened depending upon the priority ranking selected if time is a factor. Questions for each section are asked in order of their priority ranking. A priority ranking of (1) asks the minimum number of key questions in order to satisfactorily answer the problem statement. It is recommended that for the ranking selected, all those questions of the same number and less are incorporated into the analysis. For example, if (2) is selected, than all questions ranked (1) and (2) are asked. The questionnaire should be scheduled for at least three hours to incorporate all questions.

The ranking system has been determined as:

- 1- Highest priority, must be answered
- 2- Good information to know, important but not a crisis if left unanswered
- 3- May turn out to be significant but unsure of current relevance. May be used as a follow-up question if relevant, but do not ask it otherwise
- 4- Background question that may be safely discarded if decided to be redundant.

The use of subheadings was selected within each subject area based on the main overviews and arguments concluded from the analysis of theory and applicability to the problem statement. This approach has been adopted to highlight the main points and arguments within each paragraph/section, displaying the focus of what the really important issues are, whilst also helping the reader understand the arguments presented.

In relation to the statistical contractor evaluation methods presented in the theory, the details and processes for how to use each technique is presented in a reasonably detailed way in an attempt to make the differences between each recognizable, and to clearly demonstrate to the reader how to use these techniques. Figures and tables from key authors is used throughout to highlight the author's viewpoints on different process models to give an indication of the main trends and show the differences in opinions. It also allows the reader to see the models and results presented by key authors, in order to make their own comparisons to the suggestions presented in this thesis.

## 2.5 Validity and Reliability

According to Walliman (2006), validity refers to the degree to which the research findings are true. He presents three types of validity, namely, measurement, internal and external validity. Measurement validity is the degree to which the study successfully measures the targeted concepts. Internal validity is the extent to which casual statements are supported by the study. External validity refers to the extent to which findings can be generalized to populations or to other settings. Bryman (2015) also adds ecological validity, which is the extent to which the findings are applicable to people's every day natural settings.

In relation to research, validity *“refers to the issue of whether an indicator (or set of indicators) that is devised to gauge a concept really measures that concept”* (Bryman, 2015: 171). Bryman (2015) divides validity into the following categories: face validity, concurrent validity,

predictive validity, construct validity and convergent validity. In this study, the types of validity that were predominately used were face validity and concurrent validity. Face validity ensures that the measures reflect the content of the concept in question. In this thesis, this was achieved through asking the supervisor and other masters students in the program if the measures applied to collect the data, appeared to be adequately targeting the focus of the research. Concurrent validity is established by employing a criterion to which cases are known to be different and that is relevant to the concept in question. In this thesis, this was achieved through assessing literature that was known to have different focuses in relation to the construction industry, however the criterion of searching for subcontractor selection relevance and applicability to the problem statement was the same.

Reliability refers to the degree to which the results of the research are repeatable (Walliman, 2006). Bryman (2015) lists four prominent factors that are involved, namely, stability, internal reliability, external reliability and inter-observer consistency. In this study, the types of reliability that were predominately used were internal reliability and external reliability. Internal reliability refers to the degree to which the indicators that make up the scale or index are consistent. This was achieved through the same method of searching for problem statement relevance in the articles by firstly reading the abstracts, followed by the conclusions and introductions of each new piece of literature. External reliability is dependent on the degree to which the study can be replicated. This was achieved through the adoption of a literature review approach that could be repeated.

## 2.6 Qualitative Research

From this thesis, the reader has been provided with a platform to conduct a qualitative analysis in relation to the study with the results of the interview guide and theoretical process model. Qualitative research is predominately used when the study object is complex and it is difficult to make explicit hypotheses and reduce the subject to a small number of possible variables, as in this case. The variance across differing departments and organizations in ways in which they incorporate value creation into their subcontractor selection processes is assumed to be very large and hence, classical quantitative methods as a standalone research procedure is of questionable value. People are the focus of the study, particularly in small groups or individuals. It is based on information expressed in words such as descriptions, accounts, opinions and feelings.

According to Walliman (2006), qualitative research has a strong emphasis on reiteration and interpretation, and usually involves a constant interplay between collection and analysis of data, producing a gradual growth of understanding. According to Bryman (2012), the data collection in qualitative methods is invariably unstructured, and requires a contextual understanding, rich and deep data and a natural setting to be most effective.

The major reason behind suggesting this approach to the reader, is to understand the dynamics, feelings, values and perceptions that underlie and influence behavior in relation to subcontractor selection. As this process may be quite natural and automated for an experienced practitioner in the industry, semi-structured interviews are recommended as they allow the researcher to ask more probing questions. This is in an effort to get the responder to consciously think about the processes and value creation initiatives, on an organizational and on an individual level, that exist in the subcontractor selection process and why they exist. It also may provide the study with an insight into the emotions and attitudes of the organization in relation to value creation in the subcontractor selection process.

### 2.6.1 Semi-structured Interviews

The use of interviews in general is a very flexible tool with a wide range of applications. A semi-structured interview refers to one that contains both structured and unstructured sections with standardized and open-format questions (Walliman, 2006). Bryman (2012) relates semi-structured interviews to a context in which the interviewer has a series of general questions but has the ability to vary the sequence of the questions with an increased latitude to ask further questions in response to what are seen as significant replies.

Some advantages associated with this interview type is that it has this possibility to ask more probing questions, greater breadth of coverage, and more rich and deep data. This is essential when relating value creation and supply chain management to subcontractor selection to get the respondent thinking of the underlying value causes behind the choices made, possibly subconsciously, whilst selecting subcontractors. Some disadvantages associated with this interview type is related to small sample sizes, sensitivity of context, difficulty of generalization, and the potential of the interviewer having an effect on the respondent's answers (Bryman, 2012).

It is recommended in the continuation of this study that the interviews are conducted face-to-face, with each interview being tape-recorded. The interviews should be carried out in an open and semi-structured manner to allow the respondent to introduce whatever information they feel to be relevant in association with the questions. To ensure the interviewing is as effective as possible and to optimize the time of the interviewees, the purpose, format, and general outline of the interviews should be communicated to the respondents through either email or a telephone conversation ahead of time.

## 2.7 Limitations

The research conducted in this thesis has limitations and boundaries. Firstly, the scope of this thesis is limited to a cross-section of the literature presented on subcontractor selection, criteria and methods, value creation and supply chain management. Consequently, it cannot, and does not, attempt to be an analysis of the full range of the literature, but a sampling of important and influential works found during the five months of writing this thesis.

Furthermore, the measures used to collect the literature for the theoretical framework could have been wider. Only three search engines (Oria, Scopus and Google Scholar) and the NTNU library were used during the information gathering and publication selection process, which may have inhibited abilities to conduct a thorough analysis of literatures previously published on the topic.

Moreover, longitudinal effects in relation to time available to investigate and interpret the research topic was constrained by a project due date, and was just five months. Also, culture and other types of bias may have had a subconscious impact on the interpretation of the material, potentially increasing the subjectivity of the thesis.

A semi-structured interview was selected along with the development of a process model as the results of the literature review due to the time constraint and the unavailability of relevant construction personnel to interview in the time allocated. The elements of the supply wheel model in supply chain management could have also been more widely applicable to the subcontractor selection process. However, a specific element was focused on within each element of the wheel and subsequently one question to each element in the results was presented. This was due to it being a supportive part of the study, and to give only an indication



if any supply chain management elements and perspectives had been incorporated into the subcontractor selection process.

Finally, measures were taken to try to reduce the impact of the limitations presented as much as possible. The selection of articles was based on an interest to engage the most relevant themes emerging from the research topic. Whilst only three search engines and the NTNU library were used, they are highly reputable and a very reliable source of information. The thesis was written in the light of a conscious attempt to be completely objective throughout the entirety of the thesis. Although the study was completed in a short time frame, a substantial amount of time was committed to the study and time management skills adopted to optimize the use of this time.

The model and interview guide developed in this thesis constitutes a first step in this study and its details must be further investigated. In that respect, specific suggestions for further research are included in the thesis, regarding operationalizing the model to investigate its effectiveness and performing the interview guide in a semi-structured interview format.

## 3 Theoretical Framework

The theoretical framework has been developed to provide the key points necessary to develop a process model and an interview guide for qualitative research on the subcontractor selection process. It also attempts to address the main research questions in a systematic manner. The general nature of subcontracting is discussed first followed by the main characteristics of subcontractor selection starting with its position in the Van Weele (2009) purchasing process model, subcontractor prequalification criteria and subcontractor award selection criteria. The methods of subcontractor selection are discussed next which also incorporates the main statistical contractor evaluation and selection methodologies established to date; along with some other key methods that may be incorporated into subcontractor selection including partnering approaches, web-based subcontracting, case-based reasoning, bid shopping, and principal-agent theory. The chapter ends with the concept of value creation, value chains and supply chain management, through the application of the elements of the supply wheel model.

A number of significant authors with similar and different perspectives and recommendations are included in this chapter to promote some of the main ideas circulating on each research area. The reason a number of authors and perspectives are presented is to attempt to settle at a relatively conclusive evaluation of each key research area. This is in relation to the main criterion and methods not only agreed upon, but also that emerge as relevant and adaptable to multiple projects of differing scope.

### 3.1 Subcontracting

#### Definitions:

A general contractor is a contractor engaged by the client and is responsible for all work on a construction site including the engagement of subcontractors to complete part or all of the works involved. A subcontractor refers to any person or organization that performs a specific task or work for another organization as part of a larger project. A supplier is a commercial organization which stocks, produces or delivers material, components or products for a building project (Davies and Jokiniemi, 2012).

### Background:

In construction projects, many general contractors only act as construction management agents and subcontract a large volume of their work to subcontractors (Shash 1998; Abbasianjahromi et.al., 2013). Subcontracting is a long-established practice in the construction industry and provides an essential element of flexibility in the overall construction supply chain (Luu and Sher, 2012). It refers to the process of entering into a contractual agreement with an outside person or company to perform a certain amount of work. Often, the general contractor will select to subcontract works when it is more economical to do so and for work that has a higher amount of risk in order to secure competitive advantages.

### Subcontractor types:

Subcontractors can be divided into three main categories: trade contractors (those specializing on specific trades such as brickwork and painting), specialist subcontractors (those undertaking special services such as engineers or electricians), and labor-only subcontractors (such as skilled tradesmen) (Hinze and Tracey, 1994; Hoban and Francis, 2003; MBachu, 2008). MBachu (2008) states that from a contractual viewpoint, subcontractors can be categorized as domestic (in which the general contractor hires the subcontractors to perform specific tasks), and nominated (nominated by the customer to undertake specific aspects of the main contract).

### Reasons to subcontract:

Subcontractors help contractors overcome problems including the need for special expertise, resource shortage, and financial limitations (Elazouni and Metwally, 2000). In their exploratory study on the ways subcontractors are managed, Hinze and Tracey (1994) highlighted the high use of subcontractors, stating that on larger building projects, it is common for 80-90% of the work to be performed by subcontractors. In their literature review on the issues in subcontracting practice, Arditi and Chotibhongs (2005) concluded that subcontracting is valuable for main contractors as they can ensure their companies remain trim and nimble by tapping into subcontractors' specializations.

However according to Luu and Sher (2012), who conducted an empirical investigation, states that obtaining competitive quotations from suitably qualified subcontractors at tender time significantly increases the chances of the general contractor being awarded the construction project. In contrast Tserng and Lin (2002), in their proposal of an accelerated subcontracting procurement (ASAP) model, highlight that with the relatively recent look towards specialized

technological divisions of labor, the construction industry has been shown to have a highly fragmented subcontracting nature. In another view, Jamieson et al. (1996) accredited the rising use of subcontractors to the growing complexity of both the construction of buildings and the organizational relationships of recent times in the construction industry.

*Shifting of work skill base to subcontractors:*

The increased adoption of subcontracting practices suggests that much of the work skill base has moved away from the general contractor's organization, with the latter concentrating their efforts on managing site operations rather than employing direct labor to undertake construction work (Kumaraswamy and Matthews, 2000). Some potential motivations behind this utilization of existing resources already available on the market was in order for the general contractor to diversify against risk in the construction industry, reduce operation costs, secure competitive advantages and search for the most suitable profit base. It is risky and infeasible for a general contractor to include all the necessary competencies and resources to cover all aspects of a major contract, especially considering that both the content and scope of the contract is likely to change.

*Increasing transaction costs, complexity and interface risk leads to less subcontracting:*

Using transaction cost theory, when project works have increased specificity, general contractors tend to subcontract less, and subcontract more when output heterogeneity and the use of intangible assets and capabilities increase. In other words, increased complexity and dynamics will commonly increase the transaction costs, thereby encouraging the general contractor to do more of the work themselves. In relation to an increase in the interface risk between different subcontractors and the general contractor, the same generally applies, where the general contractor will be encouraged to do more of the work themselves. Bearing in mind that this aforementioned interface risk is distinctly different to the risk associated with the content of a subcontract.

Also, proxies for uncertainty do not show any clear effect on vertical integration decisions to subcontract (González-Díaz et al., 2000). Provided they do not lack resources in a project already accepted by them, neither temporary shortage of capacity nor geographical dispersion of activities seem to affect the extent of subcontracting, as construction organizations tend to adapt their resources to their needs. This is generally achieved through an adaptation to the market by adjusting the number of contracts they enter into.

Limitations exist in subcontracting:

In traditional subcontractor selection processes the limitations that may arise when subcontracting include a limited time for selection, high levels of uncertainty, bounded rationality, difficulties in judging quality, and thorough evaluation of the suitability of subcontractors to work together on the same project. As mentioned, through their analysis of published literature and subsequent proposal of an accelerated subcontracting and procuring (ASAP) model, Tserng and Lin (2002) argue that under the limitations of a rigidly predetermined work duration, the lowest bid is usually the main criterion for final decisions of each subcontract. Other difficulties that may arise with traditional processes worth mentioning include those associated with long-term cooperative relations between a general contractor and a subcontractor in which a managerial bottleneck may come about with an increased difficulty for the general contractor to control the costs, the more they become dependent upon the technical skills of the specific subcontractor.

The main contract and subcontractors:

As mentioned in Hinze and Tracey (1994), provisions are generally included by which the subcontractor is bound by the terms of the main contract. This is a result of subcontractors being regarded as inseparable or not distinct from the general contractor. Often a specific subcontract provision is incorporated in the Main Contract for the subcontractor, and they should be led in the right direction in relation to the clauses outlined in the main contract by the general contractor. However in the study conducted by Hinze and Tracey (1994), although 46% of subcontractors indicated they were bound by the terms of the main contract, they stated they were generally not afforded the opportunity of examining it.

The role of the customer:

The level of involvement the customer has in the general contractor's subcontractor selection process varies considerably in relation to the type of customer. This may range from letting the general contractor manage all subcontractor procurement, to recommending the use of certain subcontractors, to enforcing that certain subcontractors are selected on the project. Customers tend to involve themselves in procurement procedures that they have a good knowledge of and a habit of using, regardless of any differences between projects (Love et al., 1998). Furthermore,

the way the customer deals with subcontractor procurement has a substantial impact and influences the nature of the entire process, determining responsibilities and authorities, and thus affecting the degree of integration and cooperation among project participants (Love et al., 1998).

Nahapiet and Nahapiet (1985), through their empirical investigation, found that the main factors and criteria associated with the customer's preferred choice of subcontractor procurement method to be similar to that of procuring the general contractor, in combination with the project characteristics and requirements. This suggests that similar customers with similar levels of involvement in the subcontractor selection process may have similar and consistent priorities in relation to subcontractor selection methods and criteria.

### 3.2 Subcontractor Selection

Subcontractors directly influence the success of a project and the overall reputation of the general contractor in the eyes of future clients through the quality and timing of the work performed. As the selection of highly qualified subcontractors stimulates the overall quality of projects, the incorporation of value creation initiatives into the subcontractor selection model of an organization is paramount to achieving success for both the project and future of the company.

*Selection is often based on intuition and past experience due to uncertainty and ambiguity in the selection process:*

Subcontractor selection is plagued with uncertainty and ambiguity and these conditions are difficult to represent in a generalized set of rules. Decisions relating to the selection of subcontractors in the construction industry are usually based on the intuition and past experience of construction estimators (Luu and Sher, 2012). This point of view indicates that some of the knowledge relating to selecting an appropriate subcontractor is still tacit by nature. This could directly affect the formality of the selection criteria and process, potentially making it more difficult to cover all important issues.

*The importance of the subcontractor in the supply chain is commonly underestimated:*

Through their empirical investigation on the effects of partnering principles on improving subcontractor selection, Kumaraswamy and Matthews (2000) express that despite the increasing extent of subcontracting in construction, the importance of the subcontractor is commonly underestimated. Much of the current research conducted to date has taken the

relationships between a general contractor and the owner as the focal point for performance management in construction projects, rarely addressing the methodology behind how to select subcontractors, how to form criteria for selecting subcontractors, or how to create complete supply links between subcontractors (Kumaraswamy and Matthews, 2000). It is reasoned that improved selection processes are also necessary down the supply chain to the subcontractors and suppliers in order to ensure that clients' needs are satisfied and projects can be successfully completed (Loh and Ofori, 2000).

