MASTER’S THESIS

Petteri Pietilä 2019

LUT
Lappeenranta
University of Technology

LUT University

School of Business and Management

Master's Degree in Supply Management

PETTERI PIETILÄ

QUALITY-ADJUSTED SUBCONTRACTOR EVALUATION AND SELECTION METHOD:

A case study of HVAC procurement in a Finnish construction company

1st Examiner / Supervisor: Professor, D. Sc. (Tech.) Jukka Hallikas

2nd Examiner: Associate professor, D. Sc. (Econ.) Katrina Lintukangas

ABSTRACT

Author:	Petteri Pietilä
Title:	Quality-adjusted subcontractor evaluation and selection method: *A case study of HVAC procurement in a Finnish construction company*
Faculty:	LUT, School of Business and Management
Major:	Master's in Supply Management
Year:	2019
Master's thesis:	121 pages, 27 figures, 16 tables and 7 appendices
Examiners:	Professor, D. Sc. (Tech.) Jukka Hallikas Associate Professor, D. Sc. (Econ.) Katrina Lintukangas
Keywords:	Supplier selection, Supplier evaluation, Scoring, Construction, Private sector, Quality, HVAC, Tender comparison

The purpose of this master's thesis is to investigate how quality can be applied into subcontractor selection in a Finnish construction company, what are the practices of applying quality criteria and what phases should quality-adjusted subcontractor selection include. A comprehensive breakdown of tendering of a certain HVAC procurement package is used to illustrate practical application of quality in subcontractor selection along with analyzing multi-criteria selection method used outside of Finnish markets, keeping the focus on construction sector. The study focuses on main contractor – subcontractor level, contributing to the field of practical implications and guidance for procurement practitioners. The results confirm that price is still likely the most significant evaluation and selection criteria in subcontractor selection. In addition, the results imply that both buyer and subcontractors are somewhat unfamiliar with comprehensive impact of applying quality measures in evaluation and selection through both scoring and weighting. Formal quality management systems proved to be insufficient measurement of quality or basis of shortlisting or evaluation. Also, suggestions to further improve selected approach, whether being a bespoke or existing reusable procurement method, are made.

TIIVISTELMÄ

Tekijä:	Petteri Pietilä
Tutkielman nimi:	Laatuperusteinen aliurakoitsija-arviointi ja valintamenettely: tapaustutkimus suomalaisen rakennusyrityksen talotekniikkahankinnoista
Tiedekunta:	Kauppakorkeakoulu
Pääaine:	Master's in Supply Management
Vuosi:	2019
Pro gradu -tutkielma:	121 sivua, 27 kuvaa, 16 taulukkoa ja 7 liitettä
Tarkastajat:	Professori, D. Sc. (Tech.) Jukka Hallikas Apulaisprofessori, D. Sc. (Econ.) Katrina Lintukangas
Hakusanat:	Toimittajavalinta, Aliurakoitsija, Tarjousvertailu, Pisteytys, Rakennusala, Yksityinen sektori, Laatu, Talotekniikka

Tämän tutkimuksen tavoitteena on selvittää, miten laatu voidaan sisällyttää aliurakoitsijavalintaan suomalaisessa rakennusyhtiössä, millä käytänteillä laatukriteereitä sovelletaan sekä mitä vaiheita laatumukautettu aliurakoitsijavalinta sisältää. Työssä tarkastellaan kattavasti yhden talotekniikan hankintapaketin kilpailuttamista, Suomen markkinoiden ulkopuolella käytössä olevaa useaan arviointi- ja valintakriteeriin perustuvaa valintametodia. Tutkimus keskittyy tarkastelemaan pääurakoitsijan ja sen aliurakoitsijan välistä suhdetta, tuoden osansa käytännön sovellutusten ja ohjeistuksen kautta hankintatoimen ammattilaisille. Tutkimuksen tulokset vahvistavat tarjoushinnan olevan merkittävin valintaperuste aliurakoitsijan valinnassa. Lisäksi laatukriteereiden soveltamisen vaikutukset kilpailutukseen, etenkin pisteytyksen ja painotuksen kautta, olevan sekä ostajalle että aliurakoitsijalle jokseenkin vieraita. Lisäksi muodollisten laatujohtamisjärjestelmien käyttö laadun mittaamisessa tai kilpailutukseen osallistuvien toimittajien karsimisessa osoittautui puutteelliseksi. Myös ehdotuksia esitetyn toimintatavan kehittämiseksi esitetään, riippumatta siitä onko kyseessä projektikohtainen valintamenettely tai jo käytössä oleva hankintamenettely.

ACKNOWLEDGEMENTS

As this thesis reaches its end along with my almost five year journey with business studies, I feel an absolute necessity to hold a little longer to express my sincerest gratitude to those who I have met during the time, and especially those who have assisted me with my final piece of work, materialized on the pages to come. The past years have indeed passed with haste, but I have been fortunate to spend them with bright minded friends around me. For that I am forever grateful.

During the writing of the thesis, numerous people offered their help and insight regarding the subject, many of them offering their unconditional help whenever I would be in need of assistance or guidance. Some of this help I never managed to use, but every bit of it was equally as appreciated nonetheless. To the people who sacrificed their precious time while having little to obtain from this research, you were crucial in pointing me to right direction, and to right people. For me, this is without a doubt one of the biggest milestones so far and I wish that those people could experience the joy this brought to me.

More or less I feel like the themes, issues and findings in this thesis were only to be found and discovered, not invented. Due to this, I feel that this is also a work of those involved, and from my behalf I merely acted as a tool of expression.

In Lappeenranta / Helsinki 25.2.2019

Petteri Pietilä

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1. INTRODUCTION

The subject of contractor evaluation and selection is a difficult and challenging task involved with uncertainties and multiple decision problems. In these situations, individuals are required to make judgements and trade-offs between rivaling objectives with limited resources. (Watt *et. al.* 2009) In construction, project can acquire best value through suppliers' special knowledge and expertise (Beach *et. al.* 2005) and subcontractors contribute up to 90% of a construction project's value (Hinze & Tracey 1994). Supplier evaluation should provide an objective assessment of contractors' abilities to deliver across all project's value dimensions: cost, quality and time (Watt *et. al.* 2009). As an inherently complex and unique field, construction project delivery involves multiple participants (Singh & Tiong 2006), where subcontractors indirectly assist main contractor in providing the final product, for which the main contractor is ultimately responsible (Hartmann & Caerteling 2010).

Appropriate procurement method has an impact on project success (Naoum & Egbu 2016), while construction project success is strongly related to managing project risks, from which contractor selection is arguably one of the most significant (Cheaitou 2018). Thus, contractors play a vital role in project performance (Cheaitou *et. al.* 2018; Alzahrani & Emsley 2013) and selecting the right contractor for the project is *the most crucial* challenge for any buyer (Singh & Tiong 2006). The supplier selection mechanism holds an important place in procurement practice, but the subject has gained relatively little attention from academic community (Lundberg & Bergman 2017).

Construction as a project-based industry is characterized with an environment of considerable complexity, uncertainty, and fragmentation of supply chain with adversarial short-term relationships (Fearne & Fowler 2006). In addition, dynamic operating environment can be significant in contractor selection (Holt *et. al.* 1995). Reportedly, there have been many cases of contractors failing due to financial problems, poor performance or accidents arising due to lack of adequate safety considerations at worksites (Singh & Tiong 2006). The selection of incapable contractor may lead to delays, disputes (Hatush & Skitmore 1997; Ng & Skitmore

2001) and ultimately to permanent damage to main contractors' performance record (Hartmann & Caerteling 2010). Subcontractor selection based on overall ability to perform instead of final tender price alone is vital for successful project delivery (Mbachu 2008).

Previously final tender price and costs have been the major discriminating factor in contractor evaluation and selection (Cheaitou *et. al.* 2018; Kog & Yaman 2014; Watt. *et. al.* 2009; Vassallo 2007; Waara & Bröchner 20016; Jennings & Holt 1998; Proverbs *et. al.* 1997; Kumaraswamy 1996; Holt *et. al.* 1995), although construction has been reported to shift towards the use of multi-selection criteria in contractor evaluation and selection (Waara & Bröchner 2006; Jennings & Holt 1998; Wong *et. al.* 2000). Construction sector has suffered from poor quality caused by misguided contractor and subcontractor selection methods, lacking comprehensive quality considerations (Latham 1994).

Reportedly, whenever facing uncertainties with delivered quality and actual costs, often less weight is given to price (Lundberg & Bergman 2017). Securing quality in procurement is especially a complex task, when quality is hard to verify (Lundberg & Bergman 2017) and experience in implementing quality criteria in construction sector has been scarce (Vassallo 2007). Quality is still a vague subject difficult to measure and use in contractor selection process (Yasamis *et. al.* 2002). Traditionally quality has been dealt with by establishing minimum requirement imposed on bidding suppliers and awarding the contract to supplier willing to agree on established quality level while submitting the lowest bid (Lorentziadis 2010; Vassallo 2007). Whatever the influence behind supplier evaluation and selection, the chosen contractor is always dependent on the preferences in evaluation criteria and weights used by the buyer (Watt *et. al.* 2009)

1.1 Literature review

A report by Sir Michael Latham (1994) sparked the discussion of contractor and subcontractor selection in construction industry. The report was ordered by British government to review the UK construction industry, confirming that contractor

selection should be based on a value for money, combined with sufficient weighting of skill, experience and previous performance instead of putting “good” and “bad” contractors on the same line through use of lowest price as a selection criterion. (Holt *et. al.* 1995; Latham 1994) The report also pointed out a particularly low amount of money being invested in R&D in construction sector, poor delivered quality, poor productivity and adversarial market environment (Latham 1994, pp. 81, 85-86, 92). As a continuum to this, supplier selection practices in construction industry have been under examination, many of the academic researches referring to original Latham report (see *e.g.* Holt 1998 and Holt *et. al.* 1995 for supplier selection methods; Hatush & Skitmore 1997 for selection criteria; Yasamis *et. al.* 2002 for contractor quality assessment and Mbachu 2008 for subcontractor performance assessment). In addition, some criticism towards Latham’s proposed collaborative supplier relationship management practices have been provided by *e.g.* Ireland (2004) and Fearne & Fowler (2006) arguing that not all supply chain practices successful in other industry fields are directly applicable to construction industry.

Although Lundberg & Bergman (2017) stated that the *design* of supplier selection mechanism has attracted relatively little attention, the existing literature on different supplier selection methods and selection criteria is quite comprehensive. The current literature focuses on conceptual research, implying that there is no one single method of choice in supplier evaluation and selection (de Araujo *et. al.* 2017). In a project environment, procurement methods include multi-criteria-based methods, fuzzy set methods, structured frameworks, probability and statistical methods, value modelling, mathematical programming, cluster analysis, Total Cost of Ownership (de Araujo *et. al.* 2017; Kog & Yaman 214), but also bespoke approaches (Holt 1998). The number of survey and case-based researches of the subject has increased, indicating that literature seeks to adapt its supplier selection methodologies to real-life situations of different organizations (de Araujo *et. al.* 2017).

Conceptual research has been done by *e.g.* Abbasianjahromi *et. al.* (2018) creating a framework for subcontractor selection using Kano model for identifying evaluation

criteria together with Analytical Hierarchy Process (AHP) for determining exact weights, and fuzzy logic in final selection. Albano *et. al.* (2017) formed a conceptual quality implementation model for procurement. Cheaitou *et. al.* (2018) conducted a decision-making framework concentrating on price and risk measures through multi-criteria decision making (MCDM) tools and fuzzy logic. Asker & Cantillon (2008) examined the properties of scoring auctions while Falagario *et. al*. (2012) used a data envelope analysis of cross efficiency in tender selection.

Gary D. Holt is one of the most cited authors on contractor selection (Watt *et. al.* 2009) and has done multiple researches in the UK construction industry reviewing contractor selection methods. Holt *et. al.* (1995) reviewed contractor selection methods finding that those in use varied between companies; companies relied heavily on prequalification; and they were dependent on final tender sum and over reliant on subjective analysis. In another research of contractor evaluation and selection modelling methodologies, Holt (1998) argued that after prequalification phase, multi-attribute analysis or multi-attribute utility measures are the most advantageous methods for contractor selection.

The existing research has been executed in multiple different countries and regions including UK (Wong *et. al.* 2000; Holt 1998; Hatush & Skitmore 1997; Proverbs *et. al.* 1997; Holt *et. al.* 1995), Singapore (Hartman *et. al.* 2009; Singh & Tiong 2006), Hong Kong (Kumaraswamy 1996), New Zealand (Mbachu 2008) and Portugal (Mateus *et. al.* 2010), thus addressing different market environments from different perspectives. However, no studies of either quality or multi-attribute selection methods conducted in Finnish market environment were found during the literature search. The size of Finnish construction markets is considerably smaller compared to the UK market (30 billion and 177 billion respectively) (MarketLine 2018a; MarketLine 2018b). In both markets the residential construction is the largest segment, and other segments, such as infrastructure and commercial property construction, are dominated by the largest market players. Both markets also have a higher number of subcontractors compared to material suppliers. (MarketLine 2018a; MarketLine 2018b) The Finnish construction market, especially residential building, has been booming (Valtiovarainministeriö 2017) and 2018, but the growth

has been forecasted to decrease or seize during 2019 (Valtiovarainministeriö 2018). Majority of companies registered in Finnish construction sector are small or medium sized enterprises (Rakennusteollisuus), and for example in residential building sector there are over 17 000 enterprises of which only 2% are medium or large companies, accumulating over half of total revenue in residential building (Rakennusteollisuus 2017).

Even though academic literature has addressed the subject of supplier selection method and selection criteria from multiple perspectives, according to Lundberg & Bergman (2013), there is a lack of researches bridging abstract scoring rules with practical applications of supplier selection. The problem with proposed conceptual methods is that the level of complexity is usually quite high and due to multitude of methods, the choice between them is all but clear.

1.2 Research questions

Based on the notion of literature focusing on construction *client* choosing a main contractor for executing the project (Hartmann & Caerteling 2010), lack of solidified contractor selection method (de Araujo *et. al.* 2017) or research for practitioners (Lundberg & Bergman 213), scarcity of implemented quality criteria (Vassallo 2007) combined with the fact that no previous literature found on implementing quality aspects in subcontractor evaluation and selection in context of Finnish construction markets was found, the subject of contractor selection seems to have some aspects still unexplored. As sufficient contractor selection has an impact on project performance (Singh & Tiong 2006) combined with the reported shift from tender price dominant approach towards applying multi-criteria in supplier selection (Wong *et. al.* 2000), there seems to be a gap between linking theoretical and abstract scoring rules with practical applications that can be used in real procurement (Bergman & Lundberg 2013).

The aim of this study is to contribute to the field of quality-adjusted subcontractor evaluation and selection in construction, giving a practical example of quality-criteria formulation and application in tendering process. The objective is to illustrate a construction of a real-life quality-adjusted supplier evaluation method, its use in

actual tendering, analyze possibilities of improvements and finally suggest a framework for such a method. As so, the main research question of this thesis is formulated as follows:

RQ: *How can quality be included in subcontractor selection in construction sector?*

The ultimate goal of answering to this question, is to formulate a contractor evaluation and selection framework through a single case study of procurement of Heating, Ventilation and Air Conditioning (HVAC) systems and subcontracts for a certain construction project. In addition to examining a construction project tendering, a multi-criteria selection method is analyzed. To answer the main research question, two additional sub-questions were formulated, of which first being:

SQ1: *What are the practices of applying quality in subcontractor selection?*

By examining previous literature, a preliminary framework is established for quality-adjusted supplier evaluation and selection. This framework is then adjusted in the empirical part of the study according to project specific requirements and in-use multi-criteria selection method. The second additional question is formulated as:

SQ2: *What are the steps of quality-adjusted subcontractor selection?*

In a way, this study aims binding together academic literature and practices in use. Thus, one objective of this study is to compare what academic research proposes for quality-adjusted supplier selection and how practitioners approach the problem from their settings. Another objective worth mentioning, is to review the quality-adjusted supplier selection approach used in case project, thus the approach used by the project is highlighted in the empirical part.

1.3 Conceptual framework

The concepts of supplier evaluation and selection are interlinked, as the former precedes the latter (Mateus *et. al.* 2010). In any case, the selection of a subcontractor should be based on evaluation (Watt *et. al.* 2009). The evaluation criteria is derived from multiple sources, as supplier prequalification (Ng & Skitmore 2001; Holt *et. al.* 1995), supplier attributes (e.g. Harald 2013; Watt *et. al.* 2009; Singh & Tiong 2006 and Alsugair 1999; a more comprehensive listing can be found under chapter 2.2) and project specific criteria (Wong *et al.* 2000) are used as basis of tender evaluation. The evaluation criteria are then operationalized and the final supplier selection decision is based on these results. During the operationalization, uncertainties associated to costs and quality have an effect on the method of choice and the weights used for selection criteria, as proposed by Lundberg & Bergman (2017).

Naturally, the environment of the case project as well as the company under scope create boundaries for this research. The project used as the case example is executed in the Finnish construction market, by a Finnish construction company, making the construction industry the first boundary. The project is affected by requirements stipulated by a contract between the construction client (party ordering the project) and main contractor (case company), forming the second boundary. In addition, the procured product itself forms a third boundary, as not all quality aspects associated for this particular purchase are universally applicable to other purchases either inside, and even less so, outside of the industry. From these notions, a conceptual framework, in a form of simplified process with boundaries, is conducted (figure 1).

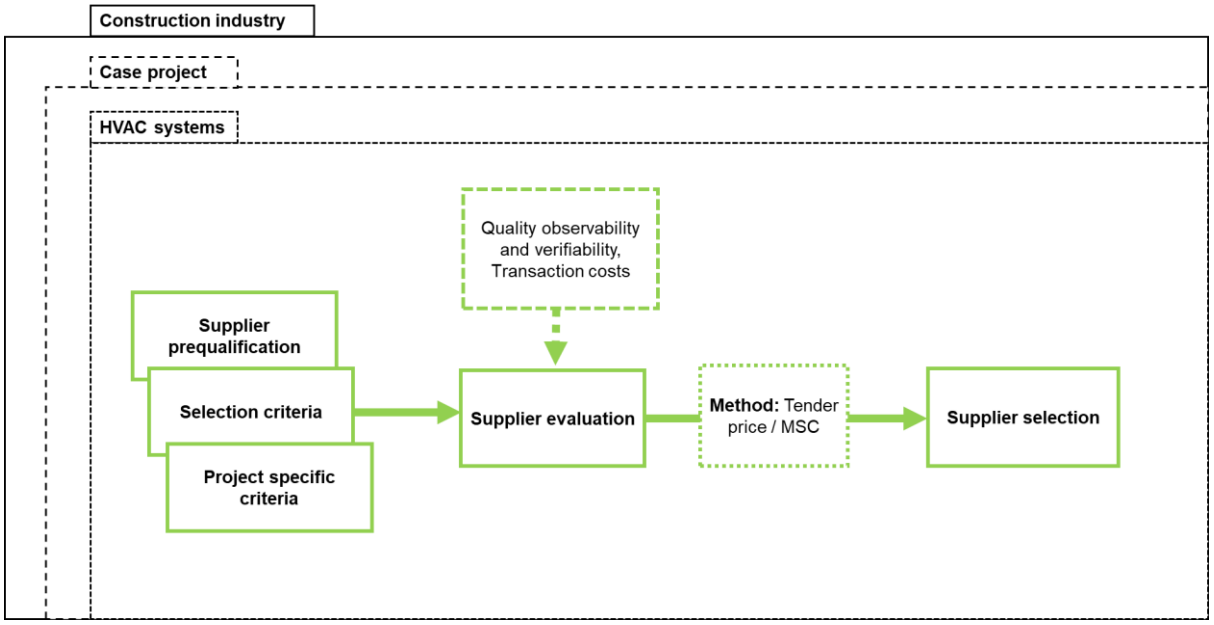


Figure 1. The conceptual framework of the research

1.4 Limitations

As hinted by the boundaries of the conceptual framework of the study, these three boundaries are also limitations of the study. The first limitation is the decision to limit the research into the context of construction and of a Finnish construction company. The field of construction provides a unique and complex setting (Singh & Tiong 2006), which as a project-based industry field differs considerably from for example many manufacturing industries with its adversarial supply relations (Ireland 2004).

The study is also somewhat limited as it examines only one project and as one of the objectives is to provide an analysis of quality-adjusted supplier selection approach used by the specific project, other construction projects are left largely in disregard. An exception to this is made when a multi-criteria selection method is described in empirical part of the study, but project description is left with much smaller attention compared to the main project this study focuses on. This limitation also excludes other than project management contracts outside of the scope of this research.

As the aim of this study is to conduct a model for a specific purpose and for a specific company, more specifically for a specific department of a company, a single project is selected instead of multiple cases. Derived from this, the second limitation is that the results are highly contextual, although the steps and reasoning behind those are visible. It is still, however, impossible to separate a model from its context and apply it elsewhere without taking into account the fundamentals and purpose for which the model was originally created for.

Although evaluation and selection criteria used in this study derive from previous academic literature, some alterations are likely to fit the proposed model properly into the context of HVAC procurement. Hence, the procured product, service and subcontract itself forms the third limitation. The company has operations in multiple countries, but for the empirical part, only subsidiaries in Finland and in UK are used as sources of information. This decision is due to the fact of project being in Finland and that the UK subsidiary has most experience in implementing multiple selection criteria in supplier evaluation and selection inside the company. Thus, other subsidiaries were excluded.

What comes to the conceptual framework (figure 1) proposed earlier, it includes prequalification as one of the sources of supplier specific data. The issues related to developing supplier prequalification and diving deeper into the prequalification are left outside of the research as this would widen the research too much. Some references are made to prequalification throughout the study, as it indeed is a prominent tool for limiting tendering to consider only those suppliers deemed sufficient. However, as later will be concluded, currently it does not provide a valid and reliable information for the company, from which selection decisions could be derived. Thus, development of prequalification criteria to fit evaluation and selection criteria are left outside of the research as the supplier prequalification is used more as a supply chain risk management procedure.

1.5 Key concepts and definitions

Next, the key concepts used in this thesis are defined to ensure that the reader perceives the concepts as intended and is able to follow the thoughts of the author. By this, unnecessary misinterpretations are hopefully avoided, and the research is easier to follow.

Client and main contractor

In this study, client is referred as the party funding the construction project (Yasamis *et. al.* 2002). Construction project itself is usually carried out by a main contractor, whose responsibility is by using its own supplier network, to construct the project. Instead of using the term main contractor, academic literature uses a plain term of *contractor*, usually referring to a party executing the whole construction project (see *e.g.* Cheaitou *et. al*. 2018; Kog & Yaman 2014; Alsugair 1999 or Jennings & Holt 1998). Sometimes the distinction between a main contractor and subcontractor is left unclear, as in case of for example Hatush & Skitmore (1997) or in the study of Jennings & Holt (1998), where some contractors examined were seemingly small and might actually be closer to subcontractors than capable of managing a complex housing or residential premise building project.

In this study, main contractor is the party with the responsibility of executing the construction project as interpreted by Hartmann & Caerteling (2010). Even though majority of previous literature assesses the evaluation and selection from client perspective (Hartmann & Caerteling 2010), which is also the case in papers used as academic sources for this thesis (see table 2), it does not form a validity problem as contractors (as in *main* contractors) agree on used multi-criteria selection factors (Jennings & Holt 1998). In addition, Harald (2013) as well as Hartmann & Caerteling (2010) reported similar themes being used in subcontractor selection, used also by client organization in their main contractor selection (see table 1). It is logical to assume that the criteria clients use in their main contractor selection are passed down when main contractors select their subcontractors for the project.

Supplier evaluation and selection

Tendering system ensures selection of appropriate contractor to deliver the project, how the project is to be delivered, price to pay and legal framework (Hatush & Skitmore 1997). Supplier evaluation is the process of investigating and measuring supplier (contractor or subcontractor, depending on an observation level in supply chain) attributes, while selection is the process of combining the evaluation results to identify a potential supplier (Holt 1998). Illustration in figure 2.

Figure 2. Supplier evaluation and selection (Holt 1998)

Quality

According to Yasamis *et. al.* (2002) different stakeholders (client, owner and end-user) of a construction project perceive quality differently, arguing that construction quality is a function of main contractor's corporate level quality (total quality management system) and project level quality (quality plans, quality assurance and quality control). De Araujo *et. al.* (2017) define quality as an ability to provide products and services in accordance to specifications, monitor quality and perform quality control by comparing products with specifications, comparing achieved quality to what was specified in contract and ensuring the existence and use of quality assurance system. Vassallo (2007, 3) approaches the quality through contractor attributes as he defines quality to be *"determined by the effort, skill, experience, etc., of the contractor ".* Lundberg & Bergman (2017) and Bergman & Lundberg (2013) make a distinction between *ex-post* and *ex-ante* quality, depending on the time when contract is signed and quality inspected. Ex-post quality is

determined (or determinable) *after* signing a contract, and ex-ante quality *before* signing a contract.

Verifiable quality and non-verifiable (non-observable) quality

Quality is considered to be *observable* when consumer of a good or service can perceive it, regardless of whether the quality is observed before or after the consumption (Vassallo 2007). Quality can be *verifiable* or *non-verifiable* (sometimes referred as non-observable, see Bergman & Lundberg 2013). When quality can be measured without excessive costs and it is possible to set up indicators beforehand to measure delivered quality as a good or service is received, quality is considered to be *verifiable* (Vassallo 2007). This is achievable through, for example, product standardization (Lundberg & Bergman 2017). *Non-verifiable* quality is a dimension of observable quality, in which quality is hard or even impossible to verify, for example quality of human capital such as ability to provide innovative solutions in consulting services (Albano *et. al.* 2017). Another concept associated with quality is cost uncertainty, which is the uncertainty of supplier meeting alternative quality levels (Lundberg & Bergman 2017), usually interpreted as higher or better quality levels.

1.6 Structure of the thesis

This study is divided into four main chapters as explained further. The first chapter of introduction presents the subject under scope to the reader, previous research and validates research problem. After presenting and identifying the research problem, research questions and key concepts are established. Finally, contents of the research as well as how the research advances are described.

Second chapter consists of theory of supplier evaluation and selection. The chapter is constructed in line with tender evaluation process by Mateus *et. al.* (2010). First, supplier prequalification is assessed, after which evaluation and selection criteria are presented. A logical continuum for this is to examine different scoring and weighting procedures. Throughout the whole chapter, quality aspects are additionally elevated and hinted towards, but the main focus on quality aspects in

tender evaluation and subcontractor selection is left under chapter 2.5. After presenting more of a quality-adjusted approaches, some problematics are introduced and discussed. In conclusion a framework for quality-adjusted supplier evaluation and selection is conducted, which is then further enhanced in chapter 3.

Third chapter presents the empirical part of the thesis. First, a short description of case company is given, after which the methodology of the study is presented. The tendering process of the project under scope is described, participants of bidding are analyzed and project specific criteria are examined. One tendering of HVAC package is examined more carefully to illustrate evaluation, scoring and selection method of the project. After examining the case project, a multi-selection criteria approach used by the company's subsidiary is taken under scopes. Lastly an enhanced framework is presented.

Final chapter presents the conclusions and discusses the reliability, validity as well as limitations of this research. As the study is constructive, aiming to solve real life business case, managerial implications are discussed. Finally, suggestions for further research are presented and findings are summarized.

2. SUPPLIER EVALUATION AND SELECTION

Both private and public sector procure similar goods and services (Tadelis 2012) and there is a strong similarity in contractor selection criteria between public and private sectors (Wong *et. al.* 2000). Thus, literature and research of public procurement is also included. Public buyer has said to be restricted by laws and regulations, whereas a private buyer has more flexibility to utilize other than price criteria in its supplier evaluation and selection (Kog & Yaman 2014; Tadelis 2012), although according to Mateus *et. al.* (2010) public buyer has a substantial freedom in supplier selection through careful use of weighting and scoring rules. The distinction between a selection method and selection criteria is that a selection method is the complete system utilizing selection criteria (de Araujo *et. al.* 2017).

In supplier selection, both private and public buyers face the challenge of bid evaluation (Alsugair 1999), and in many cases, buyer is interested in other attributes than only price (Asker & Cantillon 2008). For example, quality concerns of the procured good or service often influence the final decision (Asker & Cantillon 2010). Procurement with other than price factor involves moving towards a more complex procurement (Asker & Cantillon 2010). While private buyer can blacklist suppliers insufficient of delivering acceptable level of quality, public buyer usually does not have this possibility and is obliged to select the bid with the highest score (or lowest price) making a well-designed method for tender evaluation essential (Bergman & Lundberg 2013).

Bidding process with multiple bidders is an expensive process for all participants involved, in which client incurs costs in screening and analyzing tendered bids, and contractor in bid preparations and submission (Ng & Skitmore 2001). The use of multiple criteria consumes buyer's procurement resources as well as bidder's resources (Waara & Bröchner 2006) and involving unsuccessful bids in tendering increase costs which ultimately will be passed back to the client (Kumaraswamy 1996). However, transaction costs arising from effort to specify the project, procurement process, monitoring and resolving contractual conflicts, are hard to measure (Waara & Bröchner 2006). Even the selection method itself is affected by

transaction costs, meaning that more complex scoring rules generate more costs in supplier evaluation and selection phases compared to a more straightforward selection based on final tender price (Lundberg & Bergman 2017).

Mateus *et. al.* (2010) researched a proper tender evaluation method, formulation of scoring rules and weighting functions able to capture buyer's preferences. They use a process flow to illustrate different blocks of tender evaluation, presented in figure 3. This illustrates the necessary steps and structure of tender evaluation, as well as the logical order of different steps from evaluation criteria to scoring and weighting function, and ultimately to tender evaluation and selection. The same logic presented in this process will later be utilized when constructing a framework both in chapter 2 and chapter 3. Exception being, merging definition of performance measures and scoring functions together, as they are inherently so close to one another. What comes to the contractor evaluation, contractor selection or critical success factors, no method (de Araujo 2017; Kog & Yaman 2014) nor universal factors (Alzahrani & Emsley 2013) has been established or agreed upon.

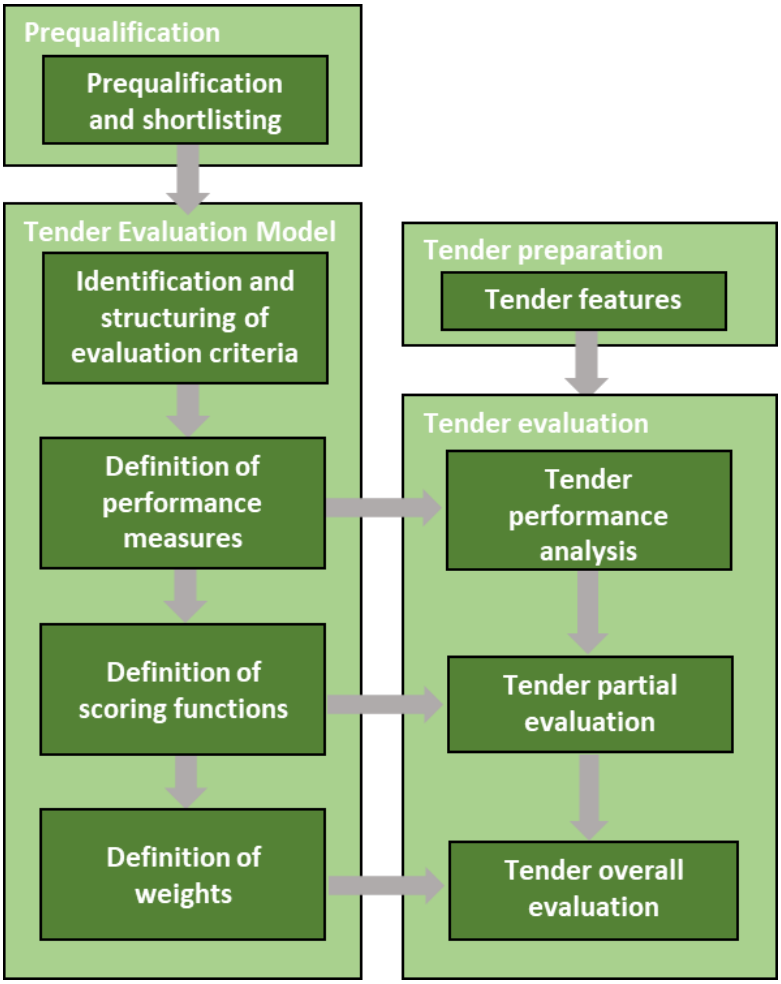


Figure 3. Blocks of tender evaluation methodology (adapted from Mateus *et. al.* 2010)

2.1 Prequalification and shortlisting

Some literature approaches supplier selection through prequalification as a method of forming a set of qualified suppliers approved to participate in tendering (Ng & Skitmore 2001), a way of implementing project specific requirements (Kumaraswamy 1996) or rooting out suppliers with inferior quality (Yasamis *et. al.* 2002; Mbachu 2008). According to Hatush & Skitmore (1997, 20) supplier prequalification is: *"a pre-tender process used to investigate and assess the capabilities of contractors to carry out a contract satisfactory if it is awarded to them".* Contractors' attributes, *i.e.* selection criteria, can only be measured during either prequalification or final tender evaluation stages (Alsugair 1999; Wong *et. al.* 2000) and through prequalification, capabilities are evaluated prior to issuing project plans,

specifications or other bid documents (Alsugair 1999). Ng & Skitmore (2001) argue that supplier prequalification criteria should be in line with evaluation criteria as well as selection practices, and by so decrease the amount of work in supplier selection. According to Holt *et. al.* (1995) any alternative supplier selection approach should include prequalification in the selection procedure. Another more specified measure is to use project specific contractor prequalification, which according to Kumaraswamy (1996, 273) is appropriate measure with *"projects of unusual scope, complexity, value, technology requirements, quality levels or time constraints, or with special forms of funding or contract"*.

Yasamis *et. al.* (2002) promote using quality and quality factors as part of prequalification. For shortlisting Holt *et. al.* (1995) and Waara & Bröchner (2006) suggest using quality assurance systems as criterion to participate in tendering, which in practice could be an ISO 9001 certification. Use of quality systems in contractor selection was also reported by Holt (1998). In Waara's and Bröchner's (2006) sample data, it was typical to award a maximum quality score to a contractor with a 3rd party certified quality assurance system, second highest score for non-certified and so forth. Reportedly practitioners use quality certifications and implemented quality systems as criteria in supplier evaluation and selection, while academic literature proposes examining quality control policy and work quality records (Watt *et. al.* 2009). However, according to Mbachu (2008) in prequalification phase, subcontractors' work quality, meaning the ability to comply with specifications and minimize rework, was deemed the most influential criterion among main contractors.

2.2 Evaluation and selection criteria

Watt *et. al.* (2009) researched contractor evaluation and selection criteria based on comprehensive literature review complemented with an exploratory survey from defense and construction sector. They ended up with 8 categories of selection criteria: organizational experience, workload and capacity, expertise of project management, past project performance, company standing, client-supplier relations, technical expertise and construction method or technical solution. Later

Watt *et. al.* (2010) reported past project performance, technical expertise and tendered price to be of a high importance among practitioners' in multiple industry fields. According to Wong *et. al.* (2000) the use of project specific criteria has increased among practitioners and they identified 15 project specific criteria used both in public and private construction, stating that the choice of contractor was based on value instead of lowest price. The term value was interpreted as contractors' positive characteristics in themes of technical and managerial capabilities, health and safety, financial attributes, production and human resources, and past performance (Wong *et. al.* 2000).

According to Singh & Tiong (2006), contracting authorities are putting high values on contractors' abilities to troubleshoot wide range of construction problems and therefore many experience related variables were reported as critical selection criteria (CSC). Alsugair (1999) emphasized knowledge and experience of contractor's technical and financial capabilities. Experience related variables of previous experience, brand credibility, reference and price were also reported by Harald (2013) to ensure unverifiable quality. Harald (2013) stresses that main contractors focus on subcontractors' previous performance, ability to stay on budget, financial situation and existing quality management procedures, continuing that for a new subcontractor, references from similar kinds of projects done for reputable main contractors are essential in getting selected as a subcontractor.

For selection criteria there exists a variety of different listings. Different sets of contractor selection criteria are used by different researchers and client organizations to assess capabilities of the contractors, basing their evaluation on selection criteria (Singh & Tiong 2006). In table 1 previously proposed common selection criteria are summarized. Only broad themes such as financial, past performance or quoted price are used instead of their original more specific interpretations to summarize multitude of different criteria interpreting more or less the same thing.

Table 1. Previously proposed selection and evaluation criteria

	Selection / Evaluation criteria									
Author(s)	**Technical Expertise**	**Financial**	**Managerial Experience**	**Past Project Performance**	**Quoted price**	**Similar project experience**	**Quality**	**Workload and Capacity**	**Company reputation**	**Health & Safety**
Abbasianjahromi *et. al.* (2018)	x	x	x		x	x	x		x	x
Alsugair (1999)	x	x	x							
Alzahrani & Emsley (2013)		x		x		x	x	x	x	
de Araujo *et. al.* (2017)		x	x		x	x	x			
Harald (2013)				x		x	x			
Hartmann & Caerteling (2010)	x				x		x			
Hartmann et. al. (2009)	x				x		x			
Hatush & Skitmore (1997)	x	x	x							x
Jennings & Holt (1998)		x		x	x	x			x	
Kumaraswamy (1996)	x	x	x			x		x		
Singh & Tiong (2006)	x	x	x	x	x	x				
Proverbs *et. al.* (1997)					x		x	x		
Waara & Bröchner (2006)	x			x			x			
Watt *et. al.* (2009)	x	x	x	x		x		x	x	
Watt *et. al.* (2010)	x		x	x	x					
Wong *et. al.* (2000)	x	x	x	x				x		x
	10	**9**	**8**	**8**	**7**	**7**	**7**	**5**	**3**	**2**

When identifying and constructing evaluation criteria, some of the criteria are manageable through contract clauses (*e.g.* specifications, plans and other minimum or maximum requirements) (Mateus *et. al.* 2010). Usually after fulfilling minimum requirements, the choice of supplier is based on price only (Asker & Cantillon 2008). As listings can indeed be found, they do not answer the question *how* these criteria should be used, which can be favored over another; or *how* they should be evaluated, scored or weighted? Overall, contractor selection needs a switch from reactive and static evaluations checking technical and financial capabilities to a proactive and dynamic evaluations leading to enhanced quality (Yasamis *et. al.* 2002).

Hartmann & Caerteling (2010) argue that majority of previous research has focused on construction clients choosing a main contractor, not on main contractor – subcontractor level. This is also appealing in table 2, where perspective of literature used in this study are listed. To counter the dominance of client – main contractor perspective, more emphasis was put on finding relevant literature focusing on main contractor – subcontractor perspective.