### 3.2.1 Subcontractor Selection in the Purchasing Process Model

Purchasing can be defined as *“the management of a company’s external resources in such a way that the supply of all goods, services, capabilities and knowledge are secured at the most favorable conditions”* (Van Weele, 2009). Subcontractor selection is part of the procurement function of a construction organization, and procurement relates to the function of purchasing inputs used in the firm’s value chain (Porter and Millar, 1985). Van Weele (2009) proposed a Purchasing Process Model, as shown in Figure 2, which schematically illustrates the main activities within the purchasing function and the recommended order of events in the purchasing process. The elements that make up the model are interrelated. Subcontractor selection is step 2 in the model, and this thesis will take into consideration steps 1 and 2 of the model, namely the specification of the details of the work package, followed by the method in which to select a subcontractor to complete that particular work package.

Furthermore, determining the specifications involves detailing the product requirements, process requirements, customer requirements, communication, functionality, standards, drawings, and level of technology to be used (Nellore et al., 1999). The specifications should protect the general contractor from any future disputes in relation to the work task to be completed and allow for subcontractors to be able to submit a price for carrying out the works. Selecting the subcontractor, or supplier of the service, should be achieved through developing procedures and routines to effectively select the best possible subcontractor. If an established strategic partnership with a subcontractor exists, then it is possible for step 2 to precede step 1, through a joint collaborative approach between the general contractor and the subcontractor, sharing knowledge and creating value.

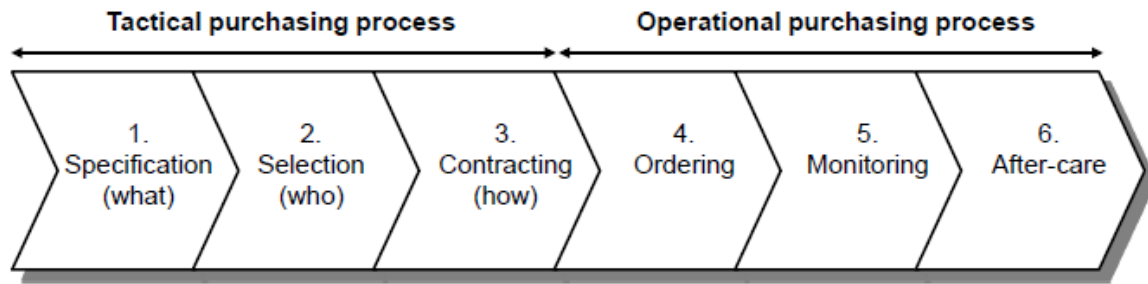


Figure 2- The Purchasing Process Model (Van Weele, 2009)

### 3.2.2 Subcontractor Prequalification Criteria

Many factors exist in the prequalification process:

The initial identification or prequalification of subcontractors who are capable of doing the specific work is essential. Contractor prequalification decision making involves an extensive range of criteria often comprising of both qualitative and subjective information. Nguyen (1985), basing his arguments on experiences from the construction industry in developing countries, tends to disagree, at least to some extent. He argues that the process remains largely an art, where subjective judgement based on the individual's experiences becomes an essential part of the process. Consequently subcontractor prequalification usually needs the use of heuristic knowledge and consequent based "if-then" decision orders. The process is frequently carried out in an unstructured and intuitive manner without the use of computer aids (Russell et al., 1990). Looking at their arguments, the authors seem to agree that whilst there is normally a framework in place for subcontractor prequalification, subjective reasoning and approaches are also normally adopted as a key part of the process.

A short list needs to be formed first followed by a preliminary investigation:

Following their empirical research, Hatush and Skitmore (1997) concluded that a short list of potential subcontractors for a project work package should be formed and each subcontractor subjected to a detailed investigation to assess the current state of the financial, technical and managerial ability of each subcontractor. These include a subcontractor's permanent place of business, adequacy of plant and equipment to do the work properly and expeditionary, suitability of financial capability to meet obligations required by the work, appropriateness of technical ability and experience, past performance of work of the same general type, and the



current financial position of the subcontractor to perform the contract well (Hatush and Skitmore, 1997).

The financial investigation should involve an update of the subcontractor's financial statements and a check on the financial exposure of the company on other existing or upcoming project contracts. Technical assessments should be concerned principally with the current commitment of labor and plant resources on other projects; the ability to handle the type, quality, size of work; and a proven track record to perform on site. This could be assessed, for example, by visits to existing sites and through meetings to discuss, in general terms, the nature of the construction work, the program dates and the customer's requirements. The managerial organization and expertise should be identified by the managerial approach to risk, contract strategy, claims and variations (Hatush and Skitmore, 1997).

*The need for a structured approach to prequalification:*

Due to the array of differing factors and intuition based approaches an organization can adopt towards prequalification, a structured approach is recommended to make it manageable and successful. Abbasianjahromi et.al. (2013), basing their arguments following the development of a subcontractor selection model based on fuzzy set theory, states that prequalification can be achieved via two approaches: introduced by field managers, who identify the subcontractor as cooperative and capable from observations in previous work; and/or through a bidding process. However first, subcontractors should undertake some form of prequalification to ensure they are capable of completing the works without any issues. Russel et al. (1990) established a knowledge-based system for subcontractor prequalification, which was directly based on the criteria of a contractor's reputation, past performance, financial stability, experience record, firm capacity, current workload, and technical expertise. The latter's goal in the development of this system was to create a more structured approach to the process allowing for more consistent, rational and timely decisions to be made. The hierarchical decision model is shown in Figure 3 where each level is referred to as a composite decision factor (CDF).

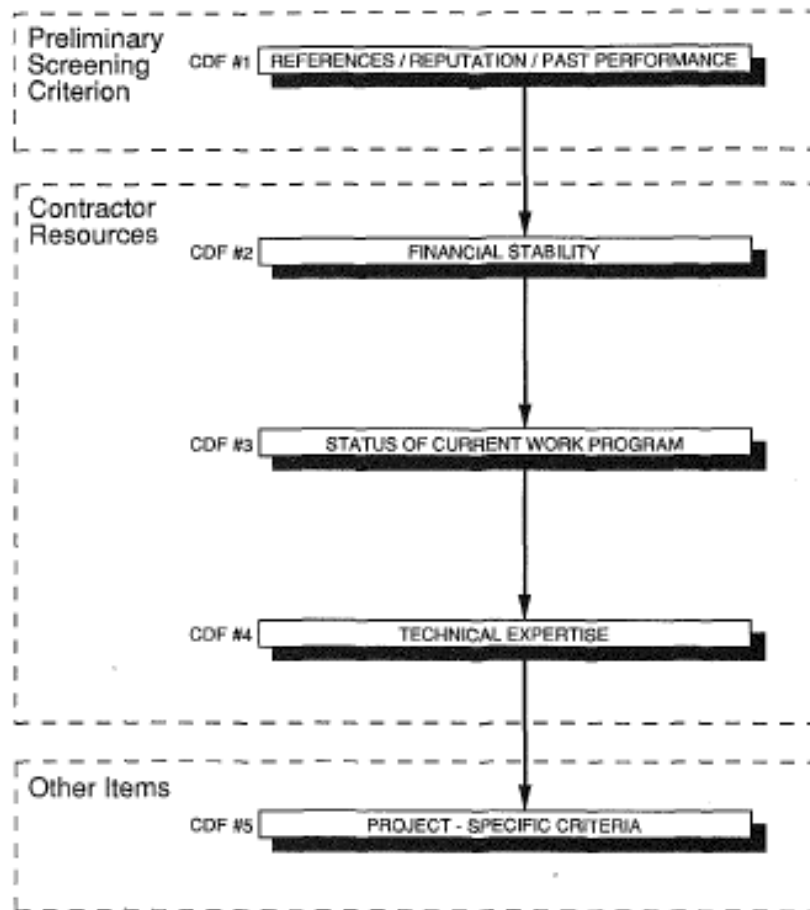


Figure 3- Decision Model for Subcontractor Prequalification (Russell et al., 1990)

In another approach, Palaneeswaran and Kumaraswamy (1999), basing their arguments on experiences in the Australian construction industry, agrees with Russell et al., (1990) to some degree, however emphasizes the importance of additional criteria. They support the general prequalification criteria recommended by CIDA (Construction Industry Development Agency) categorized under the headings of technical capacity, financial capacity, quality assurance, time performance, occupational health and safety, human resource management, and skill formation. These general prequalification criteria are being evaluated by some state government bodies for the potential to be incorporated in construction processes and issued as mandatory subcontractor prequalification check points in order for a subcontractor to be considered for work. An example of this is the Queensland Government in Australia, which has developed a prequalification criteria (PQC) assessment, in which subcontractors are pre-qualified for a period of two years and are categorized in any one of four levels. These include Level 1 (effective work practices), Level 2 (commitment to continuous improvement), Level 3 (industry best practice) and Level 4 (world's best practice) (Palaneeswaran and Kumaraswamy, 1999).

### 3.2.3 Subcontractor Award Selection Criteria

*A framework is required to define a set of criteria:*

Following a subcontractor's successful prequalification for works on a particular project, it is important to identify the subcontractor award selection criteria. The criteria identification process is a dynamic and variable one which arises from the complexity and uniqueness of construction projects. The existence of a framework for defining a set of criteria is a useful tool, which according to Hartmann et al. (2009) who conducted an empirical investigation of the subcontractor selection processes in the Singapore, should start with covering the four main categories of cost, quality, cooperation and technical know-how. Some additional criteria that could be added to this include satisfying customer criteria, contract regulation, company strategy, engineering judgement, timing, safety record, enthusiasm for the project, innovation potential, development, opportunities for future work, experience, number of qualified personnel, time accuracy in submitting tender bids, equipment, compliance with general contractor company image, proposal accuracy and many more.

Another perspective comes from Cooke and Williams (1998), who focused more on ways to control and coordinate subcontractors, emphasises that experience, the ability to manage resources, acceptability to the client, and competitiveness of the subcontractor's tender price and item rates, are the most essential criteria. In an alternate view again, Maturana et al. (2007), who combined lean management to the subcontractor selection process in their study, acclaim high performance in relation to lean principles and partnering practices as the basis for subcontractor evaluation and selection.

General contractors can define a set of criteria for specific situations and localize them based on their identified goals and specific needs. It is also helpful for the subcontractor to know the criteria for the general contractor's subcontractor selection so they can undertake appropriate tender strategies and acquire the capabilities necessary to increase their chances of being awarded the contracts. Ravanshadnia et al. (2010) developed a structured questionnaire to evaluate the selection criteria framework selected by the general contractor. It addresses four main areas which include comprehensiveness, applicability, user-friendliness and practitioner's support. Whilst all the aforementioned authors differ with their recommendations for criteria to be used to select subcontractors, they all agree upon the need for a selection framework to be in place.

### Multi-parameter Criteria:

Herbsman and Ellis (1992), who searched for ways to innovate the selection process in their empirical investigation, proposed a multi-parameter bidding system for subcontractor award bid evaluation, in which a primary and secondary criteria is suggested. The main contribution from this author is the concept of a weighted list of criteria in which some of the categorized criteria will remain the same regardless, and some will vary along with the differences from project to project, thus representing a contextual adaptation of the model. The primary parameters include the bid amount; time of execution; and quality of previous work. In addition to the major three parameters of cost, time and quality, there may be secondary criteria that can be incorporated into the evaluation, with each criteria weighted specifically to the requirements of a given project. Examples of secondary or additional criteria include social and environmental considerations, durability, security and maintenance (Herbsman and Ellis, 1992).

### Lowest Price Criterion:

Based on the subcontractors' need to minimize cost and maximize profit, the general contractor is likely to select subcontractors who submit the lowest price. Tender price has been the dominating decision basis in subcontracting choices for decades and is still shown to be a significant criterion (Greenwood, 2001). MBachu (2008) credits the lowest price award criterion to the fact that most procurement systems are, in theory, fully specified. If it is not fully specified or the specification changes over time, this may not only influence the selection criterion of lowest price, but also the type of subcontract. The price only/lowest tender wins approach directly assumes that all subcontractors are the same and will perform similarly under all circumstances. However, according to Kumaraswamy and Walker (1999), this approach is now widely accepted as naive with experiences showing that the lowest tender may have come about from inaccurate estimating, inadequate risk provisions, deliberate decisions to use substandard resources, and/or even "smart" pricing strategies intended at generating claims for extra payments through contractual loopholes.

### Around the world adoption of lowest-price criterion:

Mbachu (2008), basing his arguments from the results of his empirical research in South Africa, argues that the quality record is the most influential criterion for prequalification of the subcontractors and the tender price is the most significant influence in the subcontractor award. In addition, according to Hartmann et al. (2009), who bases his arguments on experiences from

the Singaporean construction sector, tends to agree. He argues that out of the four factors including price, technical expertise, quality and cooperation, the price criterion is the most important attribute in the award selection process. Hartmann et al. (2009) also concluded that general contractors do not intend to discount, but they will accept the low performance of a known subcontractor on the remaining criteria.

In addition, Hatush and Skitmore (1997) investigated the perceived effect of twenty contractor selection criteria (CSC) elements currently operational in the UK, on the project success factors (PSFs) in terms of time, cost and quality. They concluded that the main CSC that affected all three identified PSF's were the contractor's past failures, financial status, financial stability, experience, credit ratings, technical ability, management knowledge, and management personnel.

*A move from price only single criterion to multiple performance criteria:*

However, Kumaraswamy and Matthews (2000) argues that in more recent times, there has been a distinguished shift from “price only” single criterion to multiple performance criteria in selecting subcontractors for construction works. Similarly, Ulubeyli et al. (2010) who investigated the differences between international construction tendering practices, reasons that a focus solely on a competitive low-bid procurement process can produce poor quality work, adversarial working conditions, a high incidence of subcontractor-generated change orders, claims, extensive delays in the planned work schedule, cost overruns, and increased litigation issues.

Therefore, although price focused subcontractor selection criteria may suggest monetary cost savings, it does not reflect a true or optimum cost, possibly causing a false economy. Thus, “*subcontracts should be awarded based on the best possible combination of a variety of quantitative and qualitative criteria*” (Ulubeyli et al., 2010). A well-defined and holistic framework for selection provides a clear baseline for benchmarking performance and ensures the right sets of subcontractors are selected to do the job. An example of an extensive evaluation criteria for subcontractor selection is proposed by Arslan et al. (2008) and is shown below in Figure 4. This is based on their development of a web-based sub-contractor evaluation system (WEBSSES), founded on their studies of the construction industry in Turkey.

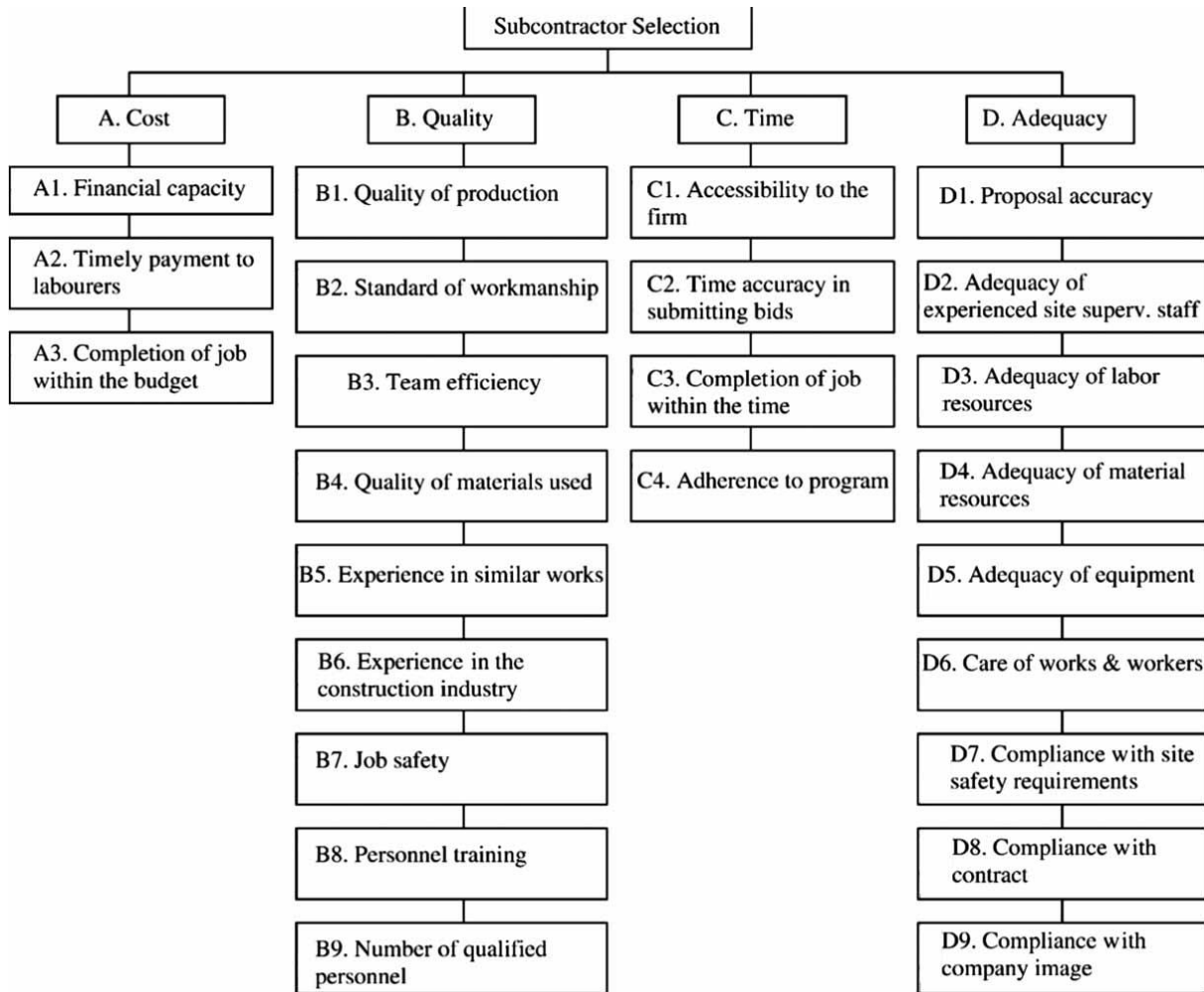


Figure 4- An example of evaluation criteria for subcontractor selection (Arslan et al., 2008)

Risk threshold point in the selection of an unknown subcontractor:

It would also be interesting to examine the trade-off level at which a general contractor takes on more risk by switching from a known subcontractor to an unknown subcontractor. This has been incorporated into the interview guide, in Chapter 4.2, from the point of view of the four key factors for subcontractor selection as identified by Hartmann et al. (2009) and shown below in Figure 5.