Table 2. Research of contractor selection criteria and research perspective

Author(s)	Public / Private	Perspective	Type of criteria
Abbasianjahromi et. al. (2018)	Unstated	Main contractor → Subcontractor	Selection criteria / Framework
Alsugair (1999)	Both	Client → Main contractor	Selection criteria
Alzahrani & Emsley (2013)	Unstated	Client → Main contractor	Success factors
de Araujo *et. al.* (2017	Unstated	Literature review	Selection criteria
Griffith & Headley (1997)	Unstated	Main contractor → Subcontractor	Procurement method selection
Harald (2013)	Unstated	Main contractor → Subcontractor	Selection criteria
Hartmann & Caerteling (2010)	Private	Main contractor → Subcontractor	Selection criteria
Hartmann *et. al.* (2009)	Private	Main contractor → Subcontractor	Selection criteria
Hatush & Skitmore (1997)	Unstated	Client → Main contractor	Selection criteria
Holt *et. al.* (1995)	Unstated	Client → Main contractor	Selection practices
Jennings & Holt (1998)	Private	Main contractor → Client	Selection criteria
Kumaraswamy & Matthews (2000)	Unstated	Main contractor → Subcontractor	Partnering criteria
Kumaraswamy (1996)	Public	Client → Main contractor	Selection criteria
Mbachu (2008)	Both	Main contractor → Subcontractor	Selection criteria
Singh & Tiong (2006)	Both	Client → Main contractor	Selection criteria
Proverbs *et. al.* (1997)	Private	Main contractor → Subcontractor	Selection criteria
Waara & Bröchner (2006)	Public	Client → Main contractor	Selection criteria
Watt *et. al.* (2010)	Unstated	Client → Main contractor → Subcontractor	Selection criteria
Watt *et. al.* (2009)	Both	Client → Main contractor	Selection criteria
Wong *et. al.* (2000)	Both	Client → Main contractor	Selection criteria
Yasamis *et. al.* (2002)	Unstated	Client → Main contractor	Quality criteria

2.2.1 Multi-selection criteria

Use of multi-selection criteria requires buyer to decide on a procedure for evaluation of non-price criteria (Waara & Bröchner 2006), and according to Bergman and Lundberg (2013) there exists only two supplier selection methods: lowest price or Economically Most Advantageous Tender or EMAT. EMAT, referred sometimes also as MEAT, is often used in literature of public procurement (see *e.g.* Cheaitou *et. al.* 2018; Bergman & Lundberg 2013 or Mateus *et. al.* 2010). When determining which tender is the most economically advantageous, an aggregation method such as weighted sum is commonly used (Mateus *et. al.* 2010). EMAT can more broadly be a combination of non-price factors and price in evaluation of proposals (Lorentziadis 2010). By this, EMAT is not only limited to quality and price, but can also include other criteria deemed important by the buyer. As commonly multiple criteria are being assessed, the question is fundamentally about value trade-offs, in which decision is based on value judgements of how much one is willing to give up in order to achieve something in return (Keeney 2002).

2.2.2 Final price

Although the use of multi-selection criteria has been on the rise in construction contractor selection (Waara & Bröchner 2006; Wong *et. al.*; 2000 Jennings & Holt 1998), some research still indicates that *main* contractors are unwilling to compromise on price (Hartmann & Caerteling 2010) and unwilling to pay price premiums for already reputable suppliers (Harald 2013). In addition, previous studies show tender price being dominant also in final contractor selection decision, despite the urge for multi-criteria selection practices (MCS) (Wong *et. al.* 2000) and urge to rise quality as an important selection attribute (Latham 1994; Proverbs *et. al.* 1997).

Main contractors have indeed adopted multi-criteria approaches in subcontractor selection, but final selection is still dominated by price (Harald 2013; Hartmann & Caerteling 2010; Hartmann *et. al*. 2009). Hartmann & Caerteling (2010) investigated the importance of price as a selection criterion and its impact on forming longer relationships between main contractor and subcontractor. Their findings suggest

that advantageous tender (as in terms of low price) is a perquisite for subcontractors' in winning an initial bid and gaining trust through prolonged relationship. Their findings also indicate that main contractors indeed favor lowest bid in their subcontractor selection, but at the same time are unwilling to compromise on quality if price is on attractive level, contradicting with previous research implying a stronger shift towards multi-selection criteria. Similar results were reported by Harald (2013) as they found that main contractors evaluated low price to be in high importance in subcontractor selection. According to Harald (2013) more quality-sensitive buyers were willing to pay a price premium for suppliers to ensure certain level of quality when inferior quality was likely to cause economic losses. Even so, buyers were unwilling to pay premiums to suppliers with *already* reputable quality (Harold 2013). Price dominant results were also reported by Hartmann's (2009) previous research, and also by Proverbs *et. al.* (1997).

However, lowest price is not always an ill based selection method and is arguably the method of choice in secure environments with low price and quality uncertainties (Bergman & Lundberg 2013), referring to more trivial purchases. In subcontract awarding phase, competitive bid (meaning price) was the most influential criteria for main contractors in awarding a subcontract (Mbachu 2008). But, when quality of other dimensions of specifications or requirements are increased, the low-cost supplier does not necessarily stay as the lowest-cost supplier (Asker & Cantillon 2008). Still, the use of both price and quality in supplier selection can enhance the efficiency of procurement, even though usually being more complex approach (Bergman & Lundberg 2013).

2.3 Scoring

A scoring rule operationalizes tender's partial evaluation on each criterion (Mateus *et. al.* 2010). When using a scoring rule, buyer announces the ranking method of bids, awarding the contract to the bidder with a highest score (Asker & Cantillon 2008). For awarding a score to a supplier, various methods can be used (de Boer *et. al.* 2006). Scoring function can be either increasing or decreasing. As for example

quality improvements are logical to be rewarded with a higher score, and for an increase in price, a decreasing scale might be more sufficient (Mateus *et. al.* 2010).

Scoring rule is also either absolute or a relative one. In case of relative scoring, scores are defined by comparing tender's performance against other tenders submitted (Mateus *et. al.* 2010). Relative scoring is also referred as endogenous scoring method (Bergman & Lundberg 2013). Use of absolute merits is suggested when evaluation criteria are easy to verify, but when buyer has an imperfect knowledge of the range of values non-price criteria refer, relative merits are preferable (Waara & Bröchner 2006). In some cases, a discount system for bid sum based on contractors' previous good performance has been used in tender evaluation (Kumaraswamy 1996) as an adjustment measure and as a reputational mechanism.

For other than price-based selection, detailed request for quotation specifying minimum standards, small set of potential suppliers or negotiation procedures are used (Asker & Cantillon 2008). According to Asker & Cantillon (2010) scoring auctions yield better results in capturing important selection criteria compared to negotiating with one supplier at a time (bargaining), which is popular amongst practitioners.

In terms of evaluating quality, a supplier selection method typically needs a scoring rule, which assigns numerical values to different quality levels in a selected dimension; or transforms price or quality values into another scale (referred either price score or quality score) (Bergman & Lundberg 2013). As for the sake of clarity towards suppliers, overall broad themes of quality and price are good to be further deconstructed into more specific sub-criteria (Mateus *et. al.* 2010). For each objective under evaluation, a clear measure indicating to which degree it is achieved, must be conducted (Keeney 2002). For qualitative or discrete performance measures Mateus *et. al.* (2010) suggest a direct rating or MACBETH methodology. For practical reasons, MACBETH methodology will be disregarded in this study as it might not be as intuitive for practitioners. In direct rating, performance measures are ranked from most preferred to least preferred level (L4 > L3 > L2 >

L1), after which the most preferred measure (L4) is given a score of 100 points, and least attractive (L1) is given 20 points. A score difference between two levels of performance (*e.g.* L1 and L2 in table 3) represents the difference in attractiveness between the two levels. To other performance measures values are assigned according to buyer's preferences. As for example, L2 can be given a score of 40 and L3 a score of 80, implicating that an improvement from L1 to L2 is considered as attractive as an improvement from L3 to L4 (20 pts.), but instead increase from L2 to L3 (40 pts.) is considered twice as attractive. (Mateus *et. al.* 2010)

Table 3. Example of qualitative performance measure, a figurative quality plan (adjusted from Mateus *et. al.* 2010)

LEVEL	DESCRIPTION (PERFORMANCE MEASURE)
L1	Quality plan is represented in a generic level; no detailed planning of preparatory nor construction phases; safety aspects are left completely absent.
L2	Only generic tasks are presented; minimum quality standards are fulfilled.
L3	Most tasks are described in quality plan are fulfilled and divided by types of work, estimated durations are presented, improvements are suggested; safety is taken seriously, and improvements are presented.
L4	Almost all tasks are presented with clear distinctions and different types of work required, resources are allocated, and resource allocation plan is resented, great improvements presented with reasonable alterations and costs, clear cost savings and improvement in quality

Lundberg and Bergman (2017) examined the problem of choosing between lowest price and more complicated scoring rules, under quality and price uncertainties. Their findings suggest that scoring rules are more likely when buyer operates under circumstances of uncertain quality or price, while using lowest price method whenever products are standardized, and quality is verifiable. When important quality aspects are non-verifiable and the threat of supplier shrinking on quality is likely, buyer may not want to reveal the scoring rule fully to suppliers. By doing so, buyer can use reputational mechanism to reward good quality performance in observable but non-verifiable quality. (Lundberg & Bergman 2017)

Ultimately there are two alternative scoring methods whenever quality is applied as a selection criterion: price-to-quality or quality-to-price. Quality only scoring is deemed to be a special case of price-to-quality scoring as it technically does not measure quality in monetary, but on a figurative scale. (Bergman & Lundberg 2013). Price to quality approach is illustrated in figure 4.

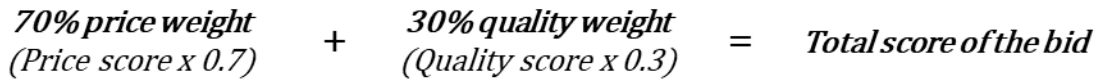


Figure 4. Price-to-quality scoring (Bergman & Lundberg 2013)

When using quality-to-price, (1) the exceeding quality compared to minimum quality requirements is to be subtracted from the bid price, or (2) the value of the quality gap relative to the required quality level (or preferred maximum quality level) can be added to the bid price (figure 5). In both cases the supplier selection method is called quality-to-price scoring or quality-adjusted lowest price. (Bergman & Lundberg 2013)

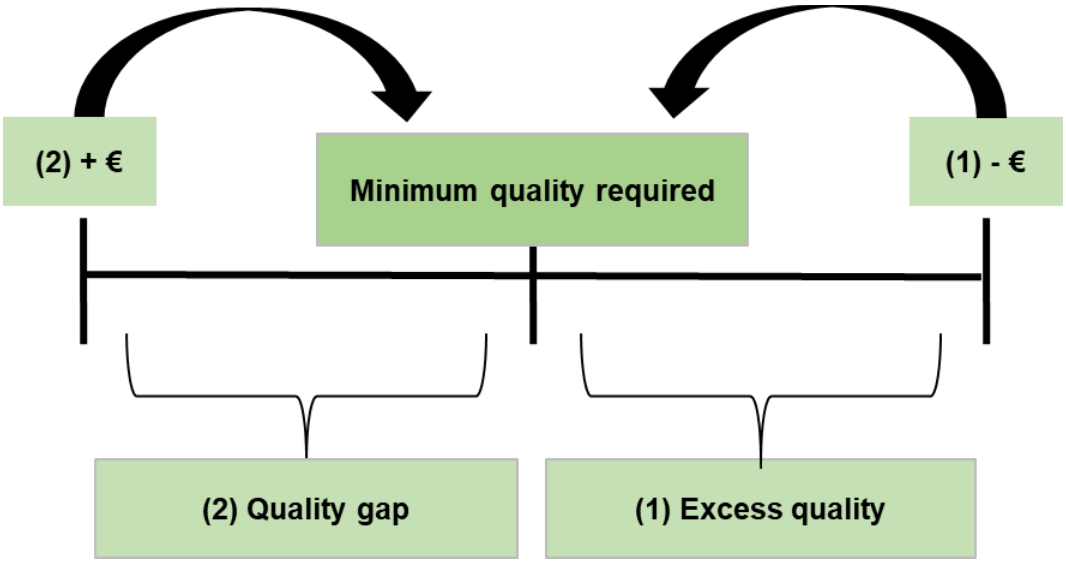


Figure 5. Quality-to-price scoring (Bergman & Lundberg 2013)

As a first step in quality-to-price scoring, monetary value of quality offered by bidders is set, or based on the quality difference compared to a minimum or maximum quality. In other words, monetary values of different quality criteria are combined

together and then subtracted from or added to the bid price. In a second step this value is combined with the original bid price, using some of the four equations proposed, preferably the second one in figure 6. The choice between absolute surcharging and discounting is said to be irrelevant. Relative approach is advised to be avoided since it rewards or penalizes identical quality variation depending on the bid price. (Bergman & Lundberg 2013)

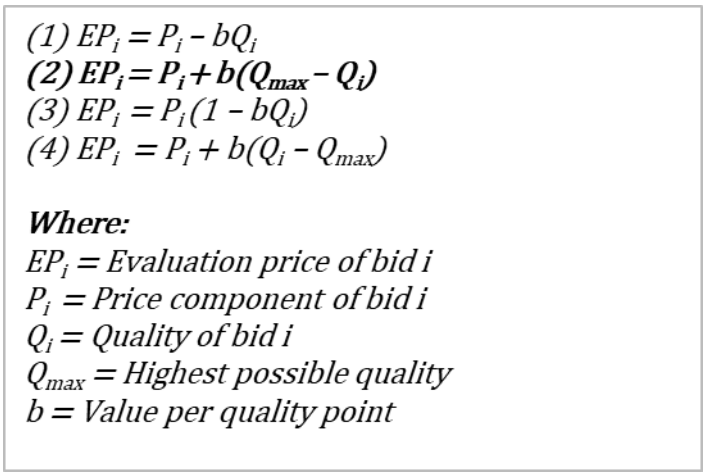


Figure 6. Quality-to-price scoring functions (Bergman & Lundberg 2013)

Bergman and Lundberg (2013) argue that quality-to-price method in figure 5 outperforms price-to-quality scoring in figure 4, since it does not require weights for price or quality, nor weights for different quality criteria. According to them, the reasons for using quality-to-price over price-to-quality approach are that the measurement scale (€) is familiar and comprehensible since we are all more familiar with making judgements based on monetary comparison than using figurative scales. Another reason is that the bid ranking does not depend on irrelevant alternatives which is the case when using relative scoring. (Bergman & Lundberg 2013)

2.4 Weighting

A logical continuum for scoring function is a weighting, which combines quantitative and qualitative measures (Griffith & Headley 1997) into a single value, making different bids comparable (Bergman & Lundberg 2013). Bid selection requires buyer

to consider bidders simultaneously, considering the specified criteria and weights assigned to them (Watt. *el. al.* 2010). Identifying relevant criteria and assigning weights is affected by many factors including organizational objectives (Griffith & Headley 1997; Watt *et. al.* 2010) and experience of the evaluator (Watt *et. al.* 2010).

Weights of each criterion should reflect their relative importance (Mateus *et. al.* 2010; Lorentziadis 2010), and for the most important criteria, a highest weight should be applied (Griffith & Headley 1997). This however cannot blindfold the buyer from tenders with superior quality with a slightly higher price, if price is deemed more important than quality and has a heavier weight (Mateus *et. al.* 2010). Final tender price and technical know-how can be rated high on importance in selection decision, but the main contractor can face a situation where the lowest bidder has little experience in similar work compared to other bidders (Hartmann *et. al.* 2009). Such a situation is ultimately a value trade-off, in which, the range of consequences for choosing an alternative option needs to be fully understood (Keeney 2002). More specifically, if quality is being evaluated and used as a selection criterion, a consequence of choosing lower quality instead of higher needs to be understood.

In public procurement, a typical contractor selection has been a 70% price weight together with three non-price criteria, but as later will be appealed, buyers should be aware of the incentives created by their selection practices (Waara & Bröchner 2006). Not all criteria can be of equal importance, *i.e.* there must be a difference in perceived importance of for example tendered price, delivery time and quality level (Watt. *el. al.* 2010). One method of supplier selection is using a weighted sum, in which the *"awarding decision is made by selecting the proposal which maximizes the ratio of the aggregated score divided by the price"* (Lorentziadis 2010, 261). The proposed approach of Lorentziadis (2010) excludes price from scoring function and uses it as a divisor. Another weighted sum method, proposed by Mateus *et. al.* (2010), includes price in weighting function itself (figure 7).

$$V(p) = k_A v_A(p_A) + k_B v_B(p_B) + \cdots + k_i v_i(p_i)$$

Where
$V(p)$ = Overall score of tender p
k_i = Weight of each evaluation criterion i
$v_i(p_i)$ = Partial score of each tender p on criterion i
p_i = Level of perfomance of each tender p on the perfomance measure defined for criterion i

k_i also represents the trade-off ratios between partial scores of chosen criteria

Figure 7. Weighted sum evaluation method (Mateus *et. al.* 2010)

This type of equation implicates that a score of a given criterion may be compensated through excelling on another criterion (Mateus *et. al.* 2010). A weighted sum method represents a shift away from managerial intuition towards more objective selection method (Griffith & Headley 1997). It is common to purchase multiple products (or services) instead of only one. When the overall price of procurement is calculated, weights should be conducted from expected purchase volumes of each component. (Bergman & Lundberg 2013)

If a weighted sum method is used, it is always possible to determine replacement ratios or trade-off scores of any criterion between the partial scores (Mateus *et. al.* 2010). As for example, if price is assigned a 70% weight and quality 30% weight with maximum overall points being 100 (maximum price and quality score each being 100), losing 10 points in price is equivalent of gaining approx. 23 points in quality. Thus, their definition *must* take into account the way scores (performance measures) were determined (see performance measures in table 4), especially if absolute measures for performance are used (Mateus *et. al.* 2010). Weighted method is only meaningful if the performance predictions, for which weightings are based on, are valid (Griffith & Headley 1997).

Table 4. Price-quality trade-off between points

Price points	Weighted price score (= P)	Quality points	Weighted quality points (= Q)	Overall points (= P + Q)
100	70	100	30	100
90	63	100	30	93
100	70	76,67	23,3	93,3

Mateus *et. al.* (2010) strongly suggest calculating weights based on trade-offs between criteria instead of using relative importance, or endogenous scoring. They propose placing specific questions, which requires procurer to do a comparison between chosen scoring units placed for performance measures. In practice this can be done by using fictitious but still plausible tenders with two distinct performance levels: defining an attractive tender and a neutral one. This forces buyer to define criteria, as well as how much more it is willing to pay for example, a better quality. This ultimately defines trade-offs between the criteria as well as the weights. (Mateus et. al. 2010)

Another method for calculating weights is to use Analytical Hierarchy Process (AHP) (see *e.g.* Abbasianjahromi *et. al.* 2018) or determine the exact weights of evaluation criteria after the submission of sealed bids (Lorentziadis 2010). The reported problem with assigning weights afterwards, is supplier perceived integrity towards the evaluation and selection (Lorentziadis 2010).

For defining relative weights, a binary questionnaire (yes/no) with impact values (no impact, low, moderate, high and reject) was used by Alsugair (1999), figure 8. This approach used expert interviews to define classes (1) and calculated class weights (2) by dividing 100% among those identified according to professional opinions. Inside classes, factor questions (3) were given a relative importance values (4). By multiplying these values, a weight for each question was obtained. (Alsugair 1996)

Class (1)	Class weight* (2)	Factor (3)	Factor internal weight** (4)	Factor's weight (5) = (2)*(4)
Experience and repuation	35 %	1. Classification	1. = 25%	8,75 %
		2. Contractor's capital	2. = 20%	7,00 %
		3. Commitment keeping	3. = 25%	8,75 %
		4. Coopreative in solving problems	4. = 20%	7,00 %
		5. Executing additional items for free	5. = 10%	3,50 %
		* 100% divided among all classes ** 100% divided among all factors	100 %	35 %

Figure 8. Class weight calculation (Alsugair 1999)

The method relies heavily on subjective assessment but does not require advanced mathematical methods and might be easier for practitioners to use. According to Griffith & Headley (1997) it is likely that in the beginning weighted criteria and scores used are based on experience and determined by individuals involved, but as the selected method is better understood and data gathered, weightings will be derived from empirical evidence.