Which one of the four subcontractors would you choose? (tick the subcontractor you prefer)

	Subcon A (known)	Subcon B (known)	Subcon C (known)	Subcon D (unknown)
Price	High	Low	High	Low
Technical know-how	Sufficient	Superior	Sufficient	Superior
Quality	Sufficient	Sufficient	Superior	Superior
Cooperation	Sufficient	Sufficient	Superior	Superior
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 5- Sample choice set for a general contractor (Hartmann et al., 2009)

### 3.2.4 Methods of Subcontractor Selection

There exists many methods to select a subcontractor:

The method by which a general contractor adopts to select a subcontractor can be determined in many ways, such as, by competitive bidding, by negotiation with only one subcontractor, based on bidding price, based on lowest bid, based on the decision-maker's experience, based on the previous working relationship, based on personal relations, and selection from the host country or from other countries, to name a few. Also to be considered is the decision making process; i.e. is it a one man-decision, mixed group of technical and managerial personnel, a few top managers, the project team, or a separate procurement department that handles all projects.

A modern day subcontracting methodology perspective:

Shash (1998), who studied the subcontracting processes of 320 construction companies in Colorado via a questionnaire, effectively sums up the modern day methodology behind construction subcontracting; *“the existing practice in subcontracting is such that the general contractor prepares a detailed cost estimate for the work to be performed in-house. For a designated sublet work, the contractor does not prepare a cost estimate but rather invites subcontractors to submit price quotations before a given deadline. Interested subcontractors adhere to certain rules and submit their quotations for the sublet work. The general contractor then evaluates the submitted quotations and selects one quotation to be used for bidding. Following the award of the contract, the general contractor awards the sublet work to either the subcontractor whose quotation was used in the bid or to another subcontractor”* (Shash, 1998:1)

*The different ways to search for subcontractors:*

Furthermore, the methods by which the general contractor searches for possible subcontractors is also important. One approach would be to search among all possible subcontractors to find the most suitable in relation to the work needed to be done in the project. Another way is to have a list of prequalified subcontractors that compete for work. A third approach would be more of a network approach where the general contractor prefers to collaborate with specific subcontractors. In this case, work is only put out for bidding if none of the preferred subcontractors are capable of taking the job or when the general contractor wishes to check the market to find a “market price” in order to ensure that the subcontractors are still competitive pricewise.

*The issue of short procurement time due to the nature projects:*

Furthermore, as a result of the pace that projects proceed, the majority of subcontractors are selected near the time that their portion of the work needs to start. The procurement time used becomes short, impacting on the choice of subcontractor and communication of works. Furthermore, the general contractor often does not consider the entire supply chain of projects, what may be suitable for one project, may not necessarily result in the best global outcome for the organization (Tserng and Lin, 2002). Therefore, the subcontractor’s fit or alignment with company strategy, mission statements and goals should also be assessed.

*Identifying an optimal combination of subcontractors is important:*

As part of their risk minimization and profit maximization computerized ASAP model for selecting subcontractors for construction works, Tserng and Lin (2002) emphasizes the importance of selecting the optimal combination of subcontractors. The interview guide incorporates questions to determine if the case company selects subcontractors based on past observations that they have worked well together on similar projects; or by any alternative prediction methods in which the procurement officer anticipates they will work well together.

*Timing of Subcontractor Selection:*

Elazouni and Metwally (2000) established a decision making support system which allows general contractors to calculate the work tasks for subcontractors and plots an overdraft profile based on the financial terms of the contract and the project schedule. This should ideally be done before the subcontractor is engaged. However, Ulubeyli et al. (2010) states that there is other time periods that the subcontractor can be selected. They state that in construction bidding,



subcontractors can be determined in one of the following time periods- selection after the project starts, selection between the main tender and project start, and selection before the main tender. The latter author, through their empirical investigation, advises that subcontractors should be awarded the contract before the project starts and as early as possible within the procurement process to estimate activity inputs accurately and overcome the adaption period more quickly (Ulubeyli et al., 2010). So looking at their arguments, the aforementioned authors seem to agree that subcontractors should be selected following the calculation of the work tasks, and early in the procurement process. The most common timing for the selection of a subcontractor will be determined of the case company.

Some recommended methods:

Kumaraswamy and Matthews (2000) recommends that as a bare minimum, when evaluating potential subcontractors in the prequalification and tender stages, provision should be made to assess:

- The proposed subcontractor selection methodology/ criteria
- Any potential/short-listed subcontractors
- How well the general contractor/subcontractor team may operate in a partnering mode with the client's project management/design team.

In addition, MBachu (2008) produced a relatively standard process flowchart for the assessment of the subcontractors' eligibility for tender invitation (prequalification) and award (selection) as shown in Figure 6. It fits well with the recommendations of the majority of authors' comments presented earlier. A common agreed upon process trend has emerged that is applicable to the majority of construction projects. A prequalification and screening stage is first presented with a short-list of subcontractors appropriately ranked as per their ability to meet established pre-qualification criteria. Following this, subcontractor award selection criteria is identified in the subcontract award or pre-contract stage and a shortlist of subcontractors is invited to tender on the works in a competitive bid. Subcontractor's tender submissions are assessed on their performance to meet subcontract award criteria. The subcontract is awarded to the highest rated subcontractor.

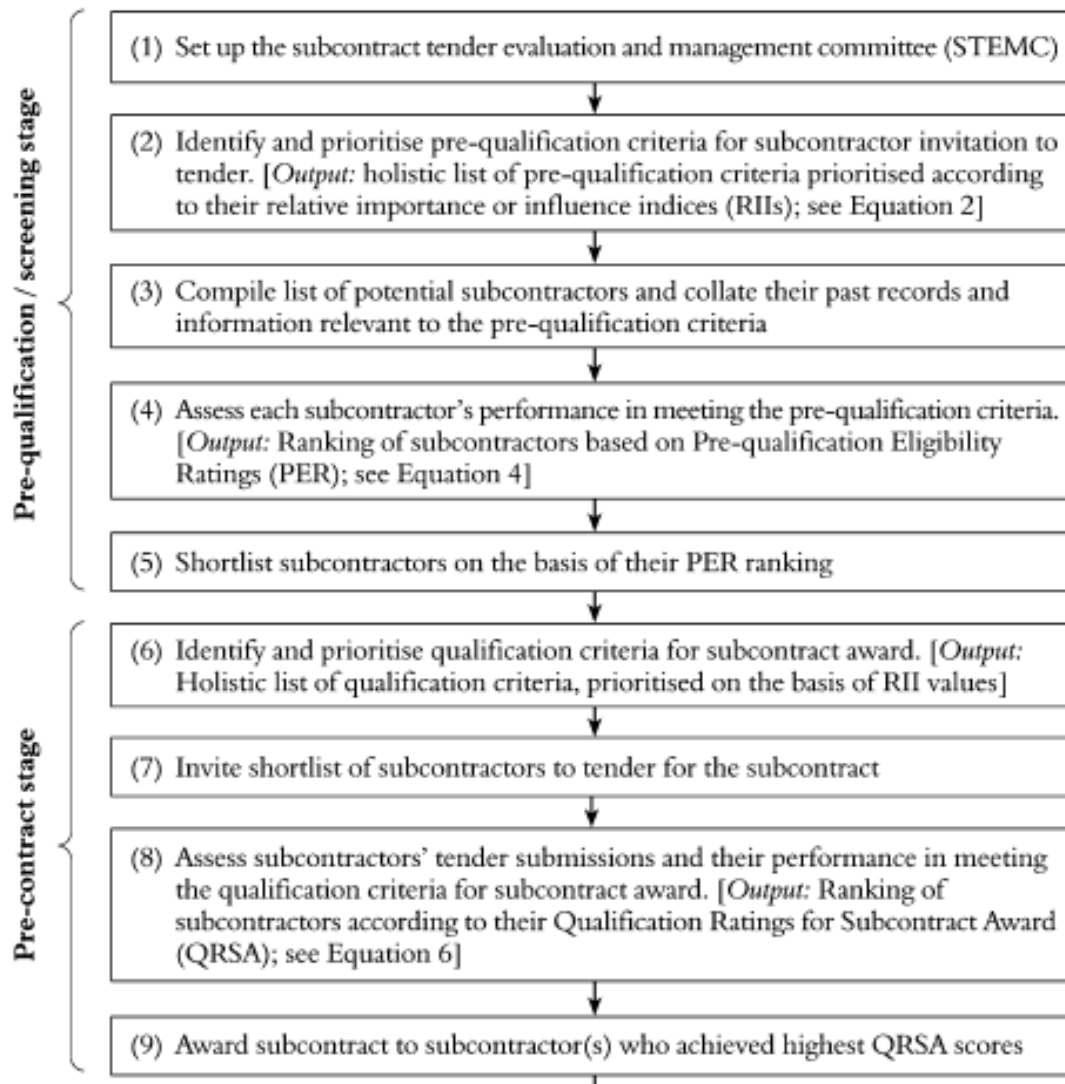


Figure 6- An example of a flowchart outlining a step-by-step methodology for subcontractor selection (MBachu, 2008)

Likewise and as previously mentioned, Abbasianjahromi et.al. (2013) proposed a subcontractor selection method based on their research into a ‘fuzzy preference selection index (PSI)’ method in which each criterion selected is calculated in order of weight given using statistical and linguistic applications. It has three steps to the model: Step 1- the identification of subcontractors; Step 2- criteria identification; Step 3- the application of the FPSI method. The model is shown below in Figure 7. It is similar to the recommendations presented by authors earlier, however with a heightened focus on customer input and corporate strategy considerations. In an attempt to assess the validity of this model to the case company, the effect the customer and key stakeholders of the general contractor has on the selection process will be evaluated, along with whether the case company uses or has used some form of fuzzy set theory evaluation techniques.

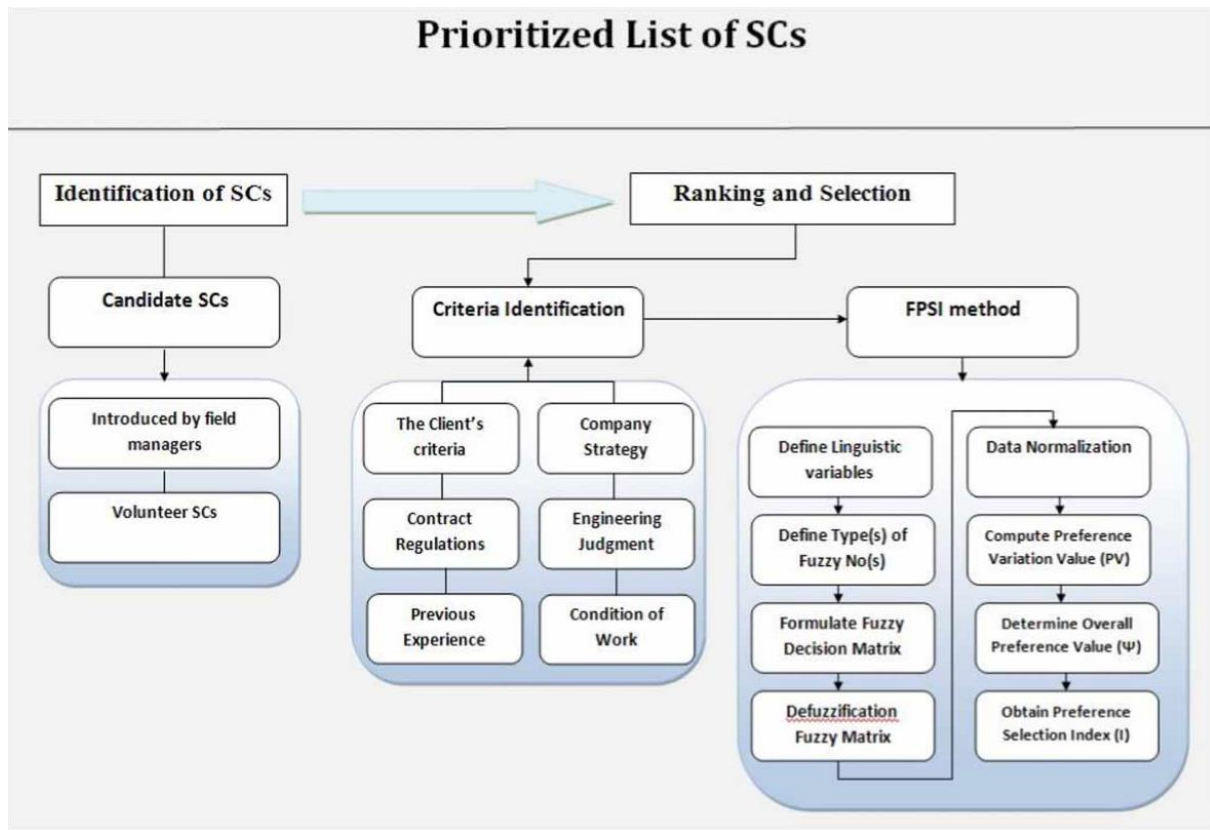


Figure 7- A subcontractor selection method (Abbasianjahromi et.al, 2013)

### 3.2.4.1 Statistical Contractor Evaluation and Selection Methodologies

A number of credited statistical selection methods have been suggested in selecting a contractor. Some of the most highly noted ones include bespoke approaches (BA), multi-attribute analysis (MAA), multi-attribute utility theory (MAUT), multiple regression (MR), cluster analysis (CA), fuzzy-set theory (FST), and multivariate discriminant analysis (MDA). The case company will be examined to assess whether they have used any of the aforementioned approaches in selecting subcontractors. The details and processes for how to use each technique is presented in a reasonably detailed way in an attempt to make the differences between each recognizable, and to clearly demonstrate to the reader how to use these techniques. It is recommended that if the technique itself is not used; elements, applications and thought processes from these techniques will be used effectively in the subcontractor selection process. The overall goal of using or at least considering these techniques is to innovate new ground breaking methods to select subcontractors into the future.

#### *3.2.4.1.1 Bespoke approaches (BA)*

BA is a popular approach to subcontractor selection in the construction industry. It consists of a substantial variance in its decision making from project to project as it relies heavily upon binary decisions and subjective interpretation. BA incorporates several decision making techniques simultaneously in mostly an ad hoc evaluation and selection process developed by a particular construction owner or client. Because of their differing nature, BA is difficult to classify in terms of a single parameter. However most tend to follow a process alike to that displayed in Figure 8 as proposed by Holt (1998), who studied the different forms of statistical evaluation methods in detail. The first stage of BA generally involves a judgment made by an individual decision maker of a project in the prequalification stage to assess if a subcontractor has conformed to the “cut off points” or “must” criteria (Harris and McCaffer, 2013). This criteria is usually a function of client preference, for example, does the subcontractor have the latest safety accreditation specific to a country. Following this, a binary decision follows in which non-conforming tenders are rejected (i.e. a NO in one criterion) (Holt, 1998). This will mostly prove to be an effective way of reducing a potentially large set of tender submissions, however there is a risk that a ‘good’ subcontractor may be wrongly excluded early in the process.

Conforming tenders are then broken into the financial and health and safety criteria of the subcontractors and comparison to the project standards (for example, does the subcontractor have the National Health and Safety Certificate and have they had a turnover revenue over a certain amount in the last three years?). At this point a second binary decision is made with nonconforming subcontractors being rejected, and conforming subcontractors undergoing further prequalification check in relation to shortlists or project criteria. From this they are either invited for tender, or are placed onto a standing list for ultimate invitation to tender. The later stages have a high dependency on subjectivity on the behalf of the customer and project decision maker (Russell, 1992). A numeric measure, yardstick, datum or score would improve the BA approach, if only as a means of comparing subcontractors relative to each other (Holt, 1998).

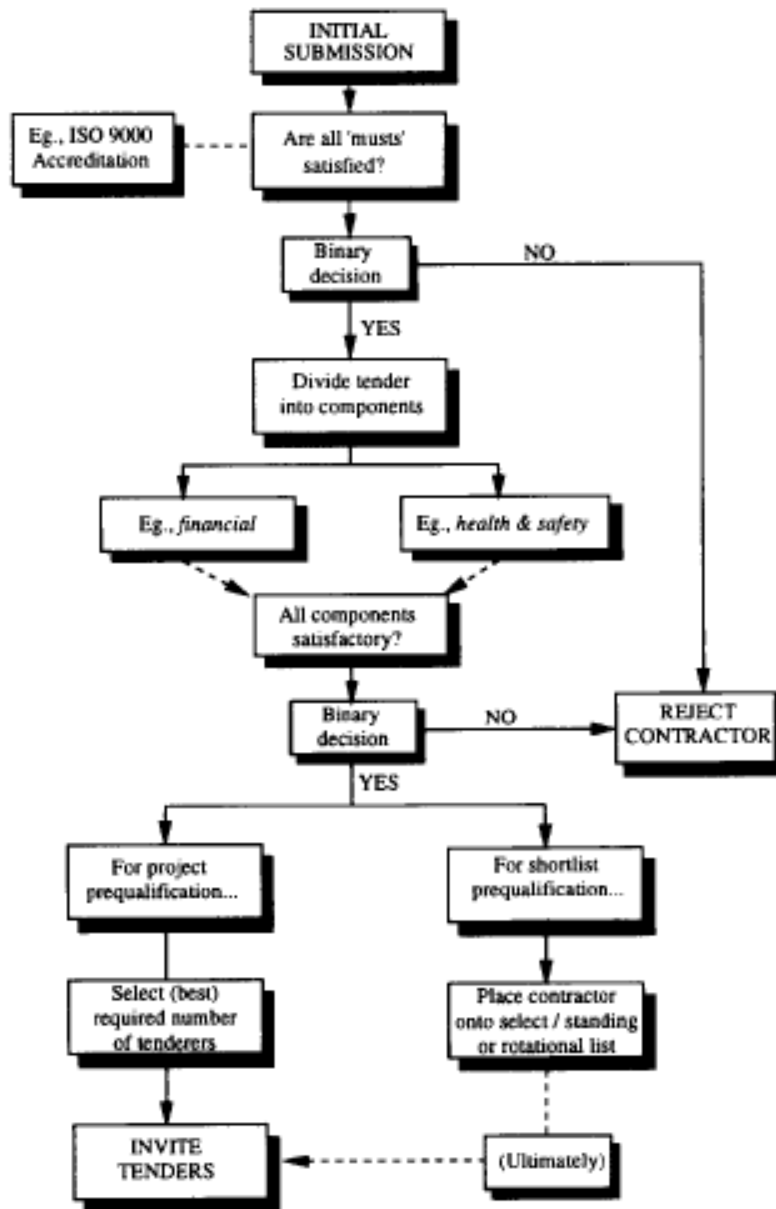


Figure 8- Typical process for a bespoke approach (Holt, 1998)

### 3.2.4.1.2 Multi-Attribute Analysis (MAA)

MAA takes into account a decision alternative with respect to a number of the alternative's attributes. For example, a subcontractor's attributes represents one aspect of a decision alternative with respect to a client or project objective (Holt et al., 1994a). Attributes may be measured quantitatively, if they are quantifiable (Hwang and Yoon, 2012). The most basic MAA equation is the 'simple scoring' MAA and can be expressed as:

$$ACr_j = \sum_{i=1}^n V_{ij}$$

Where:  $ACr_j$ =aggregate score for contractor j;  $V_i$ = variable (attribute) i score in respect of contractor j; and  $n$  = the number of attributes considered in the analysis (Holt, 1998). An improvement to the ‘simple scoring’ MAA is to add weighting indices ( $W_i$ ) to  $V_i$  thereby emphasizing contractors' aggregated scores who perform better in higher weighted criteria and vice versa (Holt, 1998).  $W_i$  can be a function of a single decision maker’s experience and preference, a group consensus, or a survey and analysis of data (Holt et al., 1994b). This equation can be expressed as:

$$ACr_j = \sum_{i=1}^n V_{ij} W_i$$

An example of a hypothetical situation is shown in Table 1, in which four subcontractors are evaluated in relation to five attributes or criteria. Here the components ( $V_i$  and  $W_i$ ) are denoted by an infinite range of integers, so that a unified aggregate contractor score (designated  $UACr_j$ , i.e.  $0 < UACr_j < 1$ ) may be reached:

$$UACr_j = \frac{ACr_j}{ACr_{jmax}}$$

Where  $ACr_{jmax}$  is the maximum attainable aggregate score utilising  $W_i$ .

	Input										Output			
	$V_1$	$W_1$	$V_2$	$W_2$	$V_3$	$W_3$	$V_4$	$W_4$	$V_5$	$W_5$	$ACr_j$	$ACr_{jmax}$	$UACr_j$	Rank
$Cr_1$	8	8	2	10	10	7	8	10	6	9	288	440	0.652	2
$Cr_2$	7	8	3	10	10	7	3	10	3	9	213	440	0.484	4
$Cr_3$	4	8	10	10	4	7	5	10	5	9	255	440	0.583	3
$Cr_4$	7	8	8	10	6	7	7	10	8	9	320	440	0.731	1

$V_i$  &  $W_i$  scored/weighted 1 to 10

Table 1- Hypothetical MAA example (Holt, 1998)

### 3.2.4.1.3 Multi-attribute utility theory (MAUT)

MAUT can be complex and is similar to MAA however incorporates an extra quantitative method for inclusion into the selection process. It uses ‘utility’ ( $U_i$ ) to quantify the subjective components of MAA. MAUT can quantitatively take into account both tangible (e.g. safety record) and intangible (e.g. contractor image) attributes.  $U_i$  is a measure of satisfaction or desirability of a characteristic (attribute) of an alternative (subcontractor) (Moselhi and Martinelli, 1990). A utility value is an abstract equivalent of the attribute being considered from

natural units such as years, or \$, into a series of commensurable units on an interval scale of 0 to 1.0 (Holt, 1998). The transformation of these values is a linear function if it is risk neutral and curved if it is risk averse or risk seeking, as illustrated in Figure 9. The result of this is fundamentally a function of the decision maker from which the function was derived.

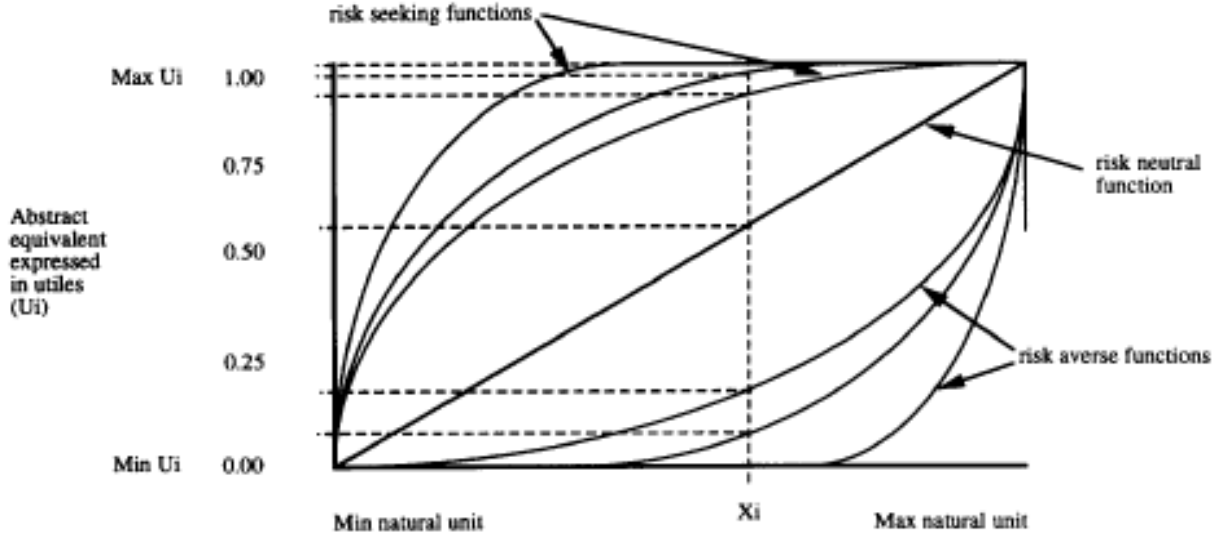


Figure 9- Characteristic utility curves in MAUT (Holt, 1998)

3.2.4.1.4 Multiple regression (MR)

MR is a statistical method that predicts the effect of several independent variables on a dependent variable through an equation. Y\* represents the dependent variable (the numeric outcome), V represents the independent variables (the actual outcome), ci are the partial regression coefficients; Co is a constant representing the intercept upon the y axis of the resulting regression line; and n is the number of independent variables within the equation. Holt (1998) states that a typical MR equation can be formalised as:

$$Y^* = C_o + \sum_{i=1}^n V_i c_i$$

Based on subcontractor (interval) attribute data, Holt (1995) claims that there is scope for building MR equations in the prequalification selection process to generate scores for each major player. This approach has been investigated resulting in the MR equation as:

$$P1 = 0.311 + 0.151V_1 + 0.035V_8 + 0.154V_9 - 0.159V_{19} - 0.031V_{20} + 0.232V_{21}$$

Where P1= prequalification score; V1= size of subcontractor organisation; V8= quality of bank reference; V9= quality of creditor references; V19= past performance (time overruns); V20= past performance (cost overruns); and V21= past performance (quality achieved). It is however worthy to note that this equation was formulated from a limited sample size and from smaller sized projects, so therefore should be approached with hesitation. A possible stepwise procedure for an MR qualification is exhibited in Figure 10.

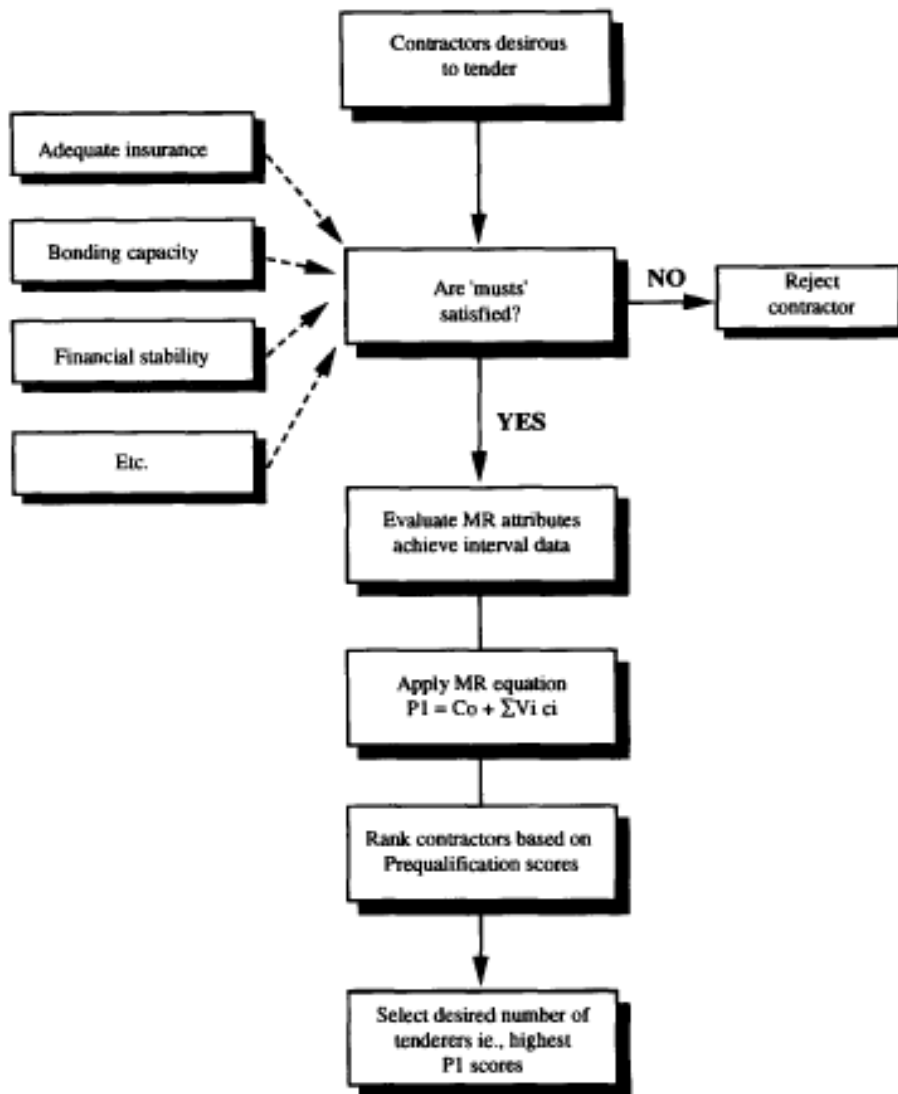


Figure 10- Example of a possible stepwise procedure for an MR prequalification model (Holt, 1998)



### 3.2.4.1.5 Cluster Analysis (CA)

In a CA, the original set of subcontractors is clustered into a series of smaller, manageable subsets of similar character. Through the examination of each subset, the quality (attributes) of subcontractors may be observed and the best subsets identified for tender invitation, if prequalification is being performed (Holt, 1998). In addition, the CA approach could help general contractors in assigning subcontractor's to standing lists. Some of the benefits of using CA include:

- the ability to apply a limited number of identified selection criteria to the entire original set, which in turn facilitates effective investigation of all subcontractor's whilst rationalising the evaluation process and reducing the possibility of rejecting 'good' contractors at an early stage in the procedure (a risk also associated with BA)
- minimizing owner resource commitment, and hence maximizing the potential for achieving client satisfaction through the selection of the best alternative(s) (Holt, 1998).

Through the use of a classification algorithm, subcontractor's are put together within clusters, unlike those from other clusters (Holt, 1996). There are two types of CA, namely jointing-tree clustering as shown in Figure 11, and k-means clustering. Figure 11 displays a dendrogram from 19 contractors, which have been split into two main clusters. It visually allows one to depict how subcontractors are similar through a hierarchical tree. The distance between the branches of the tree are proportional to the dissimilarity between contractors (Holt, 1998). There are an array of CA algorithms, however the most straightforward example computing the degree of difference between subcontractors by means of Euclidean distances is represented by:

$$D_{ij} = \sqrt{\left\{ \sum (x_{ij} - x_{jk})^2 \right\}}$$

where:  $D_{ij}$  is the distance between two points and  $x_{ik}$  is the value of the  $k$ th variable for the  $i$ th entity (Everitt, 1980; Holt, 1998).

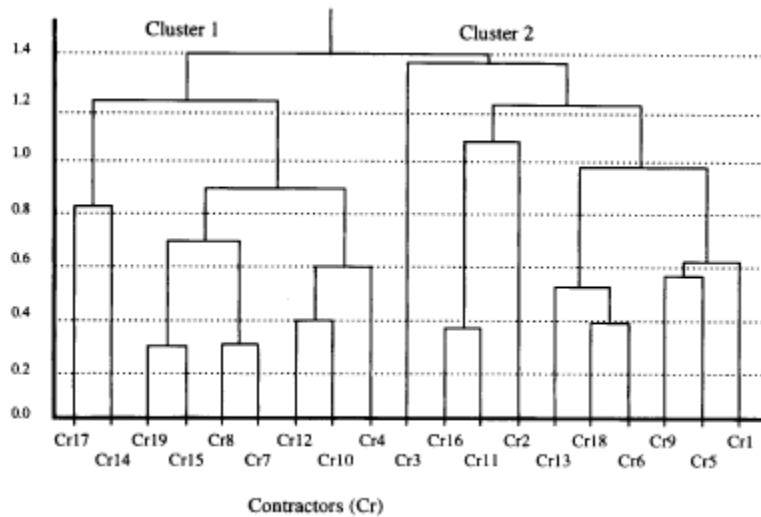


Figure 11- Jointing-tree CA dendrogram (Holt, 1998)

Table 2 shows the mean criteria scores and analysis of variance (ANOVA) for the selection scenario shown in Figure 11. In this case, eight selection criteria were used, in which 4 have been shown to be the ‘controlling’ criteria (significance at the 95% level), namely V1, V6, V7 and V8, easily identified in Figure 12. Figure 12 is a graphical representation of the ‘cluster profiles’ for the 19 subcontractors. Cluster 2 is the better set of contractors with higher mean scores in all variables except two.