2.5 Quality in tender evaluation and selection

Although buyer has a substantial freedom in designing scoring rules, weighting functions and choosing selection criteria, there is no simple answer for the importance of quality nor optimal bid-selection mechanism (Lundberg & Bergman 2017). The optimal choice depends on marginal costs and benefits from increasing the level of quality, both restricted by the extent to which quality is verifiable (Lundberg & Bergman 2017). Sometimes quality dimensions are observable, but problematic to verify by contracting parties (Albano *et. al.* 2017), illustrating the underlying problem with quality-based or quality-adjusted supplier selection. Such a context makes it hard for buyers to distinguish between high and low quality suppliers, and for high-quality subcontractors to distinguish themselves from those with lower quality (Harald 2013). Reportedly main contractors shun on compromising on price, and mainly bids with lower price have been selected. However, after price, main contractors are least willing to compromise on quality valuing acceptable level of quality over technical knowhow and cooperative skills of

a subcontractor, *if* main contractor has confidence that subcontractor has every intention meeting project specifications. (Hartmann & Caerteling 2010)

In order to understand how quality can be evaluated and tendered, one needs to understand what quality in construction sector comprehends. And even more so, what is required from a main contractor, which arguably needs to transfer quality requirements towards its subcontractors. Yasamis *et. al.* (2002) assessed contractor quality performance, quality evaluation and selection, arguing that construction quality (from a client – main contractor perspective) consist of main contractor's corporate quality level and project quality level, while previous literature of construction quality has been mainly about the quality of design and following the stipulated design. They argue that an increase in quality performance is expected to increase productivity and profitability of a main contractor in addition to client satisfaction (Yasamis *et. al.* 2002). Thus, construction quality is affected by both line and project organizations quality management. In construction stage, consistent quality with quality level required perceived to be the most important criterion of quality performance (Mbachu 2008).

As subcontractors operating on project level handle a major portion of the project (up to 90%) (Hinze & Tracey 1994), they have a significant impact on project quality. For project level quality performance indicators, Yasamis *et. al.* (2002) propose quality assurance, quality control activities, quality management activities and project management activities (table 5). For each of these a relative importance (weight) is defined and measures created (scoring). According to Yasamis *et. al.* (2002) quality performance is results oriented and seeks evidence of quality awareness both within the operations and outputs of a contractor. As these criteria were developed for client – main contractor level, they are not directly applicable, but provide a guidance for possible themes for subcontractor quality performance evaluation as these quality performance indicators are the ones main contractor being are measured by.

Table 5. Construction project quality performance indicators (Yasamis *et. al.* 2002)

Quality assurance / Quality control activities	Quality management activities	Project management activities
Inspection	Quality systems	Integration management
Control charts	Personnel quality training	Scope management
Pareto diagrams	Expediting	Time management
Statistical sampling	Operability / safety / value reviews	Cost management
Flowcharting	Constructability review	Human resource management
Checklisting	Audits	Communications management
Metrics development		Risk management
		Procurement management

Bergman and Lundberg (2013), Lundberg & Bergman (2017) and Harald (2013) researched supplier selection and evaluation methods in different quality settings with varying levels of cost and quality uncertainty. Bergman and Lundberg (2013) conducted a research, contributing to the gap between theoretical analyses of abstract scoring rules and practical application used in real-life procurement. They make the assumption that quality can be measured and quality deviations be intervened (verifiable quality) when proposing different selection methods. Harald (2013) addresses quality from a standpoint in which quality is unobservable. In figure 9 the choices for different quality-based supplier selection mechanisms, proposed by Bergman & Lundberg (2013) are shown. In this setting, EMAT combines price(s) and quality measure(s), meaning that either quality differences are evaluated in monetary terms (*quality-to-price*) or price is transformed into a score applicable to quality score (*price-to-quality*) (Bergman & Lundberg 2013).

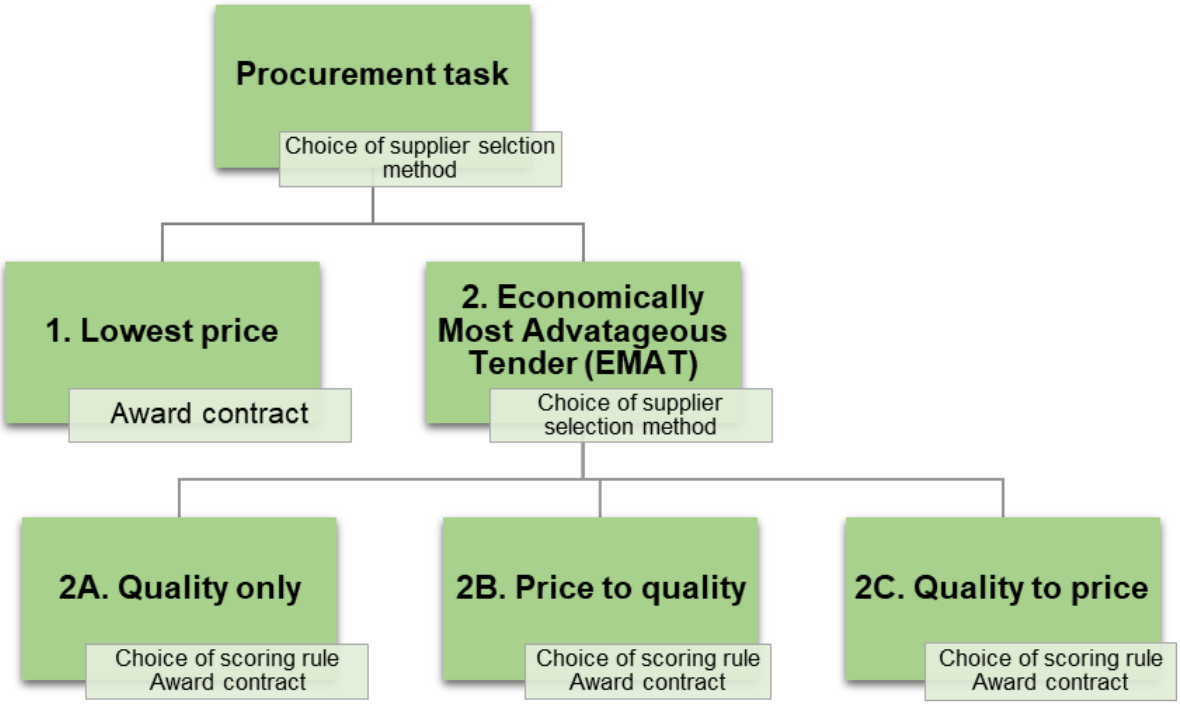


Figure 9. Supplier selection methods (Bergman & Lundberg 2013)

When costs of quality are relatively well-known, markets provide quality which is in accordance with buyer's preferences and market has several able providers, lowest price is the preferable supplier selection method. Buyer can also (1) specify minimum quality requirement and choose the lowest bidding supplier, (2) fix the price and select the provider based on best quality level or (3) use a scoring rule representing buyer's needs and preferences and select best overall score (figure 10). While the lowest-price method is in theory straight-forward, defining appropriate minimum quality requirements or combining and comparing multiple prices can be difficult in practice. In all cases buyer needs to be able to evaluate quality on monetary scale. (Bergman & Lundberg 2013) When cost and quality uncertainty is applied, the use of complex scoring rules (*i.e.* EMAT) is preferable to a point where transaction costs become too high (Lundberg & Bergman 2017).

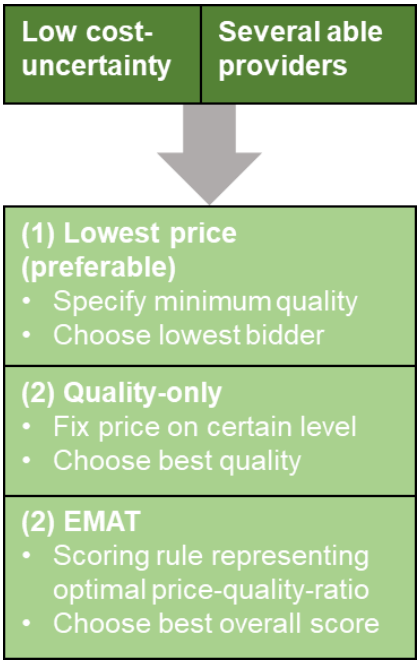


Figure 10. Supplier selection with known quality costs and several providers (Bergman & Lundberg 2013)

Quality reliant methods (figure 11) in tender evaluation are preferable when quality is non-verifiable, and when ex-post quality degradation and non-verifiable quality variations are likely. However, use of quality-only tender evaluation can become complicated if quality is measured though more than one dimension, as in order to combine quality dimensions weighs must be used. (Bergman & Lundberg 2013)

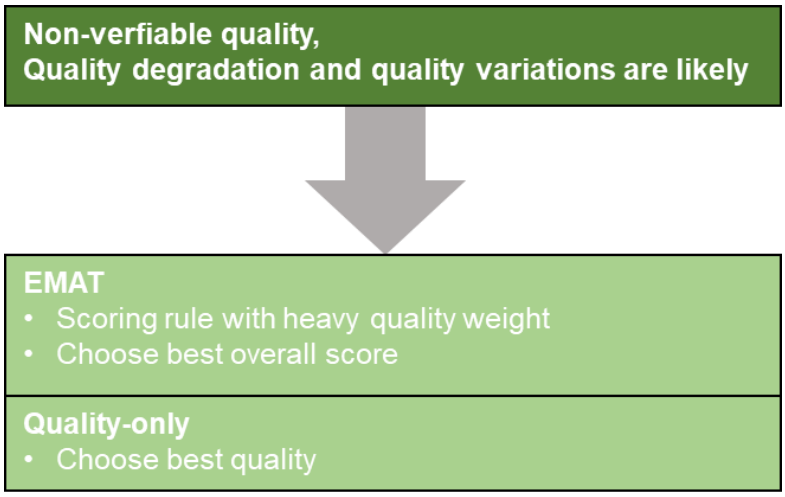


Figure 11. Quality-reliant supplier selection methods (Bergman & Lundberg 2013)

2.6 Contract design

Another aspect present in construction industry is the contract design. The design of a contract is a result of the tendering approach, but also of the environment project is executed. By this a reference is made to project complexity and level as well as completeness of plans (Tadelis 2012). Contract design is deemed to have an indirect impact on construction quality through incentivizing adoption and collaborative attitude from subcontractor's side and thus, resulting in better quality.

Fixed-price contracts incentivize suppliers to lower production costs, while cost-plus contracts facilitate adoption. Simple projects with high completeness of plans and design are suggested to be procured with fixed-price contracts, while highly complex projects characterized with low completeness of plans and design requiring some level of alterations are suggested to be procured using cost-plus contracts. The problem with fixed-price contracts is that the contractor is not obliged to agree on possibly occurring changes during the contract time. As a result, contractor can use haggling over prices in a buyer-supplier lock-in situation and use the need for adaptation to its own advantage. (Tadelis 2012) Some of the haggling during course of a project are a result of incomplete or erroneous specifications (Waara & Bröchner 2006).

To incentivize adaptation, Tadelis (2012) suggests cost-plus contracts so that contractor attains a compensation for any changes through cost-plus structure. However, as construction industry has been characterized with adversarial supply markets (Ireland 2004) and supplier relationships (Errasti *et. al.* 2007) as well as lack of trust between main contractor and subcontractor (Fearne & Fowler 2006), there should be some skepticisms against the use of cost-plus contracts. The nature of construction is also noted by Tadelis (2012), as he states that some contractors attain formidable profits through exploiting flawed plans and detecting where necessary changes are later needed. Tadelis (2012) promotes the use of cost-plus contracts when suppliers are selected through negotiating with reputable counterpart, instead of auctioning. Negotiated contracts might not be as efficient in selecting the lowest bidder, but the benefits gained from economizing from *ex-post*

transaction costs resulting in incompleteness of project design and specification (raising to over 15 % of the winning bid (Bajari *et. al.* 2014)); and friction between the contracting parties, outclass the sacrifices in the long run (Tadelis 2012). Waara & Bröchner (2006) argue that a greater use of resources at an early stage can result in reduced transaction costs later on.

Tadelis (2012) does not directly promote the use of unit price contracts, but seemingly emphasizes the idea. Unit price contracts are a mix between a fixed-price and cost plus, in which contractor submits a bid and commits to this price level even if adaptations are required compared to original quantity estimation (Tadelis 2012). However, unit price contracts seem to be more applicable with procurement of materials or with a subcontract in which the materials are major factor for final tender price, instead of mainly service based subcontract requiring vast amount of subcontractor's expertise.

Sometimes quality can be hard to stipulate in contract, while non-verifiable quality makes it hard to detect contract compliance (Harald 2013). To avoid problems caused by quality non-verifiability, using negotiation-like procedures with a number of highly reputable suppliers has been proposed by Albano *et. al.* (2017), Bergman & Lundberg (2013) and Harald (2013). According to Harald (2013), for main contractors selecting a subcontractor, subcontractor's previous experience in similar projects was reportedly the most important reputation variable in subcontractor selection. Bergman & Lundberg (2013) also promote the idea of blacklisting suppliers incapable of delivering required level of quality. Vassallo (2007) suggests using contract clauses which enable buyer to hold or reduce payments in case of lower quality than what was agreed upon. Albano *et. al.* (2017) suggest using fines or threatening contractor with being unable to submit bids in future.

If quality is determined after the delivery (*ex-post*), the buyer is exposed to a moral hazard since for the supplier it is usually cheaper to produce inferior quality. When quality is determined before signing a contract (*ex-ante*), bidding competition favors low-quality providers (problem known as adverse selection), if price or costs are used as selection criteria. A non-verifiable quality creates a troublesome situation in

which the buyer is unable to prove that the quality is degraded from what was originally interpreted and is unable to sue the supplier for damages caused by poor quality, nor terminate the contract. (Bergman & Lundberg 2013)

2.7 Problems occurring with different phases and methods

What comes to the construction as a field of industry, building process is facing problems related to separation of design from construction, low integration, ineffective communications, uncertainty, dynamic environment, changing clients' priorities and expectations; and increasing project complexity (Naoum & Egbu 2016). According to Lundberg & Bergman (2017), two significant concerns are that the right balance of cost and quality is agreed on, but also delivered. All these problems also refer to subcontractor selection.

Holt *et. al.* (1995) described four different areas of shortcomings in contractor selection in construction industry. The supplier evaluation practices (1) vary between organizations, while most organizations are satisfied with their own selection system. The weaknesses of evaluation and selection practices are realized only when problems occur, not proactively. Pre-qualification data (2) is usually a snapshot of history and conditions might have changed from the date pre-qualification was made. Using lowest bid as an evaluation and selection criteria (3) creates a risk of contractor's poor performance resulting e.g. in postponed completion date and low quality of complete project, in worst case affecting buyer's whole business. Lastly, contractor evaluation and selection methods (4) often use data and weights, which involve imprecision and subjectivity.

Mateus *et. al.* (2010) criticized some of the common practices, such as use of relative scoring methods, poor use of inaccurate qualitative criteria and inaccurate use of weights. Some criticism towards the use of weighted scoring method was also discussed in a conference paper by de Boer *et. al.* (2006), identifying a need for simple and robust selection method tackling the problems of different normalization procedures, removal of bids and in worst case, submission of fake bids.

2.7.1 Problems with prequalification

According to Jennings & Holt (1998) and Holt (1995) a problem with prequalification is the lack of adequate re-qualification, meaning that prequalification results are rarely, or in some cases never, reassessed. Jennings & Holt (1998) propose that contractors involved with critical parts of project were to be always prequalified as a standard procedure in tendering process. Holt *et. al.* (1995) pointed out that the measures themselves used might not always be appropriate, meaning that wrong things are being measured. Prequalification also has a potential of becoming too costly, if too many criteria are implemented in it (Ng & Skitmore 2001). Therefore, if prequalification is used as basis of contractor selection, criteria should be significant and measurable with minimal costs to those involved (Ng & Skitmore 2001).

2.7.2 Using lowest-bid or final price

The use of pre-set minimum criteria promotes the use of final tender price as the dominant evaluation and selection criteria, leaving bids with enhanced characteristics (technical merits, quality, experience, extent and length of guarantees, maintenance costs and after sales services and life cycle costs) with slightly higher price, without any advantage (Lorentziadis 2010). Lowest price does not guarantee the maximum value in terms of other dimensions (Cheaitou *et. al.* 2018) and cases of contractors failing due to financial problems, poor performance or accidents arising due to lack of adequate safety considerations at worksites created a doubt of using final tender price in contractor selection (Singh & Tiong 2006). Reportedly in the US the use of lowest bid as the main selection criteria resulted in suppliers cutting costs and offering bare minimum acceptable quality. To counter this effect, complex product specifications were used, which increased transaction costs and reduced competition. (Bergman & Lundberg 2013)

According to Ahola *et. al.* (2008) strategies based on competitive tendering promote perspective of short-term value, which can destroy long-term value created by inter-organizational relationships and more of a partnership approaches. Awarding contract to a supplier with lowest bid can also lead to a gap between actual quality

and user perceived quality if quality is not used as selection criterion (Vassallo 2007). Immediate cost savings usually run over the possibility to reduce risk of opportunistic behavior and diminishing transaction costs by repeated exchange relationship (Hartmann & Caerteling 2010), making decision based on final tender price suboptimal in the long run. Utilizing partnering principles in subcontractor selection increases the costs of supplier selection process through the use of additional evaluation criteria and relationship management, but in the long run increased effort can translate into price reductions (Kumaraswamy & Matthews 2000). In addition to price decreases, Kumaraswamy and Matthews (2000) reported increased ability to control time and cost performance levels as well as achieving higher quality levels with cooperative subcontractors.

2.7.3 Problems with scoring rules

In practice, it is unclear how to design a good scoring rule. Supplier selection methodologies, especially scoring rules in use, are often poorly designed and procurers rely on trial and error processes without guidance or solid principles based on economics. (Bergman & Lundberg 2013) In case of absolute scoring, it is critical to see that score differences should be thought trough, as linear scoring for consecutive performance levels (*e.g.* 10 pts for L1; 15 pts. for L2 and so forth, table 3) messages the supplier that an increase form level 1 to level 2 is equivalent to increase from level 3 to 4. This is not always the case as higher performance levels might be more valuable or sometimes insignificant, making linear scoring flawed. (Mateus *et. al.* 2010) Another example of scoring and value trade-off problematics is provided by Keeney (2002) as he illustrates that a price increase of 10 000 might be equivalent of gaining 5% better quality at some point, but as the price goes up (increase from 100 000 to 110 000 vs. increase from 250 000 to 260 000), the trade-off might not be consistent.

In Bergman's & Lundberg's (2013) research, the most common scoring method used in their sample data was price-to-quality with relative scoring. In case of relative scoring, suppliers have a possibility of manipulating tendering process by submitting fake tenders or in some cases removing them (Bergman & Lundberg

2013; Mateus *et. al.* 2010; de Boer *et. al.* 2006), depending on a tendering design and procedure. Also, in case of relative scoring, the accountability of defining the relative differences between performance levels are transferred from buyer to tenderers (to markets) making two tenders dependent on a third one (Mateus *et. al.* 2010). Using different models to solve same problems, can result in drastically different results when buyer is unfamiliar with the selected method (de Boer *et. al.* 2016). This applies to absolute scoring rules as well. An example of a situation like this is illustrated in table 6, where applying different rules, both seemingly accurate, results in completely different supplier ranking.

Table 6. Two different scoring rules for same tendering (de Boer *et. al.* 2016)

Supplier	Price	Quality
Supplier A	4200	60
Supplier B	4550	80
Supplier C	4650	85
Supplier D	4750	90

Method 1: $Price\ score = 150 - \frac{50 * price}{4300}$

Method 2: $Price\ score = 100 * (\frac{4300}{price})$

Price of 4300 is given 100 points, linear scoring is applied and thus, price of 8600 is given 50 points. Derived from this, two possible methods for price are possible, resulting in different supplier reanking

Scoring method 1	Score on price (weight 0,8)	Score on quality (weight 0,2)	Total score	Ranking
Supplier A	101	60	92,3	4
Supplier B	97	80	93,67	3
Supplier C	96	85	93,74	2
Supplier D	95	90	93,81	1
Scoring method 2	**Score on price (weight 0,8)**	**Score on quality (weight 0,2)**	**Total score**	**Ranking**
Supplier A	102	60	93,9	1
Supplier B	95	80	91,6	2
Supplier C	92	85	90,98	3
Supplier D	91	90	90,42	4

In addition, the costs of measuring, time consumed as well as marginal costs should be taken into account (Lundberg & Bergman 2017), when forming relevant criteria measurable at a reasonable cost (Vassallo 2007). Buyer should be cautious in requiring too high quality standards, as it result in higher price than anticipated and the margin costs of quality may be more than quality is worth (Lundberg & Bergman 2017).

2.8 Framework for quality-adjusted supplier selection

As in previous chapters methods for supplier evaluation and selection were presented and discussed, a framework (figure 12) is now proposed to summarize key aspects. Further, each step is explained in more detail in the following chapters.

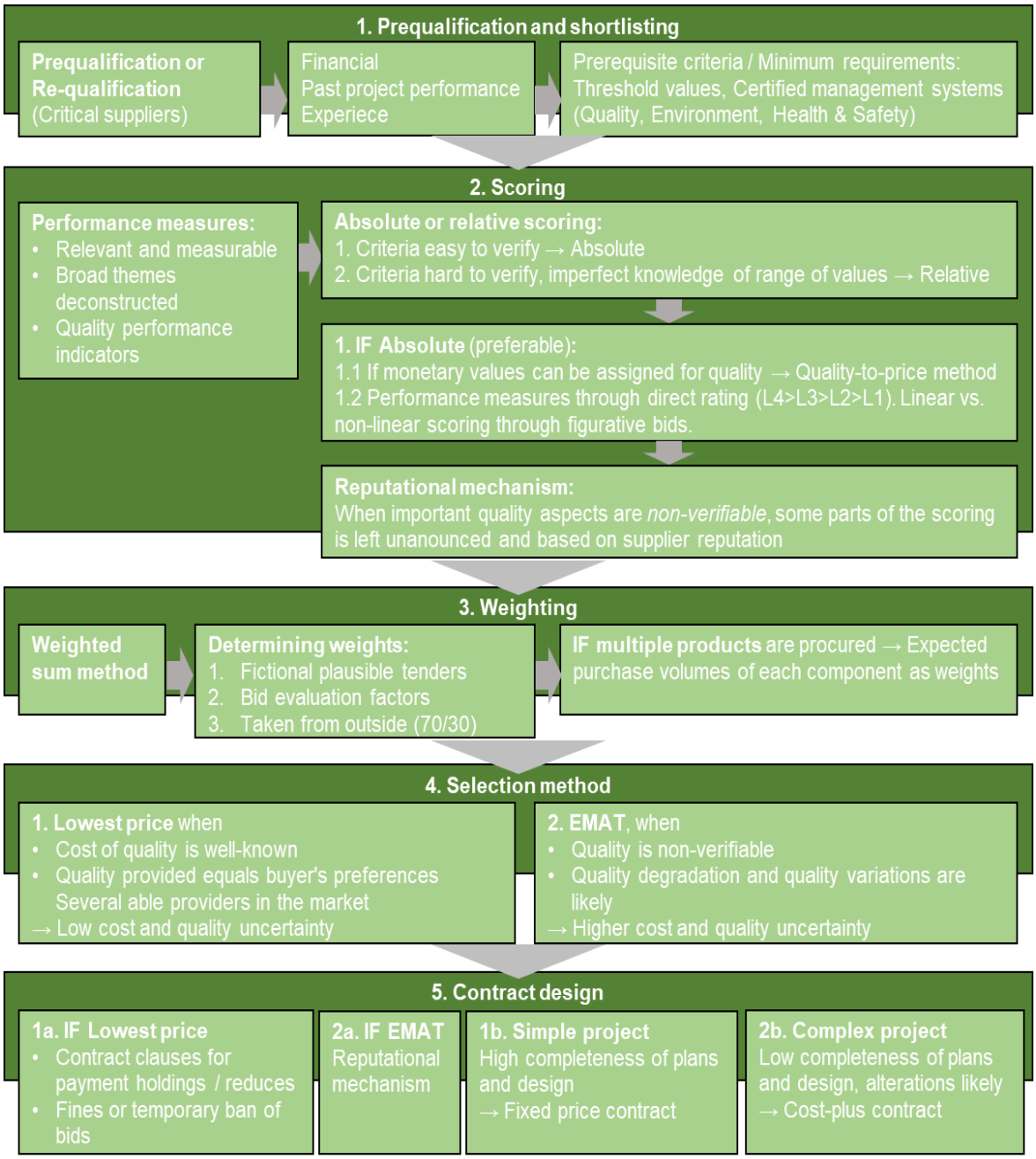


Figure 12. Framework for quality-adjusted supplier selection

2.8.1 Prequalification and shortlisting

For prequalification and shortlisting, based on most common criteria (table 1), at least financial, past project performance and experience (both technical and managerial) should be used. The information required can be collected either through prequalification or if necessary by creating a project specific questionnaire. For these criteria threshold values are then established. Arguably, these criteria are possible to measure during scoring phase, but if they are obtainable during prequalification and shortlisting phase, there is no reason to exclude them. Not all aspects need to be submitted for competition and are achievable through use of minimum requirements or prerequisite criteria (Mateus *et. al.* 2010). Quality assurance systems or implemented quality systems can be used either as a prerequisite to participate in tendering or as attributes under evaluation (Watt *et. al.* 2009; Waara & Bröchner 2006; Holt *et. al.* 1995). These can be certified ISO 9001 (or similar) systems, but also health and safety systems can be included. Critical suppliers for the project are good to be prequalified and re-qualified to ensure up to date information (Jennings & Holt 1998).

However, abovementioned are more or less only guidance of what to seek during a shortlisting phase. The main point of shortlisting should be to reduce the number of potential suppliers participating in tendering (Ng & Skitmore 2001) thus, reducing the amount of work required from both buyer and subcontractor.

2.8.2 Scoring

For scoring, attributes under evaluation should be relevant and measurable at a reasonable cost (Vassallo 2007), and broad criteria of price and quality should be deconstructed into more specific sub-criteria (Mateus *et. al.* 2010). For measuring subcontractor's quality performance, project quality performance indicators (table 5) proposed by Yasamis *et. al.* (2002) can be used as a template to be further enhanced. Evaluation criteria can be project specific (Wong *et. al.* 2000), or broader in nature. The most commonly cited supplier selection criteria in construction are associated to staff features, quality, financial, experience and costs (de Aurajo et. al. 2017).

The choice between relative and absolute scoring is done through criteria verifiability: when criteria is easy to verify, absolute merits should be used; when criteria is hard to verify or knowledge of range of values is imperfect, relative merits are a better choice (Waara & Bröchner 2006). Preferably absolute merits are used, assigned through direct rating while the choice between linear versus non-linear scoring should represent buyer's preferences (Mateus *et. al.* 2010). For buyer's preferences, figurative bids and performance measures can be used as proposed by Mateus *et. al.* (2010) and illustrated in table 3.

If monetary values can be assigned directly for quality, use of quality-to-price method utilizing equation 2 in figure 6 proposed by Bergman and Lundberg (2013), since it makes scoring rules and assigning weights obsolete. If important quality aspects are non-verifiable, use of reputational mechanism through scoring is possible by not revealing scoring method fully to subcontractor (Lundberg & Bergman 2017) and leaving some final consideration to buyer.

2.8.3 Weighting

In prequalification and shortlisting as well as in scoring phase, relevant evaluation criteria are identified. The function of weighting is to illustrate buyer's preferences and how important criteria (*e.g.* price or non-price criteria such as quality) are for the buyer (Mateus et. al. 2010; Lorentziadis 2010). For weighting, a weighted sum method is commonly used (Mateus *et. al.* 2010). To determine exact weights, advanced mathematical and conceptual methods (*e.g.* Lorentziadis 2010) might be hard for practitioners to execute. Another proposition for weight determination is to use plausible fictional tenders as proposed by Mateus *et. al.* (2010) in scoring section *or* alternatively an approach suggested by Alsugair (1999) where procurement experts determine weight by their perceived importance or impact to the project. In public sector 70% price criteria with three nonprice criteria has been common (Waara & Bröchner 2006). If multiple products are procured, expected purchase volumes of each component can be used as weights (Bergman & Lundberg 2013).

2.8.4 Selection method

As proposed by Bergman & Lundberg (2013), when cost and quality uncertainty are low, and markets are able to provide quality which is in accordance with buyer's preferences, the preferred selection method is lowest price. As the cost and quality uncertainty increase, the preferred method shifts towards EMAT. (Bergman & Lundberg 2013) When quality is non-verifiable reputational mechanism is suggested to be used (Albano et. al. 2017; Bergman & Lundberg 2013), including previous experience on similar projects Harald (2013).

2.8.5 Contract design

If lowest price is used, in order to ensure quality level, payment reduction and holds (Vassallo 2007) as well as use of fines and temporary bans for bidding (Albano *et. al.* 2017) are suggested. If quality is non-verifiable, the method of choice is preferably EMAT (Bergman & Lundberg 2013), reputational mechanism can be used to help ensuring agreed level of non-verifiable quality (Albano et. al. 2017; Bergman & Lundberg 2013). In case of simple projects with high completeness of plans, design (Tadelis 2012) and specifications (Waara & Bröchner 2006), fixed price contract is sufficient (Tadelis 2012). Vice versa, for highly complex projects with low completeness of plans, design (Tadelis 2012) and incomplete specifications (Waara & Bröchner 2006) requiring some level of alteration, cost plus contracts with reputable counterpart or unit price contracts whenever possible, are proposed (Tadelis 2012). A certain degree of caution caused by construction industry market environment should be held.

3. CASE STUDY: QUALITY-ADJUSTED SUPPLIER SELECTION METHOD FOR PROCUREMENT OF HVAC SYSTEMS

In this chapter the empirical part of the study is presented. Empirical part consists of case project analysis and analysis of a multi-criteria selection method used by company subsidiary. In case project analysis, one of the HVAC procurement packages is closer examined and the functionality of selected scoring method is illustrated, in addition of calculating replacement ratios for quality criterion. Shortly methodology of the research is presented, the company and project under scope are introduced, a multi-attribute subcontractor selection method used by company subsidiary is presented, and finally an enhanced framework for quality-adjusted selection is conducted. The proposed framework combines notions made in chapter 2 together with real-life examples synthetizing academic research together with practitioners' approaches.

3.1 Methodology

This thesis is a qualitative research, using constructive research approach and case study as its research strategy. The constructive research approach is a procedure for producing models to solve problems in business organizations (Kasanen *et. al.* 1993). According to Yin (2003, 4), when studied phenomena is hardly distinguishable from its context, case study is the method of choice. Case study is also applicable when previously found concepts are being extended or when the environment of studied phenomena is different (Stuart *et. al.* 2002). Case studies can also be used in testing theories in real life situations and refine their scope of applicability (Dubois & Araujo 2007).

Case study approach is suitable for this study, as the ultimate goal is to conduct a quality-adjusted supplier evaluation and selection framework providing help in evaluating other than price criteria in a subcontract tendering. So being, the context (or environment), is inherent to the approach proposed and thus, the model proposed is more or less a product of its environment. As many of the previous research are bound to their own presumptions, they may not be fully or directly

applicable, but form a valuable and still valid background for the model represented in this study. For some topics, existing research can provide a rich framework (Yin 2009, 28), and this indeed is the case in this study. The proposed framework finds its base from previous academic literature, and is then further enhanced with project specific criteria, already in-use multi-attribute selection method and by professional interviews from other industry fields. Previous research on quality-adjusted supplier evaluation and selection may have underlying assumptions of for example buyer-supplier power relations, function of the markets (number of players, market share, regulations etc.) as well as supplier capabilities, which many are likely to differ from the context in which this study is conducted. During the analysis of a real-life multi-attribute selection method, supplier attitudes towards alternative tendering models become distinct.

In a case-based study, according to Stuart *et. al.* (2002) the data is frequently the written and taped record of interviews, company provided documents and researcher's own observations. In this study, four main sources of data exist: previous academic literature, analysis of a case project, multi-attribute supplier selection method used by company subsidiary, and finally interviews with procurement professionals in construction industry. A case study combined with interviewing as a method of data collection allows in-depth discussion in which "*why"* and "*how"* questions can be asked while accessing the fundamental reasons behind the subject (Kähkönen 2011). To conduct a framework for a specific purpose, in-depth knowledge and understanding practitioner needs is required. By this, research tries to avoid vague framework which brings little to no use for practitioners and fails to fully grasp the reasons behind different decisions made. Below is a list of identified key interview subjects and secondary data sources of the study.

Interview subjects:

- Procurement manager of HVAC department (construction)
- Procurement professional from company subsidiary (construction)

Secondary data sources:

- Previous academic research, concentrating on construction
- Project documents
- Documents from case company subsidiary (BSC supplier evaluation and selection)

3.2 Execution and design of the research

Stuart *et. al.* (2002) propose a five-stage research model for case studies and Seuring (2008) uses the same model as a backbone for presenting analytic dimensions for content analysis. Model of Stuart *et. al.* (2002) and analytic dimensions of Seuring (2008) are combined, as interpreted by Seuring (2002), in figure 13.

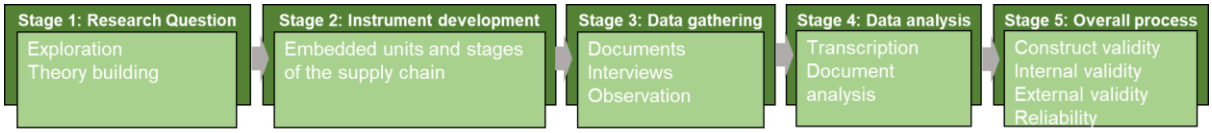


Figure 13. Five-stage research process model with analytic dimensions of content analysis (Stuart *et. al*. 2002; Seuring 2002))

In stage 1, exploration and theory building were done through analyzing previous literature of supplier evaluation and selection criteria, different methods and problems associated to them. Proposition was that there is a need for a simplified method adoptable by practitioners (Bergman & Lundberg 2013; de Boer *et. al.* 2006), and research questions were formed to support a framework creation. In stage 2, instrument development was done through conducting a proposed preliminary framework for supplier evaluation and selection (figure 12) further to be enhanced during the empirical part of the study. In stage 3, data gathered is in form of project documents, interview records, interview documents and notes. The interview with the representative of company subsidiary was held online, recoded and analyzed afterwards. With the company HVAC manager, consecutive interviews were held approximately every month. With the interview subjects outside of construction industry, interviews were held in their company quarters and

interviews were conducted personally. For every interviewee, a transcript of analyzed interview was sent, so that unnecessary misunderstandings could be avoided. Worth mentioning is the fact, that the writer has previously been employed in the company, which has some impact on how things are perceived and understood. In stage 4, gathered data is analyzed and presented so that the reader can follow the process of building a quality-adjusted supplier selection method. Lastly in stage 5, the overall process of the research is analyzed through discussing validity, reliability and limitations of the research.

3.3 Company description

The company is one of the largest construction companies operating in Finland with revenue of hundreds of millions of euros. The company wishes to stay anonymous and is further addressed as Aurora. Aurora operates in multiple countries outside of Finnish borders and is a part of an international corporation. Globally it has tens of thousands of employees and thousands of ongoing projects in selected markets. In Finland, Aurora offers construction services, both residential and commercial project development services, and public-private partnerships. Further, the construction services are divided into building construction, building services (*e.g.* HVAC services), environmental construction and civil construction.

In addition to offering different types of construction services, Aurora executes different types of contracts, meaning that same construction service can be provided through a variation of different contract types. Some of the contract types include life-cycle projects, plan and execute projects, alliances and project management contracts, to name some. The contract type depends on type of construction but also on client organization. For example, Finnish road administration stated to move towards comprehensive and longer contracts, increasing main contractor's responsibilities for overall execution of the project, include more planning and higher utilization of main contractor's innovations surfacing during the planning phase (Tiehallinto 2003, 4). This move results in more complex procurement methods, including service elements and quality as evaluation criteria when selecting main contractor(s) to execute the project (Tiehallinto 2003, 4). Recently, Aurora has been

involved in multiple projects, where client organizations had used multiple other than price criteria in selecting the winning main contractor. The weights of price criterion has been as low as only 20% of total evaluation score, while other criteria, such as usability during construction phase and ability to co-operate efficiently have had significant impact on final decision.

The procurement function of the company has elements from both centralized and decentralized approaches. Historically Aurora had a highly decentralized procurement function, which is still visible through a large degree of project autonomy and large proportion of purchases being made by project organizations instead of centralized procurement function. In Finland, Aurora has a centralized procurement unit, which is responsible for tendering and negotiation of framework agreements, supplier relationship management, supplier development, international procurement and development of purchasing function. Different divisions in the organization (*e.g.* civil construction or building construction) each have their own purchasing manager responsible for answering to the more specific needs of a given division. In addition, regions have their own regional purchasing managers. The purpose of centralized procurement and procurement manager (functional or regional) is to help projects to manage their purchases in a best possible way, providing support when needed and to develop procurement function as well as supplier relations.

The projects themselves have a large degree of independency in tendering, supplier selection and evaluation measures. As an illustration of this, the project specific purchases represent over half of the total purchases made annually. In construction, projects vary drastically and thus, project organizations might have been left with a large degree of freedom to leverage their project specific and practical knowledge, or to create and adjust tools for project specific needs. The large project autonomy is one of the factors explaining the vast amount of around 10 000 annually invoicing suppliers. Overall in the company, there exists no systematic way of evaluating quality aspects in tendering, and the major discriminating factor has arguably been final tender price. This fact has been noted in the company, and the development of procurement practices is one of the drivers for this study.

It is common for Aurora to invite suppliers and subcontractors to participate in supplier prequalification before sending request for quotations, or at least *before* a contract is agreed upon. The supplier prequalification of Aurora collects basic information of suppliers including area of expertise, possible reference projects, as well as some of supplier's possibly certified management systems. Certifications under scope are health and safety management system (OHSAS 18001 or similar), quality management system (ISO 9001 or similar), environmental management system (ISO 140001 or similar) and possible supplier code of conduct. None of the certifications are a prerequisite or if absent, do not prevent commerce. Majority of financial data comes automatically from an integrated system, provided by a third party. Financial information is based on latest annual report and payment data track record (defaults). Key financial figures are automatically shown in the system, and based on these, an overall supplier rating is calculated by the system. If supplier drops below certain threshold values, commerce is prevented until discrete approval.

3.4 Case project characteristics and requirements

As the forthcoming analyzes include sensitive information of tendering process and of tenders themselves, project is not further identified. The total project sum accumulates to tens of millions of euros, from which the procurement of HVAC constitutes almost one third, making it significant considering the overall success of the project. Type of the project contract between client and main contractor is a project management contract agreement, meaning that majority of procurement decisions needs to be approved by a client representative, when a certain threshold value is exceeded. This means that procurements associated with high risk, high amount of money or high overall impact for the project needs to be approved by the client. According to project documents, main contractor is responsible for confirming and proving the quality and functionality of constructed systems and used materials. Main contractor is also required to list all possible needs for spare parts in HVAC systems for the next five years (after the delivery of HVAC systems).

According to HVAC procurement manager, HVAC subcontracts are not the most complex ones to be procured, the level of plans and design for this project is sufficient and there should be relatively little alterations for existing plans since the client has had over two years for developing project plans. This implies that fixed price contracts (Tadelis 2012) are plausible to use. However, in project documents, the client states the following: *"in project management contract, plans become more precise as the project advances. With close collaboration between the client and main contractor, it is possible to achieve planned objectives (schedule, quality and possible alternative solutions)."* This implies that indeed there are alterations and changes in plans to some extent, requiring adaptability from a chosen subcontractor. Subcontractor's adaptability was also highlighted by the procurement manager.