Variable	Mean scores		Analysis of variance		
	Cluster 1	Cluster 2	Between clusters*	Within clusters†	Significance (P)
V <sub>1</sub>	0.42	0.79	0.64	2.50	0.052
V <sub>2</sub>	0.90	0.91	<0.01	0.25	0.911
V <sub>3</sub>	0.80	0.85	<0.01	0.75	0.650
V <sub>4</sub>	0.80	0.92	0.06	0.38	0.102
V <sub>5</sub>	0.33	0.27	0.01	0.49	0.440
V <sub>6</sub>	—	0.65	2.00	2.02	0.000
V <sub>7</sub>	0.42	0.79	0.64	2.50	0.052
V <sub>8</sub>	0.73	0.18	1.45	2.76	0.008

\*Sum of squares (1 df)  
 †Sum of squares (17 df)

Table 2- Mean criteria scores and ANOVA for Clusters 1 and 2 (Holt, 1998)

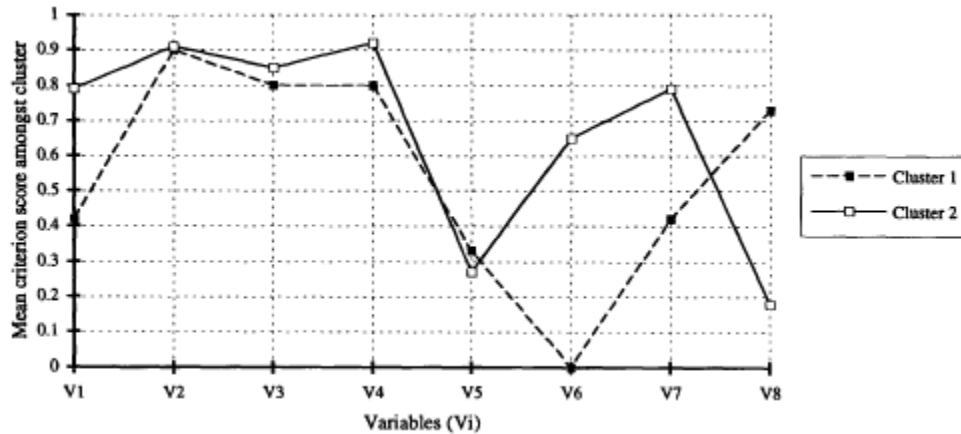


Figure 12- Mean criteria 'cluster profiles' for Clusters 1 and 2 (Holt, 1998)

#### 3.2.4.1.6 Fuzzy-set Theory (FST)

The key advantage of using FST is that it provides a way to model human judgement and handle uncertainty, functions of which are: imprecision, randomness and ambiguity (Wang and McCarthy, 1994; Holt, 1998). In addition, multi-criteria that may be subjective and inaccurate is more easily managed (Nguyen, 1985). The core of this theory is that it measures the degree to which a subcontractor is or is not a member of a class, not just that they are, or are not. A membership value (M) is assigned between 0 and 1, in which 1 entails maximum strength of membership to a particular class. From the M rating, subcontractors can be grouped in relation to being strong or weak for a certain selection criteria point. Figure 13 highlights the difference between fuzzy-set and classic set theories. However, FST may not be used as commonly by practitioners because of its complex nature (Holt, 1998).

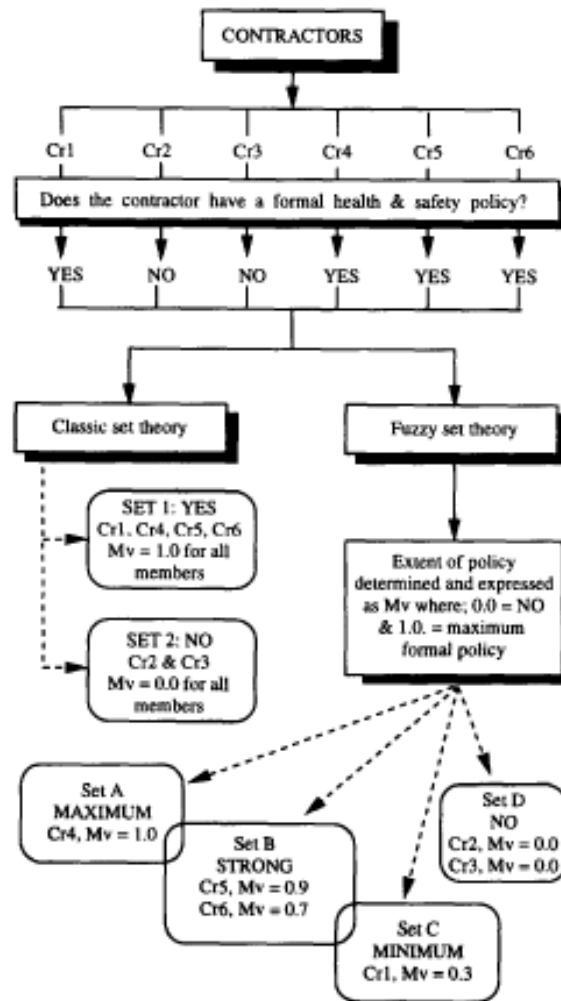


Figure 13- Graphical depiction of the fundamental concepts of classic vs fuzzy set theory for a health and safety policy criteria (Holt, 1998)

### 3.2.4.1.7 Multivariate Discriminate Analysis (MDA)

In its application to subcontractor selection, MDA studies the differences between two or more subcontractors with respect to several variables at the same time. The basic prerequisite is that two or more subcontractors are presumed to differ on several variables (Klecka, 1980). It is primarily used by examining a subcontractor's previous performance on the job site in combination with the characteristics of the subcontractor in an attempt to determine:

1. which, if any, of the contractor attributes are discriminators i.e. have the ability to predict performance on future jobsites;
2. how these attributes might be combined into an algorithm in order to achieve; and
3. the accuracy of such an equation (Tam, 1992)

Most importantly, MDA identifies the controlling criteria in the subcontractor selection process. Subcontractors are classified into a group it most closely resembles via its characteristics. The technique begins by identifying the most discriminating variable common to the group. The variable is then combined with each of the other variables in turn until the next variable is found which contributes most to any further discrimination between the groups. The process continues in the same manner until very little discrimination is gained by inclusion of any further variable (Holt, 1998). The large amount of calculations involved requires a computer software package such as the SPSS-PC+ (or Windows) suite of programs (Skitmore and Marsden, 1988).

#### 3.2.4.1.8 Summary of statistical selection methodologies

Holt (1998) provides an excellent summary of the decision methodologies:

- BA: prolific industrial use but very subjective
- MAA: academic and industrial use but can be subjective
- MAUT: academic use, scope for derivation of alternative utility functions
- MR: evidence of academic use, scope for further research and industrial application
- CA: limited academic use, scope for further research and application to prequalification
- FST: evidence of academic use but may be too complex for acceptance by industry
- MDA: academic use, broader scope for research and industrial application.

A summary to the above methodologies is provided in Table 3 which also highlights the advantages and disadvantages to the use of each with regard to practical application in selecting subcontractors.

Method	Known Usage	Degree of subjectivity	Nature of input data	Nature of output	Future scope to problem
BA	Popular with industry practitioners	Input and output both subjective	Descriptive, binary, linguistic subjective	Binary, descriptive	Limited in quantitative terms
MAA	Mostly used by industry in simple scoring models. Some usage by academia	Input reliant upon subjective evaluation of attributes	Subjective	Numeric score ranked against alternatives	Limited in quantitative terms

MAUT	Academic	Input converts qualitative data to quantitative	Raw data is qualitative. Utility achieves interval data	Numeric score ranked against alternatives	Good if representative utility curves are derived. Requires research
MR	Academic	Achieving interval data susceptible to subjective evaluation	Interval predictive	Numeric; further value	Good. Scope for research
CA	Limited	None if raw multivariate data is used	Multivariate	Group membership and group characteristics	Excellent. Scope for further research
FST	Academic	Scope for development of attribute profiles	Descriptive. Qualitative converted to interval	Group membership	Good. May be too complex for easy acceptance by industry
MDA	Some use by academia	Quantitative	Multivariate	Group membership/ group characteristics	Previously used but broader scope possibilities needs further research

Table 3- Matrix of methodology characteristics with respect to subcontractor selection (Holt, 1998)

#### 3.2.4.2 Partnering

The effect of applying partnering principles to improve the subcontractor selection process was studied by Kumaraswamy and Matthews (2000). Their study shows that general contractor-subcontractor partnering approaches can be beneficial by improving time and cost control, reducing pricing levels by at least 10% whilst improving the relationships between all project participants. The general philosophy of partnering involves integrating all key participants and identifying a common sense of project purpose, commitment, teamwork, and problem-solving. A commonly cited definition originates from the Construction Industry Institute who quotes it as *“a long-term commitment between two or more organisations for the purpose of achieving specific business objectives by maximising the effectiveness of each participant’s resources. This requires changing traditional relationships to a shared culture without regard to organisational boundaries. The relationship is based on trust, dedication to common goals, and an understanding of each other’s individual expectations and values”* (Insearch, 1991; Kumaraswamy and Matthews, 2000:50). Developing a strategic long-term partnership with a selected or a number of selected subcontractors can lead to cost and value advantages for the

general contractor through knowledge sharing, and integrating a consistent supply chain to create value and deliver high quality projects.

*Increased time, cost and quality control:*

Kumaraswamy and Matthews (2000) concluded that although the tender costs during this partnering approach were greater than those found on competitively tendered projects, it was much easier to control time and cost performance levels and achieve higher quality levels given the close cooperation and openness/transparency that facilitated earlier anticipation and minimization of potential problems.

*Withering relationships in the construction industry has led to partnering approaches:*

The adoption of these strategies can be attributed to the fact that relationships in the construction industry were lacking trust, respect and honesty between professionals, main contractors, and subcontractors which lead to procurement issues with claims, litigation, and unsatisfied clients (Kumaraswamy and Matthews, 2000). The interview guide incorporates questions to analyze if the case company has adopted any known long-term strategic partnering relationships with subcontractors across a number of projects.

*3.2.4.2.1 An example of a partnering approach to subcontractor selection:*

Kumaraswamy and Matthews (2000) also highlight an example of a partnering subcontractor selection method that involves firstly the identification of the key trades and work packages of the construction project (for example, ceiling and partitions, floors, cladding, mechanical and electrical works, structural steel frame, lifts etc.). Having achieved this, project team members with experience put forward names of subcontractors, assessed mainly on past performances, and the team as a group meets and shortens the list. Other criteria recommended to be assessed include:

- Ability to undertake this quantity of work;
- Ability to produce the required standard of work;
- Ability to undertake the work (not wanting to overstretch” the subcontractors);
- Positive attitude (past experiences);
- Firm financial background;
- Good in-house design service (where applicable);
- Good standards of management (site and head office);

- Main contractor's desire (if any) to develop a long-term relationship with the subcontractors.

Following on from the team meeting, 3-5 subcontractors should be selected as potential for each package. The latter are then invited to a first subcontractor interview which will aim to assess the subcontractor's ability in terms of attitude, proactiveness, design capability, honesty, background, and workload; whilst introducing the project, the philosophy of partnering, and handing over pricing details and other relevant information. From this the project manager and team assesses each subcontractor by way of a pro forma, an example is shown in Figure 14, on key criteria such as indicative price, technical ability, enthusiasm, past experience of similar work, quality awareness, and alternative proposals put forward for their package (including design innovation, alternative product specification and value engineering).

Following this, a second subcontractor interview should then take place based on a project briefing and tender clarification before selecting the appropriate subcontractor for each work package. An indicative price and budget rate should be agreed upon based on the clients' cost plan. Results from this method yielded that subcontractors on average reduced their pricing levels by 10% and increased quality levels provided by the close cooperation and transparency associated with earlier anticipation and minimization of potential problems (Kumaraswamy and Matthews, 2000).



SUBCONTRACTOR EVALUATION.						
Contract Name						Trade: .....
Date: .../.../...						
SC Name:	SC1	SC2	SC3	SC4	SC5	SC6
Representatives Name:						
Design Ability.	8					
Partnering Experience & Response.	4					
Level of Understanding.	5					
Value Engineering – Preliminary Thoughts	7					
Response to Construction Thoughts	5					
Reaction to 'Realistic Costs'	5					
Quality Awareness.	8					
TOTAL SCORE:	42					
Assessment made by:	60%					

Figure 14- Example of a pro forma that can be used to evaluate subcontractors in an interview setting based on certain selected criteria. Note: each criterion is scored out of 10 (Kumaraswamy and Matthews, 2000)

### 3.2.4.3 Web-based subcontracting

In recent times, the use of internet-based practices in subcontracting has made the exchange of information simple, fast, accessible, and accurate, and brings a new, pivotal opportunity and force to development of the construction industry. Through the internet, value creation initiatives and supply chain management objectives may be more effectively communicated and achieved, along with a higher accuracy of quality subcontractor selection compared to more traditional subcontractor selection processes of selecting whilst working on the project.

#### Increasing trend in the use of “e-marketplaces”:

Horta et al. (2013), who developed a framework for selecting subcontractors through the use of web-based practices, emphasizes that the use of “e-marketplaces” by construction companies has increased exponentially worldwide with some of the noted benefits relating to the promotion of a collaborative working environment, increased transparency, bidding process

acceleration and reduced costs. The goal of any effective web-based system should be to generate outcomes based on individual indicators and determine an average measure of overall performance that reflects the preferences of the decision maker in terms of the relative importance of the indicators (Horta et al., 2013).

A subcontractor selection method developed for e-marketplaces:

Furthermore, Horta et al. (2013) argues that normal subcontractor selection approaches have room for improvement, as they are not specifically tailored to be integrated into e-marketplaces. Horta et al. (2013) provides some areas that should be incorporated into e-marketplaces including bilateral evaluations to better understand general contractor-subcontractor relationships. The decisions at each stage are based on several perspectives, informed by a robust set of performance indicators, and increased flexibility to include the preferences of the decision maker in regards to relative importance of each selection criteria. In their investigation they select the most essential selection criteria for subcontractors in an e-marketplace context at the prequalification stage as financial standing, past experience, reputation, management and technical ability, and resources. At the subcontractor award stage, the identified criteria consists of company attributes, operation performance, and bid/tender attributes. The result was a CIsa system methodology specifically for subcontractor selection in construction industry e-marketplaces as shown below in Figure 15.

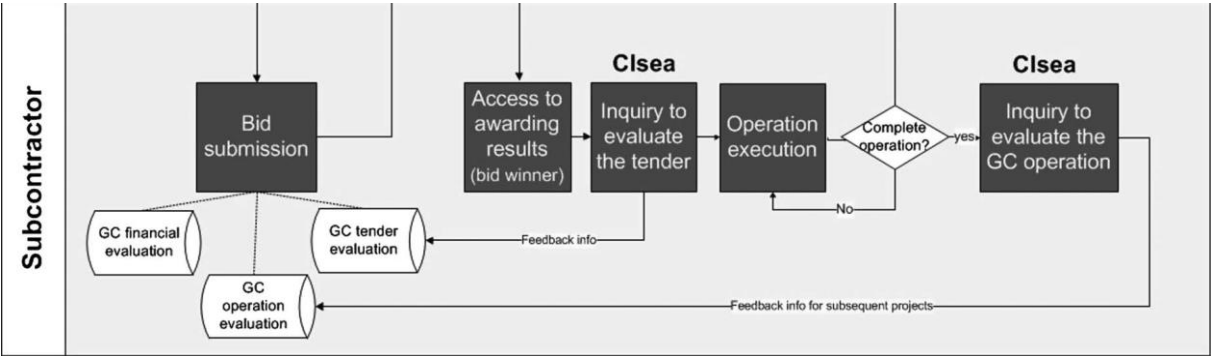


Figure 15- A subcontractor selection method developed for e-marketplaces (Horta et al., 2013)

3.2.4.4 Case-Based Reasoning

Case-based reasoning (CBR) is a recent approach to problem solving and may be an effective method in addressing the challenges of selecting subcontractors as it is able to successfully tap into the experiential knowledge of practitioners. CBR uses the lessons learned in previous cases in a computer-assisted approach that draws on solutions to previous similar problems and situations (cases). A new problem is solved by finding a similar past case and reusing it to the

new problem situation (Aamodt and Plaza, 1994). In their study using case-based reasoning to select subcontractors in Australia, Luu and Sher (2012) found that procurement officers usually awarded subcontracts based on those subcontractors used on similar successful tenders previously. In establishing the similarity, procurement officers used a number of factors to assist them in their subcontractor decision including: characteristics of proposed construction projects; the market conditions where the project would take place; as well as main contractors' expectations of potential subcontractors (Luu and Sher, 2012). Table 4 outlines these factors.

Similarity Parameters	Possible Values
<i>Project related</i>	
Project Category	Administrative and civic; commercial; educational; hospital; industrial; recreational; residential; civil engineering; others
Construction type	New construction; refurbishment; combination of both
Size	< \$0.3M; \$0.3M–\$0.5M; \$0.5M–\$3M; \$3M–\$20M; > \$20M
Location	Sydney; Wollongong and Illawara region; Newcastle and Hunter valley region; Mid North Coast; North Coast; North West NSW; South West NSW
Complexity	High, medium, low
Procurement type	Construct only; Design & construct; Construction Management; Management Contracting
<i>Subcontractor's related</i>	
Suitable experience relevant to current type of project	High, medium, low
Track record of competitive pricing	Always competitive; average; not competitive
Track record of performance during construction	Outstanding; average; poor
Financial stability	High, medium, low
Availability of suitable subcontractors	High, medium, low
Current dispute with main contractor	Yes; No

Table 4- Project similarity parameters for CBR subcontractor selection (Luu and Sher, 2012)

The three main factors- input, selection and output:

The CBR framework consists of three main components (input, selection and output). The input module provides construction procurement officers with a means of submitting data, in which they enter similarity parameters for construction tenders and rate their importance. Similar cases are accrued over a period of time, as the system is used on succeeding occasions, becoming

more accurate which each attempt (Kolodner and Wills, 1993). When the data is comparable to the current case and is selected for use, procurement officers can apply this 'case' to the new tender project. Specific subcontractors are then reported to procurement officers through the output module (Kolodner and Wills, 1993). A check on the suitability is then performed on the new case and the adopted or adapted solution is stored in the CBR database for future reference and retrieval.

#### 3.2.4.5 Bid Shopping

In addition, when subcontractor competitive bidding occurs, it is commonly associated with bid shopping, which can arise either pre or post-bid.