Ensuring on schedule operability of the construction has a high value and is prioritized by the client. Thus, client requires additional emphasis to be put on planning the schedules, joint-operations, removing obstacles and if necessary to ultimately catching up schedule by adding more resources. This implies that subcontractor's capability to plan and manage resources, and ultimately increase them if necessary, might be one criterion under evaluation. On the other hand, if everything goes according to plans without greater distortions, no additional resources are needed and possibly some situations are manageable with subcontractor's current resources.

As of requirements given by the client towards main contractor, there are some mentions of quality and safety. These are listed in appendix 1. In general, they are relatively typical for the industry. Client has also stipulated main contractor to be responsible of each subcontractor writing a quality plan before subcontractor starts to work in the project, completely covering the work. This quality plan is required to include sections described in appendix 1. During the project, client organizes regular quality meetings, in which quality documents are followed, quality defects are discussed and materials are approved. In quality plan, quality process throughout the work needs to be described along with other quality and work-related issues. For those companies holding a 3rd party certified quality plans, these requirements should be more familiar compared to subcontractors with no quality management

systems. However, as later will be seen, use of 3rd party quality certification as selection criteria would either drastically limit the number of potential suppliers or unjustly favor those with them, as according to procurement manager of HVAC systems these certifications are invalid measurement of subcontractors' quality.

Client has put a rewarding system in place, which is linked to health and safety of the project. Criteria stipulated is zero casualties or fatalities, and if either one happens the buyer instantly loses all the bonuses in reserve. Additionally, client measures level of accident frequency (accident leaving to absence divided by million working hours), and encourages main contractor to achieve better result than measured in client's previous project. Buyer has its own health and safety requirements, which every subcontractor and supplier agrees to follow whenever conducting business with the buyer. These health and safety regulations impose greater requirements to the supplier than stipulated by minimum legal requirements. The bonus system in place promotes the use of low accident frequency as an evaluation criterion. The problem with this is that not every subcontractor keeps track of its accident frequency or even measures it.

3.4.1 Potential HVAC subcontractors for the project

Client has stipulated buyer to ask tenders from at least five different suppliers or subcontractors in each HVAC procurement package, but holds a right to reject subcontractor proposed by the main contractor. Rejection must be based on likelihood of contract breach, derived from previous experience. Documents are required from each subcontractor, not limited to first tier suppliers in subcontractor's chain, by which the client ensures that subcontractors fulfill legal requirements (taxes, salaries, social security payments, insurances *etc.*).

Supplier prequalification

Overall 26 suppliers were selected to participate in tendering of different HVAC or HVAC related materials or subcontracts. Some of the suppliers were requested to participate in multiple or occasionally in every tendering. From these 26 suppliers, 14 (56%) were prequalified, from which one supplier's information proved to be

inaccessible. From the 13 suppliers left, all but one fulfilled the requirements to obtain an approved prequalification status, meaning that they fulfil minimum legal requirements as well as approve Aurora's additional requirements and the way of doing business. From these 13 prequalified suppliers, 6 had safety and health management system (from which three were certified); 9 had quality program or quality system in place (only two were certified) and 5 had an environmental management system in place (from which two were certified). Prequalification statistics is summarized in appendix 2. According to the HVAC procurement manager, current supplier prequalification system does not provide a reliable information of supplier performance levels and prequalification tool is used more as a risk management tool for ensuring subcontractors' fulfilment of minimum legal requirements. According to HVAC procurement manager, quality of HVAC systems and subcontracts seems to have its base *not* on formally established quality management systems (such as certified ISO 9001), but on superb work freed from any formal quality management system. In other words, there exists a number of subcontractors able to provide high quality work without any 3rd party certifications. The manager also states that quality management thinking in the industry seems to be lacking behind compared to other fields such as manufacturing.

Supplier feedback

Aurora collects supplier feedback form its suppliers, mainly for supplier relationship management purposes. Feedback conducts numerical values like for example contract compliance, compliance with health and safety regulations and delivered quality. However, feedback is not collected in a systematic way where each supplier would have a continuous feedback form different projects throughout the time being a supplier for the company. In addition, the amount of feedback varies drastically between different suppliers. Majority of supplier feedback is collected from either current framework agreement suppliers or those who have potential to become one. In some cases, other suppliers are also included in feedback collection cycle. Considering the large amount of different invoicing suppliers annually, it is no wonder that not every supplier is, or even should be targeted by feedback collection, but this does not conceal the fact that majority of the supplier from which the feedback is collected belongs to framework suppliers.

As for suppliers participating in selected tendering, only one had feedback from three consecutive years. This illustrates the problem of supplier feedback, as it is not systematically collected and may have poor sample size as well as continuity over time. Thus, supplier feedback does not provide a solid basis for justified evaluation or scoring in this case. Even so, it might have future potential for that. For now, collected supplier feedback is the only process in place for collecting implicit knowledge of suppliers' previous performance in company projects for wider use. This implies that information regarding previous experience of given subcontractors is largely implicit. Reportedly, a practice of asking senior foremen or construction managers about a supplier's performance from previous projects is sometimes used.

3.4.2 Tendering design in the project

Holt (1998) reported and described a use of bespoke approaches in construction supplier selection, meaning ad hoc evaluation and selection methods developed by buyer, incorporating several techniques in supplier selection. This type of an approach was also taken for the case project, as for the project itself a bespoke approach was developed. For developing a procurement method for HVAC systems, the HVAC procurement manager has been a major influencer. Another influencer has been the client of the project, requiring most significant HVAC procurements to be based on economically most advantageous decision (EMAT). In tender evaluation the weighting between price and quality is stipulated to be 70% for price and 30% for quality, while client is able to participate in definition of quality criteria. So far Aurora has conducted quality criteria for the tendering of subcontractors in the case project and asked if client has had any additional ones or if changes for proposed criteria were required. No changes were made, implying that the client agreed with the selected quality criteria and approves the method.

The chosen tender evaluation and supplier selection method for the project's HVAC systems and subcontracts can be described as EMAT with a scoring rule of price-to-quality, as it technically transforms price to same scale as quality points (Bergman

& Lundberg 2013) with weighted sum approach. The weighting is largely stipulated by client, but method has been further enhanced by the company. Supplier evaluation scale ranges from 0 to 100, with 70% price and 30% quality weighting, using already proportional scores for price (70) and quality (30). The approach represents a relative scoring method (both in price and some parts of quality), and the chosen contractor is the contractor with the highest overall score. If there were to be two equal overall scores, the one with higher price score is selected. The tender evaluation method of the case project is presented in figure 14.

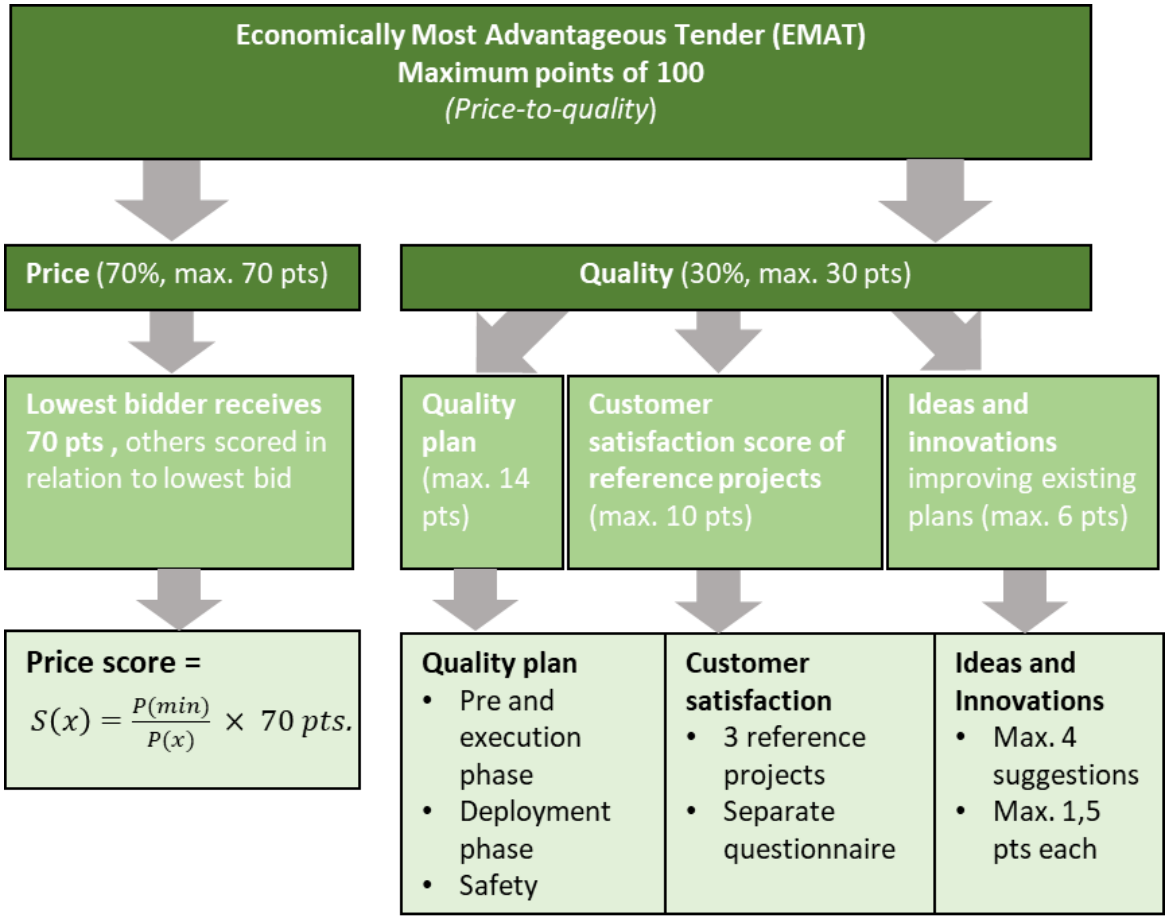


Figure 14. Tender evaluation and scoring method of case project

Procurement of HVAC systems was divided into smaller procurement packages instead of being procured through one major contract. Broadly, HVAC systems were divided into electricity systems, air conditioning (materials and work separated) and plumbing, resulting in at least six different packages, as some of the aforementioned were further divided. The project organization identified at least five, sometimes

more, potential contractors or suppliers for each subcontract, to whom a request for quotations were sent. In some cases same suppliers were asked to participate in tendering of multiple subcontracts, some even in all of the subcontracts. If deemed necessary, an additional tendering round was performed with the most prominent providers using the same scoring method. During the second round, main focus was on getting a more competitive price and previously used quality criteria were taken as unchanged.

As for price scoring, maximum price points of 70 were given to the bid with the lowest price. Other bids were ranked in relation to lowest bidder (figure 15) and only one bid was evaluated per subcontractor per tendering round. On top of price core, quality score is added resulting in total score of a bid.

$$\textbf{\textit{Price score}} = S(x) = \frac{P(min)}{P(x)} \times 70\ pts.$$
$$S(x) \leq 70\ pts.$$
$$P(x) \geq P(min)$$

Where
$P(min)$ is lowest bid submitted
$P(x)$ is the bid for which price score is being calculated

Figure 15. Price score for subcontractor bid evaluation

Quality was divided into 3 sections: (1) *quality plan*, (2) *customer satisfaction score of reference projects* and (3) *ideas for improving existing project plans*. Quality scoring differed in some parts from price scoring, as the three subsections were scored independently, but still endogenously. For the winning bid, submitted quality plan and ideas for improving plans are added as attachments to final agreement, thus binding the chosen supplier to act accordingly.

Quality plan was given a maximum of 14 points, which is almost half of the total 30 quality points distributed. Quality plan itself was further divided into three subsections of pre- and execution phases; deployment phase; and safety. Subcontractors were asked to submit a document answering nine questions of

ensuring quality of plans, for which parts of the subcontract a detailed work plan should be conducted, implementation of instructions, ensuring co-operation between different parties, ensuring stipulated quality requirements, documentation, corrective measures if necessary and how safety is ensured throughout the subcontract (complete quality plan found in appendix 3). For scoring the themes, a scale from 0 to 3 was used (table 7). No preliminary template for the document was given, but a maximum number of 6 pages was instructed.

Table 7. Quality plan scoring scale for individual questions

Scale	Description
0	Description is missing
1	Somewhat described
2	Clear overall description, but detailed actions are missing
3	Comprehensive description with detailed actions

In general, buyer appreciated a document ensuring quality, cost efficiency and safety of the project, and in which clear answers were provided for the questions submitted. The best quality plan was given the maximum 14 points, while other quality plans were compared against the winner (figure 16). Points of a quality plan were determined according to qualitative differences compared to what was examined to be the best one, meaning that subjective judgement was involved. It was possible to award identical points for multiple bidders if deemed necessary.

$$\textbf{\textit{Quality plan score}} = Best\ Quality\ plan\ (14\ pts.) - Difference\ in\ relation\ to\ highest\ scored\ quality\ plan$$

Figure 16. Quality plan scoring of the project

Customer satisfaction score of reference projects constitutes one third (33%) of total quality points and is measured through a questionnaire of subcontractor's three previous projects. The subcontractor names the projects as well as the project manager, same who would be the one responsible for executing the tendered subcontract. It was required that in these three projects, the same project manager had been in charge. Reference projects all had to be similar to the project tendered and no more than 8 years old. Subcontractor is responsible for ensuring that the

answers are submitted to Aurora prior to a given date, but no penalization for delay was placed. Results were evaluated by mean average value and the maximum of 10 points were given to bidder with the highest mean average. Other bidders were compared to the best score and evaluated according to difference between highest average and bidder specific average (figure 17).

$$Customer\ satisfaction\ ranking\ score = \frac{(\overline{X}_{supplier\ a})}{\max \overline{X}_{supplier\ x}} * 10\ pts$$

Where
$\overline{X}$ is the average customer satisfaction of given bidder
$max\ \overline{X}$ is the highest average customer satisfaction from given set of bidders

Figure 17. Customer satisfaction ranking score

Ideas and innovations for improving existing plans were evaluated according to number of suggestions, their impact on cost efficiency or quality improvements, and applicability. Each suggestion can reach a maximum of 1.5 points and points are distributed on basis of differences between descriptions with fixed intervals of 0.5 [0; 0.5; 1; 1.5]. Ideas and innovations account to total of 6 points, which translates to 20% of total quality points. Scoring of proposed suggestions was completely based on subjective assessment.

2.4.3 Bid evaluation and scoring of a subcontract

To illustrate bid evaluation process of the project in practice, one tendered subcontract was chosen to be closer examined. Since all of the subcontracts are tendered in a similar way, one sample under analysis is sufficient in this sense and gives a sufficient glimpse of tendering in practice. For the selected contract, 11 subcontractors were invited to participate in tendering, from which four submitted a satisfactory bid, one submitted insufficient documents and others did not participate due to various reasons.

For the analysis, prices were received from the company. Due to the information confidentiality, prices were multiplied with a constant variable generated by a random number generator (RNG). First, bid prices were evaluated using relative

price scoring method described earlier and a price score was assigned to different bids (table 8). The spread is quite significant with this subcontract, as the difference between lowest and highest price is over 50%.

Table 8. Bid price comparison of selected tendering

Price	Supplier A	Supplier B	Supplier C	Supplier D
Position 1	1 624 €		7 700 €	6 157 €
Position 2	16 072 €	33 740 €	24 920 €	22 456 €
Postiion 3	56 392 €	64 176 €	39 004 €	66 530 €
Postiion 4	10 892 €	17 080 €	11 508 €	12 824 €
Position 5	12 460 €	16 548 €	3 892 €	11 537 €
Total Price	97 440 €	131 544 €	**87 024 €**	119 504 €
Compared to cheapest [€]	10 416 €	44 520 €	- €	32 480 €
Compared to cheapest [%]	11,97 %	51,16 %	0,00 %	37,32 %
Ranking	2	4	1	3
Total Price points	**62,52**	**46,31**	**70,00**	**50,97**

Based on prices a table was created using equation derived from project's price scoring method, by which different prices and their corresponding price points were calculated, as well as differences compared to the next price score (appendix 4). For the clarity, price points under 30 were removed since calculated prices for these scores were deemed unrealistic. Even with the current scale, lower end of it is highly unlikely. The interesting part with bid prices is the *difference* between any given price and its consecutive price point (figure 18), interpreting increase or decrease of price for the next or previous price point.

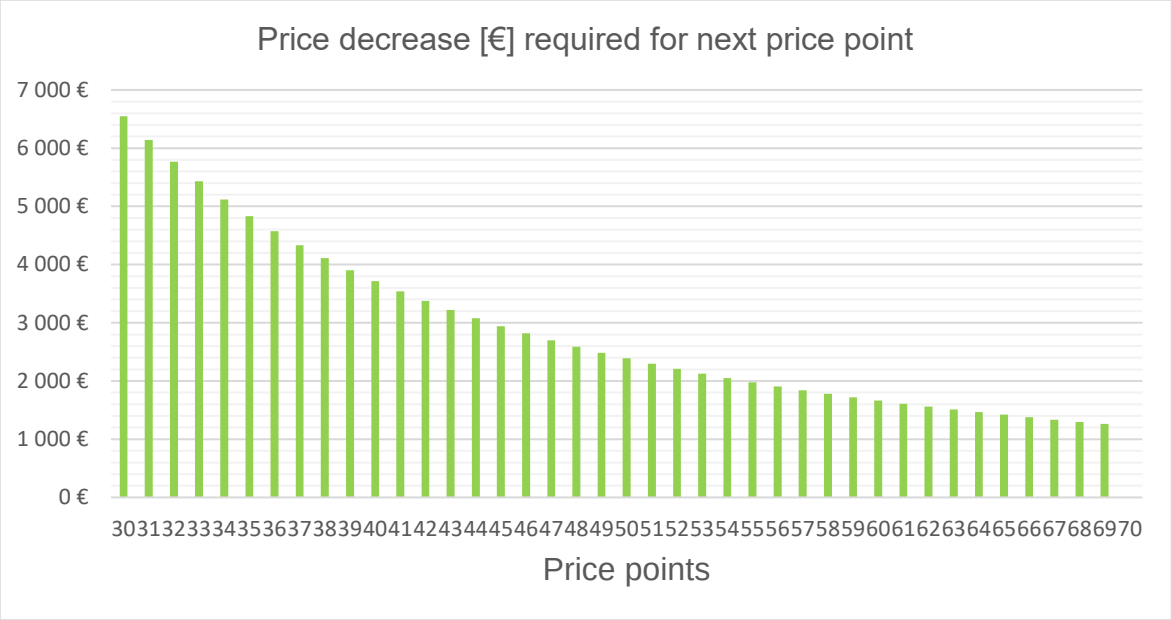


Figure 18. Difference compared to next price point

Derived from the figure 18, price drop needed to obtain next consecutive price point is nonlinear. For example, an increase from 69 price points to 70 price points equals to approx. 1 261 € reduction in bid price. However, an increase from 59 price points to 60 price points equals to approx. 1 721 € reduction in bid price. From the supplier's perspective, this messages that price points at the higher end of the scale to be achievable through smaller revenue sacrifices. From buyer's perspective, price decrease has a diminishing value (as in cost savings) as the bid price gets lower with the requirement of price reduction for awarding the next price point. On the other hand, price a subcontractor obtains price points through smaller revenue sacrifices, this can be an incentive itself encouraging price drops to obtain the next point. As a consequence of endogenous price scoring, one price point is valued for at least 1 261. Trade-offs of two different price settings are shown in table 9.