##### Pre-bid shopping:

Pre-bid shopping is normally initiated by the subcontractor after they receive specific information about the lowest amount that has been bid by competing subcontractors. Amounts being quoted in the bids of other subcontractors are used as “insider information” (by subcontractors) or as leverage (by general contractors) (Hinze and Tracey, 1994). The general contractor may be pushed by the subcontractor to give up information in relation to the price of competing subcontractor’s bids, in order for the latter to assess the merits of submitting a reduced bid.

Although this practice is widely regarded as unethical, pre-bid shopping occurs frequently, and has caused subcontractors to be very guarded about their bids, submitting them at a time after which bid shopping opportunities will be minimized (Hinze and Tracey, 1994). Such an approach may be adopted by a general contractor when they want to work with one particular subcontractor. In this case, negotiation is able to occur in which an acceptable ballpark figure on price is agreed upon, ensuring that if the general contractor is awarded the contract, the subcontractor is guaranteed a subcontract award. Bids from competing subcontractors are then not taken into consideration (Hinze and Tracey, 1994). Due to being potentially considered an unethical practice, it may be difficult to gain honest information regarding if the case company adopts this method into their selection process. However despite this, the interview guide incorporates questions in relation to bid-shopping.

### Post-bid shopping:

Post-bid shopping is initiated by the general contractor and after tendering has opened and a low bidder has been identified. The general contractor may approach this subcontractor with a proposal for the subcontractor to reduce the bid price, primarily as a means of increasing project profits or to adjust an error made in the initial bid (Hinze and Tracey, 1994). A subcontractor is bound to perform the works in accordance with their bid if accepted by the general contractor. On the contrary, the general contractor is not bound to use the subcontractor to perform the work, but is free to shop for a lower bid in an attempt to get a better price (Smith, 2000; Arditi and Chotibhongs, 2005). Again, it may be difficult to gain honest information regarding if the case company adopts this method into their selection process, however the question will be asked. While it is probable that some form of bid shopping may potentially occur on all projects it is difficult to assess the actual extent of this practice (Hinze and Tracey, 1994).

In the empirical investigation conducted by Arditi and Chotibhongs (2005) on bid shopping in the construction industry, both subcontractors and project owners noted a similar score of 1.42 and 1.36 on a scoring system of 0-3 for the frequency that general contractors shop bids to select their subcontractors after the contract is awarded. Whilst general contractors quoted the average frequency as 0.18, appearing to deny that post award bid shopping is happening at all, possibly because this practice is considered a legal but unethical practice in the industry. Submitting bid listings to owners appears to be the best way to eliminate post-award bid shopping (Arditi and Chotibhongs, 2005).

#### 3.2.4.6 Principal-Agent Model

The principal-agent theory or dilemma occurs when one person or entity, the “agent”, has the ability to make decisions on behalf of, or that impact, another person or entity, the “principal”. (Eisenhardt, 1989). The problem or dilemma arises when the agent is motivated to act in their best interests, which are conflicting to the principal. In this case, the agent is the subcontractor and the principal is the general contractor. This theory is relevant in the subcontractor selection process as a general contractor could select a subcontractor on the basis that they know the behavior of a particular subcontractor better than an unknown subcontractor, and select the known subcontractor on the basis of predicting they will act in the best interests of the general contractor. It comes as a result of the subcontractor, a specialist in a particular area of work, knowing the work better than the general contractor, putting the subcontractor in a controlling

position. The case company will be investigated to see if principal-agent theory is considered and incorporated into the selection process as a criterion or in any other form.

*The issue of conflicting goals and divergent attitudes towards risk:*

According to Eisenhardt (1989), who assessed and reviewed agency theory, there is two problems that occur. The first arises when the desires or goals of the principal and agent conflict and it is difficult or expensive for the principal to verify what the agent is actually doing. Thus, the general contractor cannot verify that the subcontractor has behaved in their best interests. The second is the problem of risk sharing that arises when the general contractor and subcontractor have dissimilar attitudes towards risk, and thus, may prefer different actions due to having different risk preferences.

*Application to the construction industry:*

In relation to principal-agent theory's application to the construction industry, it can occur when activities that are useful to the general contractor are costly to the subcontractor, in particular, where components of the subcontractor's actions are costly for the general contractor to observe. This may lead to a moral hazard. If a general contractor is concerned at the possibility of being taking advantage of and cheated by the subcontractor, for whatever reason, they may take them out of the tendering process on this basis alone. This deviation from the general contractor's interests by the subcontractor is coined "agency costs" (Bebchuk and Fried, 2004).

*Recommended ways to mitigate principle-agent problems:*

Furthermore, there exists a number of mechanisms that can be used to align the interests of the subcontractor with the general contractor including piece rates or commission contractual setups, profit sharing, efficiency wages, performance measurement, and the threat of contract termination (Mitnick, 2013). Levitt and Snyder (1997) recommend that principals should reward agents for coming forward with bad news and this will contribute to mitigating the risks of encountering principal-agent problems.

### 3.3 Value Creation

Value creation as it applies to subcontractor selection refers to creating value for the subcontractor, to the organization and to the customer through the use of subcontractors for a particular task or number of tasks. Value creation is viewed by many reporters as the key to corporation competitive advantage and long-term success. However, the conception of value



creation has proved to have differing interpretations. A good analysis of value creation is *“The value created may be from any new task, service, or job that provides greater utility or lower unit costs for the user over the closest alternative”* (Lepak et al., 2007:183). The interview guide includes questions to analyze if the case company has adopted a value creation perspective and integrated it in any conscious form into the subcontractor selection process.

*The two main components of value- perceived use and exchange:*

According to Bowman and Ambrosini (2000), who focused on the different definitions of value and their implications, value has two main components, that of perceived use value and exchange value. Perceived use value is a subjective concept, defined by the customers and is based upon the perceptions of the customers in relation to the usefulness of the product or service. Exchange value is realized when the service is actually sold. It is the amount paid by the customer to the producer. Bowman and Ambrosini (2000) propose a perspective on value creation: *“Inanimate resources purchased as inputs to the production process, whether they be machines, buildings, steel, computers, or flour, are incapable of transforming themselves into anything other than what they are. They need to be activated, worked on before they can contribute to the production of new use values”* (Bowman and Ambrosini, 2000:5).

*Sustainable value creation is achieved by using and developing resources and incorporating key stakeholders in the process:*

Therefore, sustainable value creation occurs when a firm uses and shapes the resources they have available to develop a product or service that the customer and they themselves perceive to be valuable. This does not mean the inanimate resources have no value; in fact, it has a value for the manager that decided to select these items on behalf of the firm (Bowman and Ambrosini, 2000). Laszlo (2003) emphasizes the importance of sustainable value creation in which the common boundaries of value creation are expanded to include all the stakeholders of a business, incorporating not only economic aspects but also social and environmental concerns.

*The three levels of value creation- individual, societal and organizational:*

Lepak et al. (2007) introduces three aspects of value creation that is created in three levels; individual, societal and organizational level. These are all important sources of value creation and create values of different scales. At the individual level, people can contribute to value creation through the development of new and proper tasks, services, products or other contributions that the target user (such as employer, client or customer) perceives to be of value relative to the target user’s needs. At the societal level, value creation can be achieved through

programs and incentives for entrepreneurship and innovation. The development of such programs should aim to broaden not only the values that exist in an organization but also transfer these values to the society in which the organization operates. At the organizational level, the central goal should be to continually adapt to the surrounding environment by creating new advantages through the use of new technologies and methods that develop the product or services offered.

### 3.3.1 Porter's Value Chain Model

Porter's Value Chain Model, illustrated in Figure 16, divides an organization's activities into technologically and economically distinct "value activities" it performs to do business (Porter and Millar, 1985). For a general contractor in the construction industry, the purchasing of services, namely subcontracting, is considered an essential support activity in gaining competitive advantage. Porter and Millar (1985) mention that to gain competitive advantage over its competitors, a company must perform these activities at a lower cost or perform them in a way that leads to differentiation and more value. As the activities are interdependent, entailing that the way that one activity is performed affects the cost or effectiveness of other activities, the trade-offs in performing the activities should be assessed and optimized (Porter and Millar, 1985).

Furthermore, cost and value advantages can be achieved through the selection of the best subcontractor for a particular work package. It can also be achieved through developing long-term strategic partnerships with subcontractors that have the potential to deliver a large volume of work in future projects, and also have the capacity and the resources to develop and grow. The long-term goal of the general contractor should be to extend the value chain beyond the boundaries of the general contractor to the entire supply chain, including the strategic subcontractors selected. This will deliver a highly integrated supply chain, creating value, improving access to information and resources, and providing cost and value advantages for the general contractor.



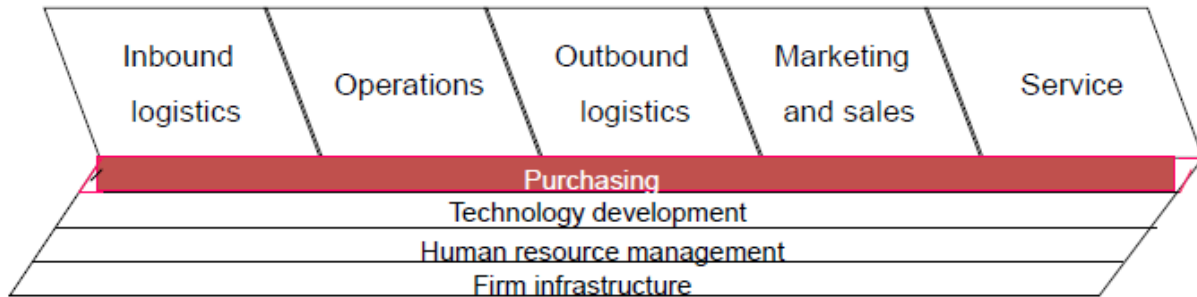


Figure 16- Porter's Value Chain Model (Porter and Millar, 1985)

### 3.3.2 Supply Chain Management (SCM)

Supply chain management as a form of value creation:

Supply Chain Management can be considered as following details and processes that contribute towards value creation. The growing importance of construction subcontracting strengthens the importance of comprehensive selection methods that draw on experiences from all parts of the supply chain. Whilst there has been some ambiguity to the term of SCM, a concise definition is proposed by Lambert and Cooper (2000), who developed a supply chain framework from their case study investigation on several companies, as *“the integration of business processes from end user through original suppliers that provides products, services, and information that add value for customers”* (Lambert and Cooper, 2000:66). In this thesis, supply chain management will be considered in the light of the subcontractor as part of the project supply chain, offering not a product, but a service. All organizations participate in a supply chain, and in most cases, the supply chain is more a network of customers and suppliers, and less like a linear pipeline or chain. In terms of the focus of this study on construction, the general contractor (customer) commonly has a number of different subcontractors (supplier of services) that make up the project network or supply chain. In turn, the general contractor delivers the project (a supplier of service) to the client or project funder (customer).

Corporations act as part of a supply chain:

According to Lambert and Cooper (2000), a significant paradigm shift of current business management is that individual businesses no longer compete as solely autonomous entities, but rather as supply chains. *“The importance of corporate culture and its compatibility across in supply chains cannot be underestimated”* (Lambert and Cooper, 2000:73). The subcontractor's

values and business culture should not be conflictive in any nature to the general contractor's culture and interests, and common grounds should exist for doing business and hence, for successful contractual work to be completed. The interview guide incorporates questions to assess if the case company potentially selects subcontractors on the basis of a similar corporate and business culture to their organization allowing for a more integrated synergy of project culture.

### 3.3.2.1 Strategic Supply Chain Management (SSCM):

Furthermore, the term Strategic Supply Chain Management (SSCM) has recently gained popularity in the strategic planning processes in organizations, and SCM should be included in organizations' overall strategies (Handfield et al., 2005). If firms want to increase competitive advantage, then they must go further than the buying process and look at how they strategically manage the supply process (Harland et al., 1999). In relation to the problem statement, this is an essential concept in passing down value creation initiatives and models by means of SSCM formulated by the key stakeholders to the project teams so that they can be incorporated into subcontractor selection processes. However as mentioned by Cousins et al. (2008), SSCM must be viewed as a dynamic strategic process, and not just as a bureaucratic function. This implies that SSCM involves not just a linear passing down of these value creation initiatives from the top, but also balancing it out with other key factors and "bottom-up" approaches that contribute to creating value.

#### 3.3.2.1.1 *The Supply Wheel Model:*

In their study conducted on strategic supply and the management of inter and intra-organizational relationships, Cousins et al. (2008) introduces the supply wheel model which we can apply to a construction company's ability to incorporate SSCM in the subcontractor selection process. After selecting a few criterion that can be adapted from each area of the supply wheel to the subcontractor selection process from the point of view of the general contractor, the case company will be analyzed to assess if they have integrated these selected criterion into their subcontractor selection framework. This aims to provide a general idea as to how much supply chain management has been considered and used throughout the process.

Furthermore, some theory behind the supply wheel is that it provides a framework for developing strategic supply in concept and practice. From the identified factors in the supply

wheel, one can analyze the behavior and preferences exhibited by organizations as they approach the need for strategic purchasing and supply (Cousins et al., 2008). As the supply function permeates across the company, the idea behind the model is to find the most ‘appropriate’ strategy based on the five key dimensions depicted within the model. Figure 17 displays the supply wheel showing the primary elements in SSCM and the way they are interrelated.

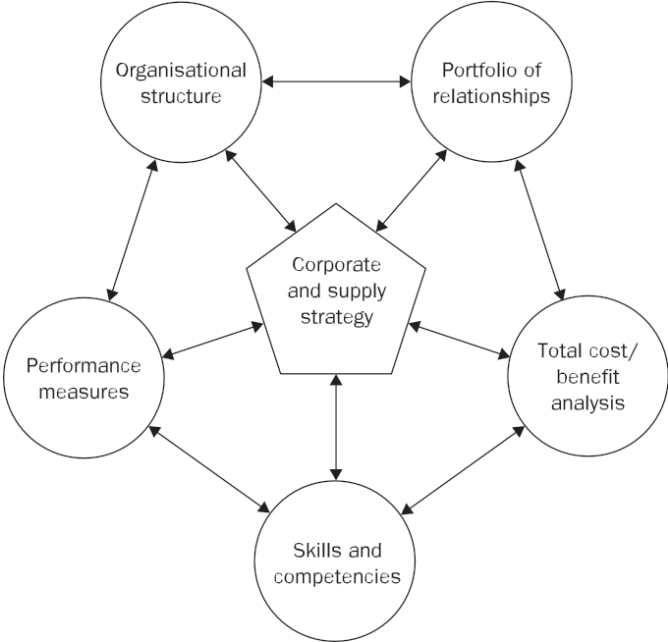


Figure 17- The Strategic Supply Wheel (Cousins, 2002)

The model can be used in maximizing a construction company’s contractual function and originates from the three identified basic approaches to strategic supply, namely, process-based, procedures-based and policy-based approaches. These three dimensions are all linked in the wheel, some in terms of the lines linking the elements and others in relation to the elements themselves. It is useful to note that a focus on one element of the model needs to be considered in relation to the entire model (Cousins et al., 2008). In other words, no element in the subcontractor selection process should be looked at in isolation as each element affects the other elements. The wheel must stay in balance at all times, and the level of value creation strategic attainment is limited by the lowest common denominator within the model. Hence, this makes it ever more essential for corporate strategy to be aligned with project contractual strategy or alternatively, subcontractor selection strategy with value creation strategy.

### Corporate and Supply Strategy:

Ideally, the supply structure should fit with the supply strategy and the policies of the organization. Cousins et al. (2008) emphasizes five different factors, namely, cost, quality, flexibility, delivery and innovation. These factors are called competitive priorities and companies usually focus on one or a combination of them.

### Organizational structure:

Linking the strategic supply wheel to this study will entail looking at the case company's ability to balance and succeed in incorporating value creation initiatives in each of the elements in their subcontractor selection processes in projects. The organizational structure of the case company will be examined in terms of the purchasing type adopted by the general contractor (centralized, decentralized or hybrid), and their ability to communicate value creation corporate strategy models and initiatives to the project teams to include when selecting subcontractors. A centralized purchasing structure entails a central department directly established for the sole purpose to procure and select subcontractors for all projects in the organization, normally in the head office location. Some advantages to this structure includes standardization, consistency in selection methods across the organization, and policy deployment. A decentralized format entails a central department that develops the policies, however the individual project teams take control of the selection of subcontractors. This is normally more common in the construction industry, and has the advantages of a faster response, less missed opportunities, and autonomy. A hybrid structure combines both a centralized and decentralized approach, combining the strengths of central planning with the opportunities of local sourcing.

### Portfolio of relationships:

The portfolio of the relationship between the general contractor and a subcontractor will also be examined. Cousins et al. (2008) has defined two key variables in order to manage relationships, namely, dependencies (historic, economic, technological and political) and certainty (contractual, competence, goodwill and political). By analyzing these factors it is possible to categorize, in general, the relationships the case company has with project subcontractors into different groups, as shown in Figure 18.

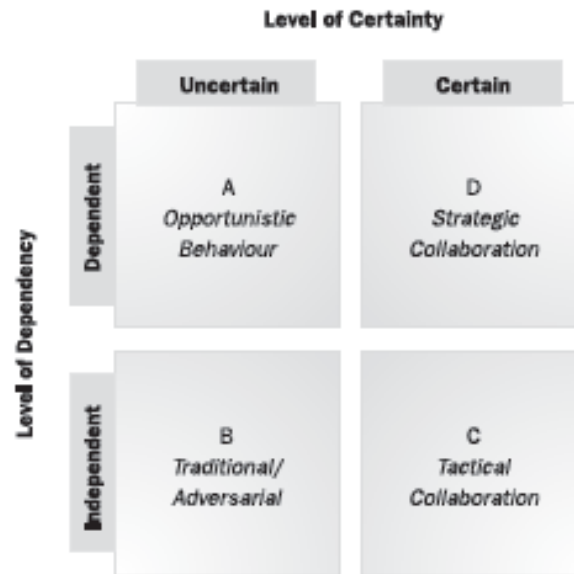


Figure 18- Strategic Relationship Positioning Model (Cousins et al., 2008)

Total cost/ benefit analysis and total cost of ownership:

The total cost and benefit analysis is a balance between the benefits/costs and relationship strategies used to create value in subcontracting. Total cost of ownership (TCO) is the actual price of the subcontractor service, including management, delivery, service, communications, price and quality. Questions in the interview guide will analyze the case company as to whether they take into account all costs that can be incurred by using a particular subcontractor along the entire supply chain, and not just the price submitted at the tender stage.

Skills and competencies:

The skills and competencies of the subcontractor will be assessed through the interview guide on the weight placed on the selection of a particular subcontractor on the basis of a successfully proven track record in completing similar works. Also questions in the interview guide will analyze the skills and competencies of the procurement officers within the case company will be examined.

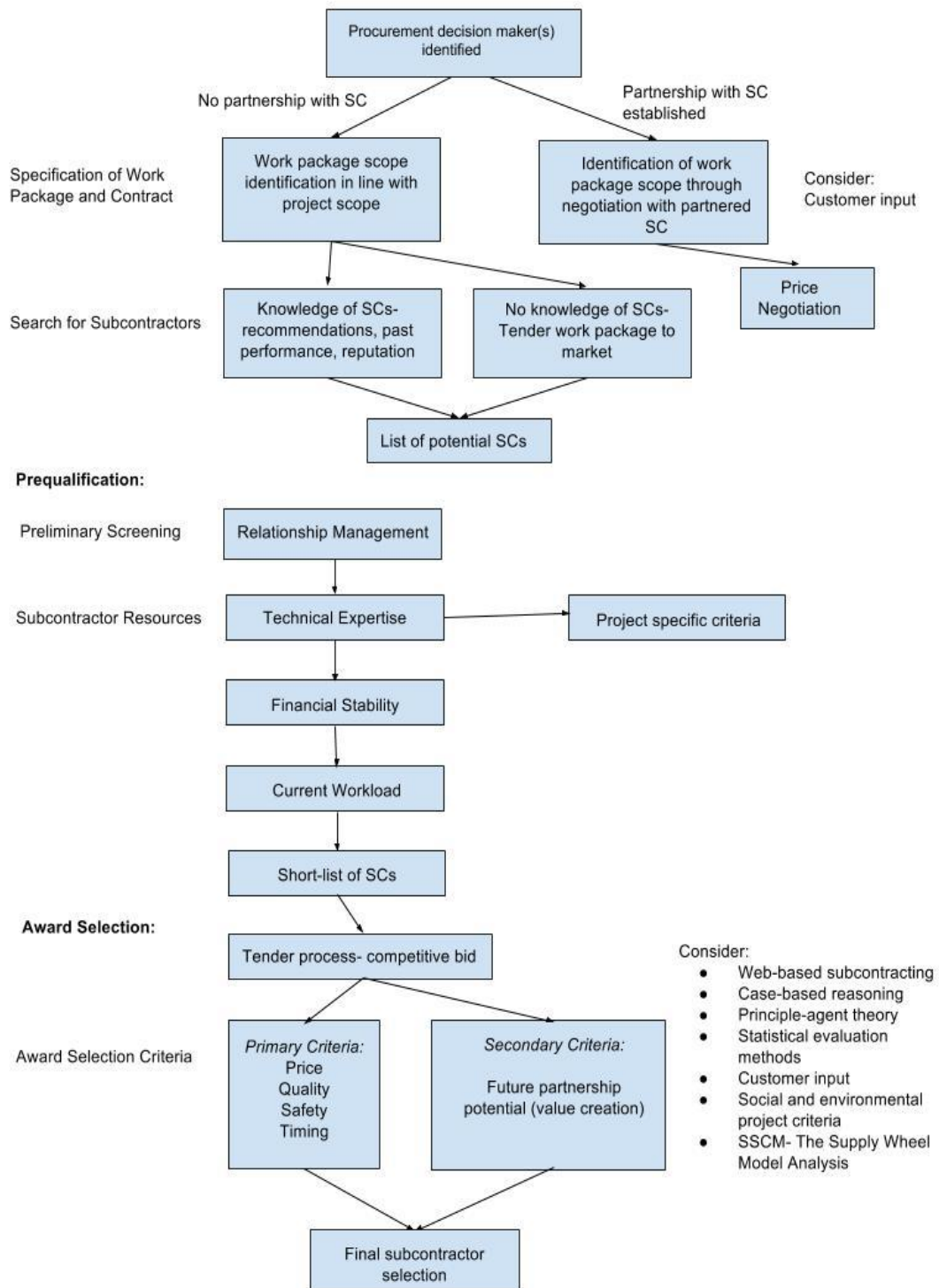
Performance measurement:

The purpose of a supply chain performance measurement system is to monitor and evaluate the supplier and the subcontractor selection process. Questions in the interview guide will determine whether they have an appropriate and periodic review and audit system in place that measures the performance of the procurement officers in selecting the right subcontractor for a

particular job. Also, one that measures the incorporation of value creation initiatives in the subcontractor selection process.

# 4 Results

## 4.1 Subcontractor Selection Process Model



## 4.2 Interview Guide

**The purpose of the interview guide is to address the following main research questions:**

7. What is the role of the project manager/ procurement officer in subcontractor selection and their general view on the process?
8. What is the nature and details of subcontracting at Company X?
9. What are the key subcontractor prequalification and award selection criteria used at Company X?
10. What is/are the main method(s) by which Company X selects subcontractors? Is partnering, web-based subcontracting, case-based reasoning, bid shopping or principle-agent theory considered and used?
11. Has Company X adopted a value creation and supply chain management perspective to the subcontractor selection process?
12. What is Company X's view on the proposed process selection model?

The interviews should be performed as semi-structured interviews based on the methodologies presented in Bryman (2015) and Walliman (2006).

### *Priority Ranking:*

Each question has a priority ranking in relation to its relevance to the problem statement.

- 1- Highest priority, must be answered
- 2- Good information to know, important but not a crisis if left unanswered
- 3- May turn out to be significant but unsure of relevance now. May be used as a follow-up question if relevant, but do not ask it otherwise
- 4- Background question that may be safely discarded if decided to be redundant.

### **Introduction:**

Introduce yourself and explain the purpose of the interview. Give a short introduction about the topic and subcontractor selection in the construction industry.

### **Introducing questions:**

#### **Personal:**

- How long have you worked in project and construction management? (4)
- How long have you worked for Company X? (4)



- What kind of background do you have? (4)
- What services does the department or unit you work in provide? (4)
- What are your main responsibilities? (4)
- How does Company X separate itself from its competitors? (4)
- What do you think are the most important areas for conducting a successful project? (4)
- How important is the subcontractor selection process for you as a project manager/ procurement officer to the success of a project? (4)

**Role in Procurement and General View:**

- What is your role or function in the procurement of subcontractors for projects? (3)
- What percentage of your work deals with the procurement of subcontractors, materials and services for projects? (3)
- Do you consider subcontractors to be an extension of Company X or as an operation in their own entity? (3)
- In general, do you consider the decision of selecting a subcontractor to hold high amounts of uncertainty and risk? (3)
- Are subcontractors viewed as a form of risk reduction or mitigation to Company X? (3)

**Main questions:**

**Subcontracting:**

- What do you consider are the reasons for Company X selecting to use subcontractors? (e.g. standardization, product and process innovation, reduction of quality costs, shorten the lead time, increase the flexibility) (1)
- From a contractual viewpoint, how much of the work performed by subcontractors is domestic (in which the general contractor hires to perform specific tasks); and nominated (nominated by the client to undertake specific aspects of the main contract)? (1)
- On average, how much of project work is subcontracted at Company X? Is there more for residential or commercial projects? (1)
- Who is normally responsible for the selection of subcontractors? (The project/ a tender department; project manager, specialized procurement officer or similar?) (1)

- What is the role of the customer in subcontractor selection? (1)
- Are subcontractors generally bound by the terms of the main contract? If so, are they generally afforded the opportunity of examining the main contract before signing the subcontract? (2)
- Has there been situations where Company X has chosen to use subcontractors even when the company may have sufficient capacity and knowledge to do this work in-house? Why? (2)

### **Key Subcontractor Selection Criteria:**

#### Prequalification Criteria:

- Is there a structured approach in the form of a generic model or process for how Company X selects a short list of potential subcontractors for a particular work package? (1)
- Is the criteria of a contractor's reputation, past performance, good relationship management, financial stability, experience record, firm capacity, current workload, and technical expertise, along with project specific criteria considered? (1)
- What is the process by which a list of subcontractors are identified or short-listed for a work package? (1)

#### Award Selection Criteria:

- What is the framework and key selection criteria used by Company X in selecting their subcontractors? (e.g. price, quality, safety, and timing) (1)
- If multi-parameter criteria exists, what would you identify as the most common primary criteria and the secondary criteria used in the evaluation? Is future partnership potential considered? (1)
- How much does social and environmental requirements influence the selection of subcontractors? (1)
- Does a subcontractor need to have completed a certain number of similar jobs? Do they need to hold the latest national risk or safety certifications or any others to be selected? (2)
- What factors would need to be present for which you take on more risk by switching from a known subcontractor to an unknown subcontractor? What criteria needs to be

met to take such a risk? Select the most appropriate box from the Table by Hartmann et al. (2009) below: (2)

Which one of the four subcontractors would you choose? (tick the subcontractor you prefer)

	Subcon A (known)	Subcon B (known)	Subcon C (known)	Subcon D (unknown)
Price	High	Low	High	Low
Technical know-how	Sufficient	Superior	Sufficient	Superior
Quality	Sufficient	Sufficient	Superior	Superior
Cooperation	Sufficient	Sufficient	Superior	Superior
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Subcontractor Selection Methods:

- Is there a generic model or process for how Company X awards a subcontract for a particular work package? Is it different for residential and commercial projects? How do you deal with circumstances that are outside the scope of the model? (1)
- In general, what method does Company X use to select a subcontractor? (for example, by competitive bidding, by negotiation with one subcontractor, based on bidding price, based on lowest bid, based on the decision-maker's experience, based on previous working relationship, based on personal relations, selection from the host country or from other countries) (1)
- To what extent do you have the freedom to select the approach you think is the best? If you have used several approaches, what do you consider is the strongest and weakest property of each of them? (1)
- Who selects subcontractors? (is it a one man-decision, mixed group of technical and managerial personnel, a few top managers, the project team, or a separate procurement department that handles all projects) (1)
- How does Company X search for subcontractors for a work package? (1)
- When is the subcontractor usually selected? (e.g. after the project starts, between the main tender and project start, selection before the main tender, near the time that their portion of the work needs to start) (1)
- Is there an issue of shortened procurement time, due to the speed of projects, that impact on the subcontractor selection process? (1)
- Does Company X select subcontractors in combination for different work packages based on observations that they have worked well together on similar projects in the

past or by any alternative prediction methods that have anticipated they will work well together? (2)

- Does Company X use any statistical contractor evaluation and selection methodologies? (e.g. bespoke approaches (BA), multi-attribute analysis (MAA), multi-criteria decision making, multi-attribute utility theory (MAUT), multiple regression (MR), evidential reasoning, graph theory, matrix methods, data envelope analysis, cluster analysis (CA), fuzzy set theory (FST), and multivariate discriminant analysis (MDA)). (2)
- Has Company X adopted any long-term strategic partnering relationships with a subcontractor across a number of projects? What value has this created for the general contractor, subcontractor and customer? (2)
- Has Company X established or made use of any e-marketplaces to facilitate bid submissions and evaluations, and as a means of communication with potential subcontractors? (2)
- Does Company X use any case-based reasoning (CBR) approaches to select subcontractors? Does it occur where subcontracts are awarded mainly based on the good work conducted by them on similar work packages on past projects? (2)
- During competitive bidding, has there been any pre or post-bid shopping conducted during the subcontractor selection process? Do you usually submit subcontractor bid listings to the client? (2)
- Is principal-agent theory considered and/or incorporated into a selection criterion? (i.e. select a subcontractor based on the prediction that they will act in the best interests of the general contractor or avoid a subcontractor on the basis they will not act in the best interests of the general contractor)
- Generally, how often does Company X include an indicative price in a tender work package based on the client's cost plans? (2)
- Has Company X ever imitated a superior subcontractor selection model or process from competitors? (2)
- Does Company X generally fit the subcontractor to a designated work package or break up the work accordingly to fit in with the expertise of certain subcontractors? (2)
- Does Company X select subcontractors on the basis of a similar corporate and business culture to their organization?

- Does Company X consult previous clients of subcontractors and asked for feedback on the work conducted by them as part of the selection process? (3)
- Is it a normal process of firstly identifying the specification (what), then the selection (who), and then the contractual details (how)? (3)
- Is it common to include early subcontractor involvement and input before the specification (what) stage? (3)

### **Value Creation:**

- How would you define value creation? (1)
- Does Company X adopt any value creation models in their subcontractor selection process? If so, where do these originate? (boardroom, stakeholders, customers, employees etc.) (1)
- How can value creation be further incorporated (maximized) into the subcontractor selection process? (2)
- What do you think about Company X's value creation profile? (3)
- To what extent does Company X encourage subcontractors to contribute towards innovation and value creation through new ideas, methods, approaches etc.? (3)

### **Supply Chain Management: (The Supply Wheel Model)**

- *Corporate and Supply Strategy*- Are there specific value creation initiatives and models that are developed in corporate strategy by the key stakeholders that are passed down to project teams to be incorporated into the subcontractor selection process? (2)
- *Organizational Structure*- Is the company setup as a centralized or decentralized organizational structure in relation to subcontractor procurement in projects? (2)
- *Portfolio of Relationships*- Generally speaking across all projects, would you define your relationship with subcontractors as dependent or independent; and certain or uncertain in their ability to successfully complete the job as per the specifications and in the time allocated? (2)
- *Total cost/benefit analysis*- When assessing the price of a subcontractor, is it done on the sole basis of the price submitted by them at the tender stage, or do you also take into account the Total Cost of Ownership (TCO), which includes management of them, material delivery, services, communication, price and quality? (2)

- *Performance measures*- Does your organization have an appropriate and periodic review and audit system in place that measures the performance of the procurement officers in selecting the right subcontractor for a particular job? Also, that measures the incorporation of value creation initiatives in the subcontractor selection process? (2)

**Proposed Subcontractor Selection Process Model:**

- What is Company X's view on the proposed process selection model? (1)
- Has Company X adopted similar approaches? (1)
- Does it seem like a rational encompassing approach to the selection process? (1)
- How can it be further developed and where can improvements be made? (1)

**Ending questions:**

- In the future, how important will it be to the success of projects to effectively select subcontractors? (3)
- What should be changed to improve the subcontractor selection process at Company X? (3)
- What do you think is the key to developing a subcontractor selection model that can promote value creation in projects? Is general contractor- subcontractor partnering a good approach? (3)

## 5 Discussion

The interview guide, developed from the main themes emerging from the theory analyzed, serves as a research base to further study and understand the subcontractor selection process and value creation initiatives in a general construction contractor organization, whilst simultaneously validating or falsifying the proposed process model. This will be achieved through the answering of the selected questions on a general contractor's incorporation of the key elements of the model and themes identified in the study into the general contractor's subcontractor selection procedures and processes. This may be conscious or subconscious, and the interview guide is intended to penetrate past models and processes used by an organization, and bring to the conscience, the elements in the case company's intuitive and informal decision-making.

The subcontractor selection process model provides a visual outline of a suggested approach to the subcontractor selection process. By conducting the semi-structured interview, the case company outlines whether they have incorporated the key elements of the model at the different stages of their subcontractor selection processes. The interview guide also allows for feedback on the case company's general view of the model and whether it appears to be a rational encompassing approach to the selection process; also allowing for suggestions on how it could be further developed and improved. The model consists of a framework that is well-defined and holistic in its approach, combining a variety of quantitative and qualitative criteria. In the prequalification and award selection process, a scoring system such as 1-5 numbering system or equivalent, should be used to rank subcontractors. It is also possible to put a higher emphasis on certain criteria by applying a factor system, to give extra weight to criteria identified as more important for a particular project setting. It is recommended that this process occurs before the project starts for all work packages.

The first step in the proposed subcontractor selection process model is to identify the procurement decision maker(s). This will be a direct reflection of the type of organizational structure adopted by the general contractor (centralized, decentralized or hybrid). In line with modern day construction contracting, it can be reasonably presumed that in most general contractor organizations, a decentralized format will have been adopted and the responsibility of selecting subcontractors will lie with the project team. The role of higher management in the

majority of cases will be that of issuing general rules and procedures in relation to the selection process, from a centralized office.