Table 9. Trade-offs in price

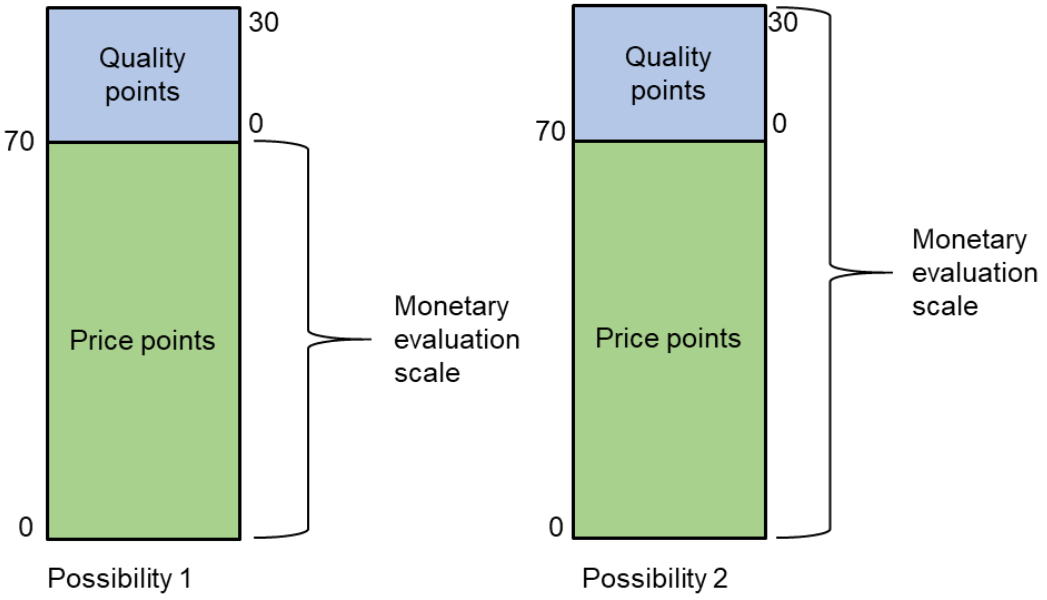
Price point increase	Buyer	Supplier
Price point 69 → 70	+ 1 261 (Savings)	- 1 261 (Loss of revenue) +1 Bid evaluation point
Price point 59 → 60	+ 1 721 (Savings)	- 1 721 (Loss of revenue) +1 Bid evaluation point

Quality point distribution is shown in table 10. Supplier A scored highest overall quality points with highest scores in quality plan and in ideas and innovations for improvements. Suppliers C and D were almost equally scored while supplier B received lowest overall quality score. The difference between highest and lowest overall quality points is over 10 points, which is quite considerable.

Table 10. Summary of quality point distribution

Quality point summary	Supplier A	Supplier B	Supplier C	Supplier D
Quality plan total score	14,0	7,3	10,6	9,5
Ideas for improvements, total score	6,0	3,5	4,0	5,0
Customer satistfaction total score	8,9	7,4	8,5	9,3
Overall quality points	**28,9**	**18,2**	**23,2**	**23,8**
Ranking in quality	1	4	3	2

For quality scoring, similar analysis as in case of price is infeasible, as scores are determined through subjective evaluation. What is possible however, is to put the impact of quality points into perspective. For example, by submitting four well thought and feasible suggestions for improvements grants a supplier with 6 quality points. In order to obtain 6 points in price, from supplier's perspective, minimum loss of revenue would be a price score increase from 64 to 70 points. To put this into monetary value, it equals 8 159 €. This is almost 10% compared to the lowest bid, a considerable price reduction if it were to realize. However, the trade-off for quality points is not so straight forward as in the case of price since quality points are calculated "on top of" price points, meaning that the scale of 70 points is technically insufficient. Arguably in this case it is a matter of perspective how quality points are evaluated in monetary terms: *i.e.* is a scale of maximum value of 70 used or is the scale increased to 100 meaning that monetary values are calculated for price scores over 70 points as if *price* scores over 70 would be obtainable. The two alternative possibilities are presented in figure 19 with calculation of theoretical maximum value for price point utilizing equation in appendix 4.



Possibility 1		
Pts.	Price equivalent to points	Difference to previous [€]
70	87 024 €	- €
69	88 285 €	1 261 €

Possibility 2		
Pts.	Price equivalent to points	Difference to previous [€]
100	60 917 €	- €
99	61 532 €	615 €

Figure 19. Alternative scales for evaluating quality points in monetary terms

Possibilities 1 and 2 are based on replacement ratios mentioned by Mateus *et. al.* (2010), but there exists also a third option to calculate how much quality is being paid for. This approach compares the price of winning bid to other bid(s) and if the price is higher than the alternative, excess price is interpreted as sacrifice to obtain improved quality for buyer's perspective. For example, let the price of the first bidder be 80 000€ and the price of second bidder be 70 000 €, but the first bidder has arguably better quality. If buyer chooses the first bidder, according to this logic, it pays a 10 000€ premium for better quality. Arguably this logic, or the one in possibility 1 is more into the right direction. Arguing for possibility 1, in real-life price points cap at 70 and "excess" price points are nonexistent. Thus, if a scale were used, possibility 1 should be the method of choice. Also arguing for the third option, when comparing how much more buyer is willing to pay for better quality since it is easy to comprehend. It may be argued that the third option is easier to comprehend in many ways and sufficient when scores are already determined and calculated.

This however should not exclude analysis of how buyer rewards or penalizes different quality levels.

For the three different sections of quality points, quality plan, customer satisfaction score of reference projects and ideas for improving existing plans, minimum monetary values (as in replacement ratios) are shown in table 11 utilizing a maximum of 70-point scale for calculating trade-offs between quality and price points. Trade-offs are calculated by comparing how much maximum quality points are in monetary terms (value of price points on a price point scale). The logic from the buyer's perspective is that buyer is willing to give up an amount of price points in order to achieve given amount of quality points *i.e.* willing to pay more for better quality, rewarding good quality. Theoretically from buyer's perspective a bid with 60 price points and 10 quality points is equally as attractive as 70 price points and 0 quality points. Thus, a negative monetary value is applied for the buyer when calculating value of quality points. However, this logic of quality trade-off presented completely ignores the value gained from increased quality (sufficient quality plans, reputable subcontractor and feasible improvement plans), as these are extremely hard to valuate. For measuring the exact impact of improved quality on monetary terms, no sufficient statistic exists. From a perspective of supplier, trade-off is deemed positive, as by obtaining quality points, a supplier can compensate higher price and thus, a certain loss in price points (translated also to a loss in revenue). In other words technically superior quality points allow supplier to submit a higher price. However, as supplier does not know other bid prices, it is unable to calculate exact trade-offs for price and quality scores although some estimation is possible if the supplier somehow has a sufficient information of its competitors' approximate price levels.

Table 11. Trade-offs for quality score

	Max. points	Reference point	Trade-off (Buyer)	Trade-off (Supplier)
Quality plan	14	56 → 70	- 21 756€	+ 21 756€ + 14 Bid evaluation points
Customer satisfaction score of reference projects	10	60 → 70	- 14 504€	+ 14 504€ + 10 Bid evaluation points
Ideas and innovations	6	64 → 70	- 8 159€	+ 8 159€ + 6 Bid evaluation points

This trade-off is calculated based on the lowest bid trade-offs, as it would also be possible to determine individual trade-offs for each participant based on their bid prices. This might better consider the cost structures of each subcontractor. A logic of this is shown in table 12, where total score is kept the same, but price points are decreased as quality points are being increased. This calculation is based on tender of the lowest bidder. As the lowest bidder scored 93.2, scores lower than that were excluded from the table.

Table 12. Price-to-quality trade-offs for lowest bidder

Price points	Price equivalent to points	Difference to previous [€]	Quality points	Total bid score
70	87 024 €	- €	23,2	93,2
69	88 285 €	1 261 €	24,2	93,2
68	89 584 €	1 298 €	25,2	93,2
67	90 921 €	1 337 €	26,2	93,2
66	92 298 €	1 378 €	27,2	93,2
65	93 718 €	1 420 €	28,2	93,2
64	95 183 €	1 464 €	29,2	93,2

Final tender points are presented in table 13. In general, there was a high variation between bid prices which translates directly to high variation in price points. The difference between lowest and highest bid, in terms of bid price, was almost 50% of

lowest bid value. In case of price points, the lowest points were received by supplier B with also the lowest quality points. When comparing quality points, there is a remarkable variation between different suppliers. Closer examination revealed qualitative differences between quality documents provided. As for example, supplier A submitted documents specifically created for this tendering, using announced criteria as a template. Therefore information was easy to find and to distract from the supplier provided document, and directly answered questions buyer had regarding the quality plan. Supplier B on the other hand submitted a default quality document as a quality plan, which vaguely addressed the questions asked in quality plan.

Table 13. Overall tender evaluation scores and supplier ranking

Summary	Supplier A	Supplier B	Supplier C	Supplier D
Total quality points	28,90	18,16	23,16	23,82
Total Price points	62,52	46,31	70,00	50,97
Total Points	**91,41**	**64,47**	**93,16**	**74,79**
Difference to #1	1,74	28,69	0,00	18,37
Ranking	**2**	**4**	**1**	**3**

3.5 BSC based supplier selection tool

Company subsidiary has developed a multi-criteria selection method, part of the procurement process of the subsidiary, called a balanced scorecard method (later referred only as BSC method). Information of this method was collected through an expert interview with a company procurement expert specialized in procurement of subcontracts, services and high cost assets. The person has been involved in multiple projects using BSC based supplier evaluation and selection tool, including currently on-going multimillion large-scale alliance project.

The output of BSC method is a recommendation which supplier would be economically most advantageous based on overall score. The procurement process of the subsidiary is Chartered Institute of Procurement & Supply (CIPS) approved,

which is the largest professional body representing procurement and supply globally (CIPS 2017). Process description of tendering with BSC is presented in figure 20.

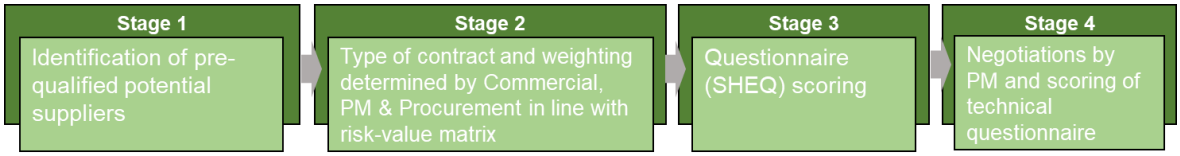


Figure 20. Tendering process with BSC method

At the request for quotation stage, questionnaires are sent out and required to be submitted as a part of compliant tender. Experts, usually part of the project organization, are responsible for scoring subcontractor's answers *e.g.* an expert in health and safety is responsible for evaluating and scoring health and safety section of tendering. By doing so, less subjectivity is included in scoring, validity of questionnaire is improved and project team has a stronger involvement in procurement process. According to the interviewee, different experts would like to have a say on how different suppliers are selected based on the criteria, and this is a method for getting those people involved and to get their expertise and input on the matter. The process of involving professionals and project management in weight distribution and evaluating criteria is likely to increase the successful implementation of BSC as the project's default supplier selection method.

BSC supplier selection method can be used with any size of purchase at any point, but according to company subsidiary's procurement policy it has to be used with purchases exceeding a threshold monetary value. In addition, if the subcontract or procurement package appears on a critical path of a project, use of BSC becomes compulsory. BSC tool measures safety and health, environmental and quality (SHEQ), customer experience, skills, delivery and previous performance in addition to commercial attributes. Commercial attributes include financial risk information of credit rating, payment history (possible disruption in payments) and final tender price. Additionally, previous and on-going law suits are checked. Only price is scored endogenously while other attributes are evaluated by using a scoring scale

from zero to five (table 14). An exemplary questionnaire of quality is given in appendix 6.

Table 14. Scoring range of BSC method

Evaluation Score Key	
0	No information provided
1	Minimum information supplied
2	Information supplied within minimal detail included
3	Good information supplied but with gaps in the detail
4	Good information supplied
5	Full and complete response

For weighting, no mathematical methodology is being used. Instead, weighting is determined by project management together with procurement. Weighting is also in line with risk-value weighting matrix (appendix 7). At the end of tendering phase, most prominent subcontractors are negotiated with and a technical questionnaire is scored during or immediately after the negotiation. In the technical questionnaire, themes of construction method, safety challenges and mitigation, risk mitigation including price risk and quality are evaluated through multiple questions. By so, each BSC is modified to fit he project needs and takes project specific issues into account. This way a BSC provides a broad universal tool with adjustable weighting. What differs compared to Finnish setting or to HVAC procurement presented, is that the

At the start of a project, a procurement kickoff meeting with project manager, estimators and designers is organized. During this meeting, different procurement packages are highlighted including information of what is to be procured as a package, which subcontractors are asked to participate in tendering as well as deciding weighting of BSC. Base on this, a procurement plan is conducted. Project teams assign weights for each theme of SHEQ so that the theme deemed most important receives highest weighting. An exemplary weight distribution is presented in table 15.

Table 15. Exemplary weight distribution among BSC scoring criteria

Area	Weighting in Section	Overall Weighting
Commercial		**60 %**
Graydon Rating (Letter)	5 %	3,0%
Graydon Risk Indicator	5 %	3,0%
Graydon Risk Rating	5 %	3,0%
Graydon Maximum Credit	5 %	3,0%
Commercial Total	80 %	48,0%
SHEQ		**40 %**
Health and Safety Total Score	15,0 %	6,0%
Environmental Total Score	5,0 %	2,0%
Quality Total Score	7,5 %	3,0%
Customer Total Score	7,5 %	3,0%
Skills Accord	7,5 %	3,0%
Delivery Total Score	40,0 %	16,0%
Previous Perfromance	17,5 %	7,0%

Different projects have different weightings on different criteria and project specific risks, client requirements and success factors influence the weighting. For example, there had been an instance in which a high risk and high value part of the project was subcontracted. In this case, SHEQ criteria had a much greater weighting compared to financial criteria or final tender price, and the company ended up choosing a subcontractor with a considerably higher price than the lowest submitted. The project performed under budget with no issues regarding safety and health, environment or quality reported.

On rare occasions, there has been disagreements with the recommended supplier or subcontractor, and sometimes project manager has not been able to approve with the recommendation proposed. However, according to the interviewee there is an encouraging atmosphere to select the right subcontractor for the job instead of choosing the cheapest one since the costs created by poor subcontractor selection easily surpass the possible excess price paid for right subcontractor.

Multi-selection methods are also a standard practice and widely accepted in the country subsidiary operates in. According to the interviewee, both project management and suppliers actually prefer the tool, and it has a lot of backing by the line organization. In addition, other construction companies reportedly use similar

supplier evaluation and selection methods, implying that the supplier base is familiar with buyers using other attributes than price in evaluation. Suppliers prefer this kind of tool since, according to interviewee, the supply chain is worried that the company focuses on only price in its supplier selection. According to the interviewee, by this method the company ensures that not only price is looked, but instead the overall economic value of tender examined.

Another reason for the wide acceptance and use of BSC in supplier selection might be that the tool lets other than procurement experts as well as project management to participate in supplier selection, thus increasing the involvement and hindering the possibly occurring resistance. Involving project management in weight determination gives the project manager a buy-in for the method, also involving the person to procurement at an early stage. According to the interviewee, there has also been a reduction in disappointments in work carried whenever people have been involved in using the tool. The interviewee stated that procurement team needed to do a little marketing to get the BSC model applied in one of the large projects. In the beginning the project organization was said to think of doing a “tick-box” exercise, but after couple of years of active use of the tool they now know the importance of the approach.

According to the interviewee, the biggest weaknesses of BSC model are situations in which suppliers or subcontractors submit a non-consistent and insufficient bid lacking some attributes under tendering. This can be due to miscommunication or misunderstanding what the buyer is procuring and what are the specs. To avoid these scenarios, during negotiations with a potential subcontractor, buyer ensures that everything under project or tender scope is included in the bid. Reportedly, another weakness is that the model requires quite extensive data as well as planning. In the subsidiary, BSC model is used from the very beginning of procurement process starting from project risk-value assessment. By doing so, the approach is applied throughout the procurement process instead of only final phases of tendering.

Involving project organization and SHEQ professionals in supplier selection and evaluation is much easier when the project organizations mechanically includes teams responsible for managing and monitoring health and safety, environmental or quality issues; or when the line organization has sufficient resources to assist project organizations. According to the interviewee, the current project where the person is employed, has 8 to 10 health and safety people alone. In the Finnish project environment, project organizations are considerably smaller and rarely include their own environmental or quality teams. In exception are the largest projects executed, where these types of organizations are possible but the number of professionals is still considerably lower than compared to what is considered a large scale project organization for the subsidiary. In the Finnish setting, support provided to project organizations comes from the line organization, or in case of bigger projects some experts might be physically present in the project premise.

3.6 A proposed method for HVAC procurement

Based on the theoretical framework in chapter 2, a method is now proposed for HVAC procurement synthetizing both academic theory as well as practical implications described in earlier chapters. For the method, a same template as in chapter 2 is used, but this time it is adjusted by real-life context of HVAC procurement. The suggestions are summarized in figure 21, while each of the components are further deconstructed.

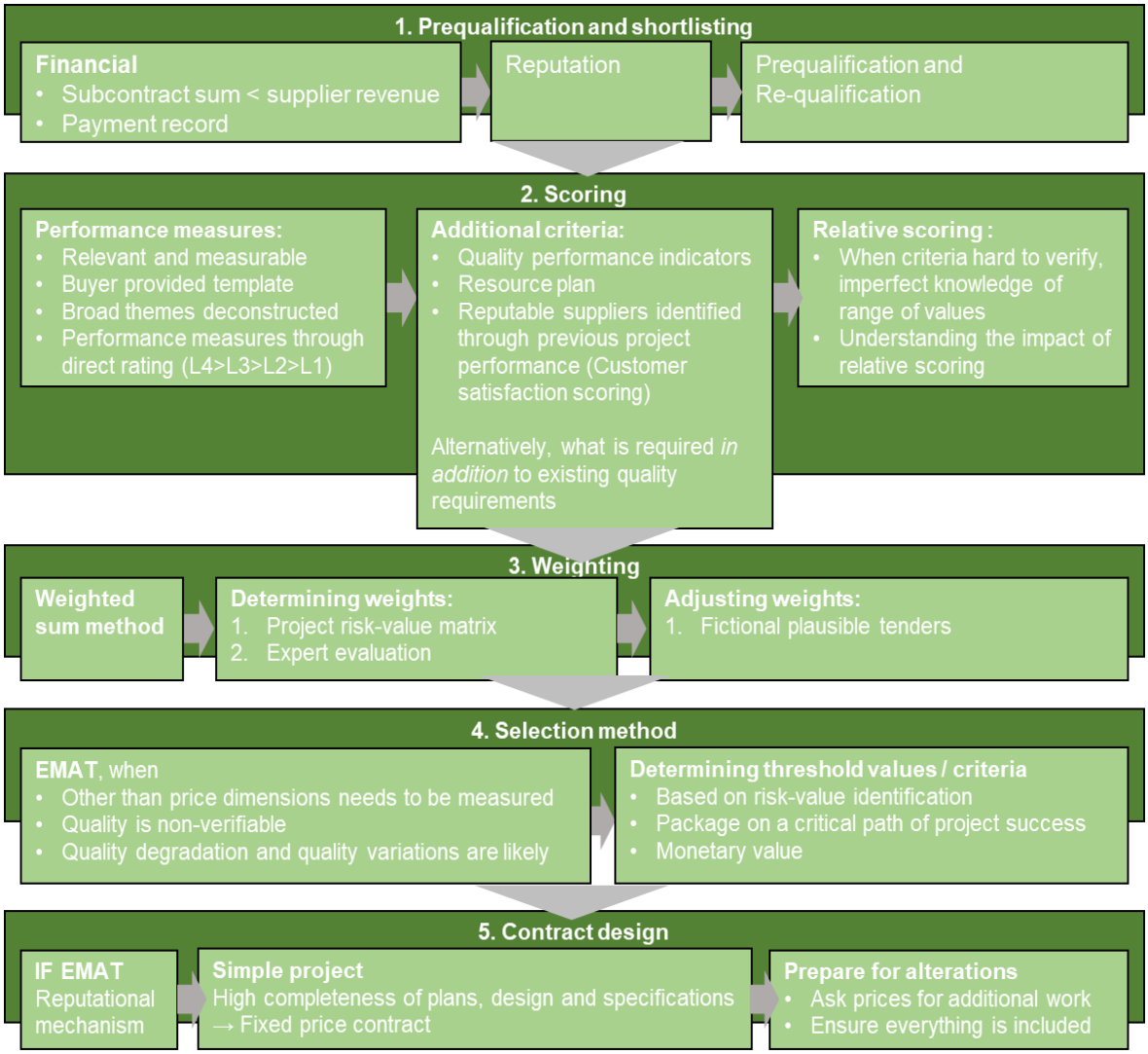


Figure 21. Proposed complete method for HVAC procurement

Prequalification and shortlisting

First, in the prequalification and shortlisting phase, project organization identified possible subcontractors to participate in tendering. In the Finnish HVAC markets, the number of medium or large suppliers is relatively limited and the players are well-known, making supplier screening relatively fast. However, a limiting factor was the size of the contract, excluding some of the smaller subcontractors outside of the tendering. No other prerequisite criteria such as existing quality management systems (proposed by Holt *et al.* 1995 and Waara & Bröchner 2006), or any other was used to limit the number of participants to ensure sufficient number of tenders. Arguably, use of other prerequisite would not have brought any additional value to

shortlisting. In addition, subcontractors without buyer's approved supplier prequalification were asked to participate in tendering. The approach of limiting the number of participants to include only "reputable" suppliers is misleading, since in this phase little information is available regarding subcontractors' previous performance.