Following this, as outlined in the Van Weele (2009) purchasing process model, the work package and contract should be specified to a good level of detail of the task required. This can be further developed as the process develops and more information becomes available, however it should be at a comfortable level for the subcontractor to be able to submit a price on the task. The specifications should communicate the task's essential product and process requirements, customer requirements, level of technology, standards, drawings and end functionality of the completed works from a user context. It should also protect the general contractor from any future disputes in relation to the work task to be completed.

If an established partnership exists with a subcontractor, it will be possible to involve the subcontractor in the specification process of the work package. This may considerably reduce search, communication and transaction costs through the process, and provide both cost and value advantages, a contributing reason to why partnerships with strategic subcontractors is recommended. The subcontractor is the specialist in the carrying out of procedures and processes for a particular work task and can provide valuable input of the best practices and approaches to the work package. The possibility to fit the project work tasks to the subcontractor's skills, entails identifying a specialized work package in line with what the partnered subcontractor can deliver. For example, on a building project, instead of having an individual ceiling and an individual partitions package, if the partnered subcontractor can do both, a joint ceilings and partitions work package may be optimal.

Furthermore, negotiation with the partnered subcontractor in relation to the specifications and price can occur, and the subcontractor selection process for that work package will be complete. In the negotiation, the general contractor may wish to still check the market to find a "market price" in order to ensure that the subcontractor is still competitive pricewise. Also, the tendering process could be used at this stage as an indirect strategy to apply competitive pressure, through a switching threat and/or multiple sourcing, to drive the negotiated price lower. If no partnership exists with a subcontractor for a particular scope of works, the work package is recommended to be identified and outlined according to the project scope with input from the customer and the selection process continues.



The next step of the process is to search for potential subcontractors to carry out the works. A list of possible subcontractors for a work package can be achieved via reputations and recommendations of good past performance from project team members, on-site experienced personnel, other subcontractors, general contractor managers, customers etc. If no knowledge of possible subcontractors exists or the project team would like to expand the list, then tendering the work package to the market may be necessary. For public projects, the procurement process may have rules in place in which it is mandatory to determine a list of subcontractors by including all those who wish to tender on the works, or have been approved to conduct the works by the customer. In private projects, there is generally more flexibility.

Once a list of subcontractors has been identified, the prequalification process starts to identify a short-list of subcontractors. In the theoretical framework, the aforementioned authors have slightly different selection approaches and criteria in relation to subcontractor prequalification. After taking the different approaches into account, it has been possible to establish a process and set of general criteria that is generally relevant for most projects. It is proposed that prequalification be based similarly on the knowledge-based model suggested by Russel et al, (1990) with an additional criterion, namely, good relationship management in the preliminary screening process. This is based on past performances and reputation along with cooperation and communication in the precluding steps of the process. Next, each subcontractor's technical expertise and experience is assessed and compared with project specific criteria. Then, the subcontractor's financial stability and current project workload should be evaluated through an assessment of their current and predicted financial status and credit rating. The final step is to check the current workload the subcontractor is currently involved in and upcoming work they are planning to bid on. This should be in relation to their resource capacity, both which they internally hold, and the resources they have external access to through their suppliers and subcontractors.

After a prequalified short-list of subcontractors has been identified, the award selection process commences, in which a tendering process is recommended by way of a competitive bid between the short-listed subcontractors. As is evident in the theory, the authors have emphasized differing selection approaches and criteria. After taking these into account, it is proposed that subcontractor award selection be based on a multi-parameter approach, incorporating both primary and secondary criteria. This should be analyzed according to a partially compensatory decision rule in which a poorer score in one criteria can be compensated to a certain degree by

high scores on the other identified key criteria. However, it should be noted that there should be a limit for a very poor score in a certain criteria. Arguments for outranking subcontractor B by subcontractor A and vice versa in terms of criteria scores could be a way to select a subcontractor for a particular work package.

Furthermore, the primary criteria identified as the most relevant includes price, quality, safety, and timing. The price criterion will be based on lowest or on a reasonable price for the task to be completed. It is important to ensure the subcontractor has included all relevant costs in their submitted price, as per the specifications, to avoid extra costs and variations being submitted once the project starts. The quality criterion stems directly on a proven track record to deliver as per the standards set out in the specifications, and quality certification for processes. The safety criterion could be assessed on a subcontractor's proven track record in relation to safety incidents and loss-time injuries; along with certifications held, corporation safety emphasis and submitted safety plans and procedures for conducting the work task. The timing criterion should assess the subcontractor's resources (human and equipment), timing reputation, and capacity to work in an effective and efficient manner in line with project scheduling.

The secondary criteria identified in award selection is the future partnership potential of a strategic subcontractor, and thus, the capability of producing future value together. This is due to the changing nature of construction competition, and as a result, general contractor-subcontractor relationships have become more essential to competitive advantage, moving from transactional to relational affiliations. The general contractor's capacity to handle various types of subcontractors needs to be assessed before making a selection of a subcontractor for a work task based on their potential partnership value. Partnerships are generally high involvement relationships, in which an organization can only handle a few of at any given time. This is a result of high involvement often being costly and resource intensive.

Therefore, the partnership potential value should be targeted at the work packages that make up a large portion of the general contractor's current and planned future work. The subcontractors that should be rated highly in future partnership potential, are those that show consistent alignment with the general contractor's corporate strategies and mission statements; are closely located; have the skills and experience in the work packages the general contractor is likely to need in future projects; have shown an ability to work with other partnered subcontractors, hold a high potential to grow, innovate, continuously improve; and have the willingness and the

capacity to undertake subcontractor development programs that will increase their performance and capabilities to produce value for themselves and the general contractor.

As touched on, it can be expected that the competitive bid setting is generally suitable for most public project contexts, due to fair competition requirements, and for both public and private projects if low-cost is defined as an important parameter. Partnerships and long-term relationships would be assumed to be more common in private organizations, as it is more likely the general contractor has built these relationships over time through working with particular subcontractors.

In general contractor-subcontractor partnerships, it is worth noting that the real value adding benefits are not normally reaped immediately, nor automatically. As mentioned in the Kraljic (1983) purchasing portfolio approach model, an assessment of the activities the partnered subcontractor carries out should be evaluated as to whether it is a strategic item (holding a high supply risk and potential for profit generation) for the general contractor. An important element in gaining competitive advantage comes from the accessing of additional resources through outsourcing non-critical activities, in a well-integrated supply chain, to subcontractors who hold higher ground from a value and cost advantage standpoint in a particular strategically categorized construction project task. Strategic choices based on the company's mission, strategies and direction goals should be made on whether to hold high or low involvement, economically or behaviorally focused, and complex or simple relationships in partnership with a subcontractor.

As the focus of construction competition has moved away from an individual general contractor's value chain to their ability to focus on their core competencies, the goal of the general contractor should be to prioritize logistics and supply chain management with the selected partnered subcontractor through the adoption of a "oneness" mentality. This replaces traditional and outdated individual firm mentality, to deliver cost and value advantages by way of improving access to information and resources through use of the supply chain. The process of partnering should extend the firm's value chain to incorporate the partnered subcontractors.

It is also important to keep in mind that the relationship should hold an informal nature, to allow for trust to develop, and hence openness to follow. It is also critical to not become too dependent on the partnered subcontractors, which may lead to the general contractor losing forms of

control in the relationship, and principle-agent theory being exemplified. Effective communication, transparency, openness, trust and information flow is essential for this to occur. Continuous adaptations and both conflict and cooperation should be expected as the relationship evolves based on the past and the future (Snehota and Hakansson, 1995). No two general contractor- subcontractor relationships are alike, and the extent of involvement with a particular subcontractor should relate to the economic importance of that subcontractor, the potential for continuity of the relationship into future projects, and the sourcing strategy (Gadde and Snehota, 2000). High involvement and potential subcontractor development initiatives is a recommended relationship approach in the partnership, to fully integrate the supply chain and set the subcontractor up to become profitable through their capacity development, innovations and performance improvement. This also provides long-term competitive advantages (through cost and value advantages) for the general contractor.

Through a partnership, the relationship interface with the subcontractor would be presumed to change from a specified nature with precise directions on the task to be completed, to take on more of an interactive nature in which joint development of specification and negotiation is used as a means, based on open parameters and combined knowledge of use and production of the task (Araujo et al., 1999). This has been included in the specification of the contract stage of the process model. It is also worth mentioning the interconnectedness of these relationships and what is occurring in one relationship with a subcontractor will affect other relationships. Knowledge-sharing and subnetworks between subcontractors is recommended, with rules in place to protect the explicit and tacit knowledge information shared between general contractor and subcontractor. This limits the spillover of information to competitors and the unlikely proposition of subcontractors forward integrating to become competitors of the general contractor.

The goal of the subcontractor should be to differentiate themselves becoming both the cost and service leader in relation to their competition. Providing value and service enhancement at a reduced cost will provide them with a competitive advantage and almost certainly guarantee their selection for a work package. Some of the ways a subcontractor can provide unrivalled value is through being reliable, cooperative, responsive, adaptable, sustainable, and making an attempt to provide value-added tailored services to the general contractor (Christopher, 1998). Correspondingly, in line with comments by Kumaraswamy and Matthews (2000), the general contractor should assess whether they are gaining a cost and value advantage, on that project

and through potential long-term partnering, in the selection of a particular subcontractor for a work task. Ultimately an assessment should be performed on whether the potential benefits provided by a particular subcontractor outweigh the total cost of ownership (TCO) of the subcontractor in both a project and potential partnership lifecycle context. An element to be considered in TCO is the fact that long-term partnerships can increase the complexity of relationships, and be more resource intensive for the general contractor. Increasing the relationship with a particular subcontractor is a complex task as the economic consequences are often difficult to assess and the general contractor can exercise only limited control over a subcontractor (Gadde and Snehota, 2000).

Furthermore, in line with remarks from Horta et al. (2013), the use of web-based subcontracting and electronic procurement, such as electronic bidding systems, e-tendering and e-marketplaces is recommended to promote a collaborative working environment, increase the relationship and transaction transparency, accelerate the bid process and reduce transaction costs. Case-based reasoning should also be considered throughout the process for similar projects through the use of the decision maker's experience and knowledge of works and subcontractors. As it is more often than not, a computer-assisted approach that draws on solutions to previous similar problems and situations (cases), there may be a considerable installation cost with CBR. The future benefits must outweigh the startup costs, and this approach will generally be more applicable for general contractors that undertake a number of complex work projects. Solutions and best approaches to new problems can be found by finding a similar past case, and adapting the lessons learned to the current project.

Furthermore, principle-agent theory is important to consider in the subcontractor selection process to avoid any issues related to trust and advantage arising during the project. A general contractor should consider the known behavioral patterns of a particular subcontractor before selecting or partnering, and be assured the subcontractor will act in the best interests of the general contractor. After the subcontractor is selected, they are immediately positioned in a more controlling position for their specialist work package. It can be difficult for the general contractor to verify what the agent has done once the project has begun, especially in relation to actions that are costly for the general contractor to observe. If a general contractor suspects a subcontractor is not trustworthy and they are concerned at the possibility of being taken advantage of by the subcontractor, principal-agent theory should become part of the selection criteria. From this, more information can be asked for, in consultation with recommendations

from other customers, before proceeding with the setup. In partnerships, contractual setups, profit sharing, efficiency wages, performance measurement, rewards for coming forward with issues, and the threat of contract termination can be used as motivators for the subcontractor to exercise honesty and openness with the general contractor.

In addition, components, thought processes, applications and uses of statistical contractor evaluation and selection methodologies may prove worthwhile in a general contractor's ability to innovate their subcontractor selection process, through the different approaches. As discussed in theory, the most commonly accredited methods for application to the subcontractor selection process include bespoke approaches (BA), multi-attribute analysis (MAA), multi-criteria decision making, multi-attribute utility theory (MAUT), multiple regression (MR), cluster analysis (CA), fuzzy set theory (FST), and multivariate discriminant analysis (MDA).

The level of customer input is circumstantial depending on the customer. As outlined in the theory, this can range from letting the general contractor manage all subcontractor procurement, recommending the use of certain subcontractors, or enforcing that certain subcontractors are selected on the project. The general contractor should ensure that the customer is involved throughout the selection process, in particular in the specification of the work package and the award selection phases. It is essential the customer provides feedback on the specification of work to be completed, to ensure their thinking is aligned with the general contractor to avoid differences in interpretations of the work to be conducted occurring at later stages. The customer should have input on the final choice of subcontractor and agree on the way the general contractor has arrived at that choice.

Furthermore, the social and environmental requirements of the project should be considered in the final selection of a subcontractor. These requirements will vary from project to project as per the specifications of the customer and key stakeholders. Subcontractors that hold a social and environmental focus in their supply chain should be held in high regard. This incorporates an emphasis on sustainability in relation to social responsibility and environmental protection alongside economic profit. As social and environmental priorities are being further emphasized in corporate management, and sustainability is becoming the focus of many business operations, the subcontractor's values and working methods reflect the general contractor's practices. General contractors can assess a subcontractor's sustainability focus through reputation, past performances, assessing if they hold membership to the UN Global Compact, corporate social

responsibility standard compliance (e.g. ISO26000 and AA1000 guidelines), environmental standard compliance (e.g. ISO14001), and checking their sustainability index rating (e.g. RobecoSAM and Dow Jones). Bid shopping should be eliminated from practice, and this should be enforced by top management.

Uncertainty should be expected to be a part of the process. Both stochastic uncertainty, based on probability theory in which predictions cannot always be completely determined precisely; and indetermination uncertainty, where different requirements of a criterion is interpreted uniquely by the different decision makers, will be factors in the selection process. Also, it should be accepted and worked from the premise that the selection process will be incomplete and selective due to the decision maker's bounded rationality. Bounded rationality is a human element that limits the decision maker's ability to discover new alternatives and process and gather information due to a limited cognitive capacity and the cost of search and assessment of alternatives. The types of searches for a subcontractor that can be expected include a combination of both cognitive and experiential searches. A cognitive search refers to an off-line process, where a representation of the potential reality of future problems and actions is graphically represented in the decision maker's mind (for example, imagining the problems and actions that will occur when a particular subcontractor is conducting a task). The experiential search incorporates an evaluation of alternatives through real life action (for example, going to the market to assess tender submissions).

The supply wheel model is used as one form of assessing the ability of the general contractor to effectively manage their supply chain and subsequently create a competitive value advantage. The questions selected in the interview guide provide merely an insight into the inclusion of strategic supply chain management initiatives in the general contractor's assessment of subcontractors. This form of future value creation potential could be used by the general contractor in their subcontractor selection process, as part of the secondary criteria in the award selection framework.

## 6 Conclusion

The purpose of this thesis was to develop a theoretical foundation and research platform for future studies on subcontractor selection in the construction industry. This has been achieved through the formulation of an open ended semi-structured interview guide to be applied in a case study context; along with a recommended subcontractor selection process model, validated or falsified through the interview guide. The interview guide incorporates a number of key research questions that have been selected as key themes emerging from the theory, which focused on purchasing, subcontractor selection, value creation and supply chain management within a construction project based context.

It is recommended that a prequalification process occurs to produce a short-list of potential subcontractors for a work package, based on the subcontractor's relationship management skills, technical expertise in comparison to project specific criteria, financial stability and current workload. Following this, a competitive bid should occur through a tendering process between the selected subcontractors, with the final selection based on a multi-parameter approach including both primary and secondary criteria. The primary criteria identified as the most relevant includes price, quality, safety, and timing. A suggested way a general contractor can create value and gain a competitive advantage is through the secondary criteria identified in the award selection, namely, assessing the future partnership potential of the subcontractor. A high-involvement strategic partnership with a key subcontractor, selected in line with the needs of future projects, can lead to both value and cost advantages through the development of an integrated supply chain that is transparent, innovative, well-informed, and shares knowledge and information.

Other approaches and theories outlined in relation to the subcontractor selection process, and incorporated into the interview guide and proposed subcontractor selection model, includes web-based subcontracting, case-based reasoning, bid shopping, principle-agent theory, and statistical evaluation methods.



## 6.1 Suggestions for further research

From a research standpoint, a logical next step would be to further the study by gaining industry insight through conducting the qualitative analysis interview with selected general contractor construction companies. The feedback provided by industry professionals should assist the study to be further progressed from a value creation and supply chain management perspective, whilst providing improvements to the proposed selection model's structure and applicability in the subcontractor selection process.

Furthermore, the proposed process model could potentially incorporate more elements from outranking models, which would allow for the decision maker's experience, subjective analysis and estimate to be held in higher regard in the selection process. Thus, it could be adapted to the feedback from the empirical investigation, transforming it from its current relatively rigid structure to incorporate more intangible aspects such as the decision maker's "feel".

Also, the further incorporation of the statistical evaluation methods mentioned in the subcontractor selection process would be particularly interesting in potentially re-engineering and optimizing the process. A quantitative analysis could also be performed on the number of general-subcontractor partnerships that successfully exist and give indication to the contribution of partnerships in creating value and competitive advantage through an integrated supply chain. Further study on the application of the supply wheel model to construction management and its use as a vantage point for value creation in the subcontractor selection process would also be interesting.

Finally, it would be particularly interesting to develop benchmarking criteria to complement the interview guide. This should include indicators that relate the performance of a general contractor in their subcontractor selection function, in relation to other companies. To allow for contextualized comparisons, it would be compelling to select organizations that are geographically close, compete in the same market (e.g. public or private, residential or commercial), and compete on similar sized projects.

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