The shortlisting relied heavily on project team's experience and no extensive criteria were applied during this phase. One advisable shortlisting criteria is the use of financial data, but this was not mentioned during the interviews, although key numbers are available directly from the system. The problem with these financial figures (*e.g.* quick ratio or credit rating) is that they are based on *previous* annual report, and as some of the tenderings are executed during the beginning of a year, the information in the system might be in worst case more than a year old, hindering the validity of figures available. However, the information of payment defaults provides more reliable up-to-date information and is a feasible criterion to apply. Indirectly this was included as an underlying assumption to be checked, as the company policy prohibits ordering from suppliers with a certain credit rating, caused by payment defaults.

As the client had a possibility of rejecting a proposed supplier based on likelihood of contract breach, it is suggested that only reputable suppliers were to be used in such a case. However, the identification of a reputable supplier is not an easy task, when much of the experience and information regarding suppliers, at least in the selected case tendering, is left with previous project organizations This is shown though the lack of collected supplier feedback. Reportedly, project organization used its own best knowledge to determine reputable suppliers to participate in tendering instead of using any formal system or procedure.

There seems to be a limited number of tools to improve shortlisting phase in this case. The approach of relying on team's experience seems to be valid considering also time restrictions, meaning that shortlisting phase should be as light as possible to allow a fast move towards the next phase. However, when the requests for quotations are sent, it would be advisable to involve suppliers with company

prequalification, as a risk measure to ensure that the subcontractors approve e.g. buyer's safety and health regulations (figure 22).

Figure 22. Proposed HVAC procurement method, phase 1

Scoring

For scoring price, selected endogenous method might have been appropriate since the variation between prices and thus scores, was considerable. To place a threshold value for price by which a maximum price score would be determined, a detailed knowledge of price levels would have been required. Such a method also includes a risk of misplacing the threshold value of price and selecting the wrong subcontractor.

Regarding quality plan, no predefined performance levels were defined, and the score depended on the level of accuracy and extent of given description. There was a considerable variation of quality of contents between different quality plans, partly because suppliers were granted the freedom of using their own forms and templates when submitting quality plans. Some suppliers failed to answer the stipulated information and submitted documents twice as long than what was required. This made comparison of different quality plan timely, providing one explanation of why the variation of scores was so wide. The subjectivity on evaluation is not highlighted here, but instead is the variety of received documents. In addition, suppliers might not have understood the full impact of quality scores (impact is also affected by weighting), implying that some subcontractors have little experience of defining quality management activities or are unfamiliar with quality management thinking. Another explanation is the fact that the market is currently deemed to be on the high end of economic cycle (Valtiovarainministeriö 2018) and many subcontractors already have their order-log filled for the immediate future, thus hindering the interest of taking additional work with thinly spread resources. Some of the largest

subcontractors withdrew from tendering since they did not have sufficient resources and thus, the sample of quality plans is not complete as it consists only those willing to tender, not every supplier considered potential.

The inability to provide requested information hints of unfamiliarity, due to which a more descriptive approach from the buyer's side is suggested. To tackle the variety of document quality, a buyer conducted template for quality plan is suggested. By this, the variations would be caused by different levels of quality management activities, not by answering technique. The problem with used quality plan was stated to be that it should have been more about what will be required *in addition to* existing requirements; a different perspective compared to the used one in which more or less already stipulated quality levels are ensured.

Another emerged problem was that the questions were broad in nature, leaving buyer's exact requirements sometimes vaguely expressed. It was discussed during the interviews that a predefined performance levels for attaining each score might be more feasible in future. This approach is heavier for buyer and requires redefinition of some or all of the criteria, but arguably wields better result and increases comparability of different bids as less room for variation is left. By defining more precise performance levels and reassessing evaluation criteria it is also possible to participate project team to subcontractor selection process, similar to company subsidiary.

During the interviews, subcontractor's ability to adapt to changes was highlighted and also a criterion under evaluation in quality plan. One aspect of adaptability is securing sufficient resources for the project and adjusting the in accordance with changing requirements. As for the buyer, it is difficult to say what is a sufficient management resource required on site beforehand. One possibility, which emerged during an interview, but not currently used by the company, was the requirement of a resource plan from a subcontractor. In this, a clear description of different resource requirements and types of resources would be given, and the document would then be attached to final contract. If such a document were required, it could be assigned with a heavier weight to quality plan questionnaire either by extending the evaluation

scale to reach numbers greater than current maximum of 3, or the quality plan itself could be assigned a greater weight through increasing the maximum score achievable from it. A possibility is also to score resource plan separately.

Customer satisfaction score was deemed successful as the projects subcontractors used fulfilled the requirements, the procedure was deemed helpful and it received a positive feedback even outside of the company. Thus, it provided an effective way of evaluating subcontractor's previous performance as well as experience on similar projects, complementing the shortcomings of buyer's internal feedback process. Ideas and suggestions for improvements were also deemed somewhat useful, although many of the ideas were already identified by the buyer. The fact that one supplier submitted three suggestions instead of four hints that the impact of scoring was not fully understood. Another notable aspect of giving out tender points based on improving existing plans, is the possibility of it reducing the likelihood of subcontractor obtaining additional income from haggling over prices when original plans need adjustments, but the main contractor has failed to notice this and becomes a victim of the subcontractor's maleficent practice (Tadelis 2012).

As the evaluation criteria were created specifically for the project, it would have been appropriate to include more detailed scoring for health and safety, as the client had put a bonus system in place if required safety levels are achieved throughout the project. For determining health and safety evaluation criteria, an expert possibly part of the project organization could have been used, similar to procedure used by company subsidiary. However, an approach including more than price and quality themes, appears as a step away from bespoke approach such as the one designed for the project. Involvement of multiple themes, such as in the method of the subsidiary, seems to be more likely to work when experts are involved in defining and scoring of the selected criteria. Thus, it seems to be more of a step towards renewing the company procurement policy, as it is likely to require the support of the line organization to be fully implemented. This option is further discussed in next chapter of weighting, while the proposed method for scoring is presented in figure 23.

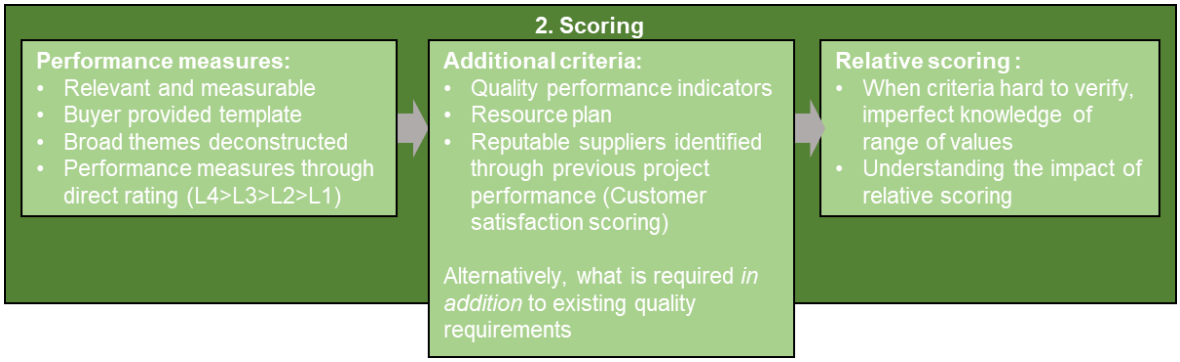


Figure 23. Proposed HVAC procurement method, phase 2

Weighting

For weighting the different selection criteria, a weighted sum method was selected for the project. The client had a strong influence on weight distribution, stipulating that important and critical HVAC procurements must use a 30% quality weight and 70% price weight. Thus, buyer had limited influence on the stipulated weights. During the interviews it was also appealing that buyer was unwilling to make adjustments or argue against the stipulated weight distribution. As the procurement process went further, it was discussed that the 30% quality weight was actually quite heavy, and the expert estimation was closer to a 7- 10 % weight being assigned to quality.

As impacts of weights were not tested, buyer might not have had a complete understanding of how drastically quality weighting affected the outcome of tendering, or what were the replacement ratios for quality points. At this point it must be addressed that in the case of analyzed tendering, buyer was pleased with the results and experienced that involving quality as evaluation criteria increased the value of tendering, rewarding a subcontractor excelling both in terms of price and quality. However, in future it would be advisable to test the impact of weight distribution for example by using estimated price as lowest price and calculating trade-offs based on this price level. This would at least give a hint of whether the weight distribution express buyer's preferences or if it needs adjustments to be made.

Derived from the subsidiary's procurement method using risk-value matrix in guidance of weight distribution, a similar approach is worth considering in future projects. Project's risk assessment is out of the scope of this thesis but known is that for each project a risk evaluation is made, which might guide weight distribution. For weight distribution, academic research offers some mathematical methods, but also weight distribution based to expert evaluations (Alsugair 1999), both being a valid option when properly executed. Expert evaluation-based weight distribution method is in place in the company subsidiary, and once again the use of similar approach might increase the level of involvement of the project team in supplier selection, bringing their valuable insight to it. The suggested improvement uses risk-value matrix as a base of determining weights, which can then be adjusted to some extent by the project organization. Complete procedure for weighting is illustrated in figure 24.

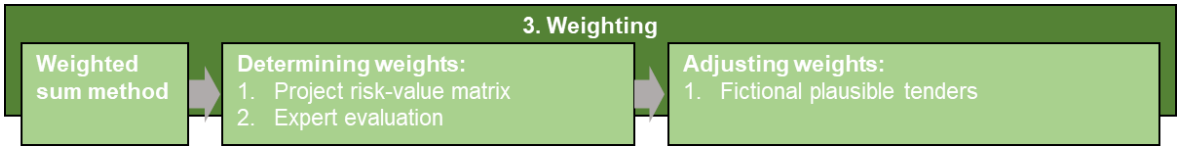


Figure 24. Proposed HVAC procurement method, phase 3

Selection method

The selection method chosen was similar to Economically Most Advantageous Tender (EMAT), in which price and quality were evaluated and scored. Regarding the selection method, no improvements are suggested, as including quality criteria in subcontractor selection provides assessment of contractor's abilities to deliver on other than price dimension (Watt et. al. 2009), meaning quality in this instance. Bergman and Lundberg (2013) stated that increase in cost and quality uncertainty is likely to shift supplier selection method towards a more complex scoring and use of EMAT as the selection method. As including multiple criteria in supplier selection is likely to increase transaction costs (Lundberg & Bergman 2017), a threshold values or criteria are suggested to be used when considering should more complex selection method be applied, similarly as in case of company subsidiary. Suggestion is presented in figure 25.

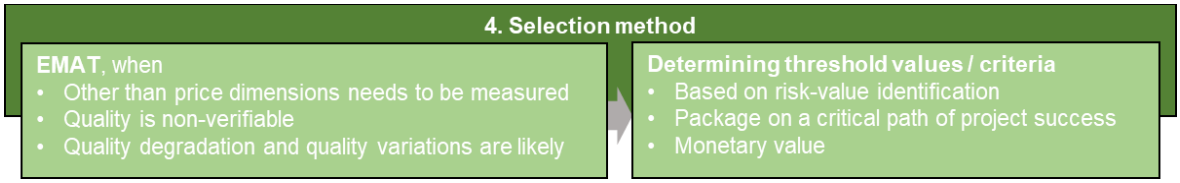


Figure 25. Proposed HVAC procurement method, phase 4

Contract design

Considering the contract design, according to interviews, the plans were complete, specifications were complete and overall the subcontract was not considered to be the most complex one. This promotes the use of fixed price contract (Tadelis 2012; Waara & Bröchner 2006), which was also the case. To tackle impacts of haggling (Tadelis 2012; Waara & Bröchner 2006) as well as inherent characteristics of construction industry, also prices for additional work were asked, although these did not affect the final subcontractor selection. In addition, reputational mechanism (Tadelis 2012) was used through measuring customer satisfaction of subcontractor's previous projects. Same procedure of negotiating with prominent subcontractors and ensuring that everything is included in the bid is also a common practice in the company, as compared to its subsidiary. Proposed contract design is presented in figure 26. However, as the tendering is still on progress and the contract design falls outside of the scope of the study, it will not be further discussed due to the fact that there is no reference of empirical data to analyze the final outcome of selected design.

Figure 26. Proposed HVAC procurement method, phase 5

4. CONCLUSIONS AND DISCUSSION

Previously contractor (Cheaitou *et. al.* 2018; Watt. *et. al.* 2009; Vassallo 2007; Jennings & Holt 1998; Holt *et. al.* 1995) and subcontractor (Harald 2013; Hartmann & Caerteling 2010; Hartmann *et. al.* 2009) selection decisions have reportedly been based on final tender price. Construction sector has been reported to struggle with delivered quality (Latham 1994). Combined with the fact that subcontractor's carry out a significant part of a construction project (Abbasianjahromi *et. al.* 2018), contributing up to 90% of construction project's value (Hinze & Tracey 1994), it is no surprise that the project success is affected by right contractor (as well as subcontractor) selection (Cheaitou *et. al.* 2018; Mbachu 2008). When making selection decision, identifying relevant evaluation criteria as well as assigning appropriate weight causes complications (Watt *et. al.* 2010). In addition, lack of adequate models giving practitioners useful tools in real life situations as well as difficulties with scoring rules has been reported (Bergman & Lundberg 2013; de Boer *et. al.* 2006). In addition, there has been little experience in implementing quality as a selection criterion in construction (Vassallo 2007). All this implies that there is still room for research in construction supplier selection practices applying multiple criteria in addition to price, and especially so from a main contractor – subcontractor perspective (Hartmann & Caerteling 2010). Problematics of quality-adjusted supplier selection method, or more so, the lack of adequate methods, was also identified by case company as it currently has no formal procedure for applying quality measurement in tender evaluation. For these reasons, the main research question was formulated as:

RQ: *How can quality be included in subcontractor selection in construction sector?*

First of all, buyer needs to understand that there are other relevant criteria in addition to final tender price. Many of the previous research assesses quality through listing multiple evaluation and selection criteria, from which quality is one (*e.g.* Abbasianjahromi *et. al.* 2018; Alzahrani & Emsley 2013; de Araujo *et. al.* 2017; Harald 2013; Hartmann & Caerteling 2010; Hartmann *et. al.* 2009; Proverbs *et. al.* 1997 and Waara & Bröchner 2006). Prior to determining evaluated and scored

quality criteria, buyer can assess supplier's capabilities through prequalification (Hatush & Skitmore 1997). One of the capabilities assessed can be quality either through prerequisite minimum criteria, or it can be scored during prequalification (Holt *et. al.* 1995 and Waara & Bröchner 2006). However, both Holt *et. al.* 1995 and Waara & Bröchner (2006) examine selection and prequalification from client – main contractor perspective, instead of main contractor – subcontractor. The empirical evidence does not support using formal quality management systems in shortlisting a set of subcontractors able to participate in tendering as it might unnecessarily limit the number of participants and may not be a valid measurement of quality. Thus, majority of quality measures is more likely to be implemented during the formulation of evaluation and selection criteria.

Empirical evidence shows that client organizations can have a strong influence in implementing quality criteria in main contractor's subcontractor selection by direct stipulation. Based on wide variety of received quality plans and their contents, some suppliers seem to be somewhat unfamiliar with applications of quality-adjusted subcontractor selection in the Finnish construction.

Market environment, such as the one of company subsidiary, can encourage use of multi-selection criteria. In the supplier markets where the subsidiary operates, multi-selection is widely used by main contractors, but also preferred and accepted by subcontractors as it considers more than only price aspects, rewarding companies excelling in other fields of operations, such as quality and safety. The analysis of BSC method proved that involving experts of different fields, such as safety and health or quality, to determine evaluation criteria and to score subcontractor's submitted documents is likely to hinder the resistance and improve adoption of multi-criteria selection method. The adaptability of the model to fit projects is important, as it allows reusability of the method. The linkage between risk-value assessment and selection criteria weighting is also appealing, with the involvement of project team in weight distribution. In addition to linking multi-criteria selection to company processes and involving experts and project teams in supplier selection, reportedly a strong support from line organization is required.

As in this thesis, scoring, weighting and selection methods were analyzed, they are deemed as extensions of the *decision* of applying quality in supplier selection, and thus a tool of implementation or practical implications of applying non-price criteria in supplier selection. This means that without the decision of applying quality in supplier selection, there exists no quality criteria to be scored nor quality to be weighted. Thus, the initial decision of involving quality as an evaluation and selection criteria is important. By this, it is clear that quality measurement must be applied from the very beginning of tendering, instead of applying it during the tendering. The sub-questions also bring light on the main research question of how to include quality in subcontractor selection, by assessing practices and steps of quality-adjusted tendering. The first sub-question was formulated as:

SQ1: *What are the practices of applying quality in subcontractor selection?*

The breakdown follows the logic of previously introduced tender evaluation methodology by Mateus *et. al.* (2010) (figure 3), complemented with prequalification and shortlisting, followed by evaluation criteria, performance measures, scoring rules and weight distribution. All these components are summarized in table 16, where quality-adjusted academic research is compared to empirical evidence received.

Table 16. Comparison quality-adjusted subcontractor selection practices

	Academic	**Empirical evidence**	
	Previous research	Case project	BSC
1. Shortlisting	● Prerequisite (Ng & Skitmore 2001) ● Prequalification and evaluation criteria in line (Ng & Skitmore 2001)	● Prequalification infeasible in evaluation ● Risk management procedure	● Prerequisite ● Part of tender compliance
1.1 Prequalification			
1.2 Shortlisting	● Minimum requirements (Mateus *et. al.* 2010) ● Rooting out suppliers with inferior quality (Yasamis *et. al.* 2002; Mbachu 2008) ● Quality management (Waara & Bröchner 2006; Holt *et. al.* 1995)	● Project team's implicit knowledge ● Payment defaults ● Contract sum ● Formal quality management system infeasible criterion	● Payment defaults ● Ongoing lawsuits
2. Evaluation criteria & Scoring	● Deconstruction of broad themes (Mateus *et. al.* 2010) ● Quality control activities, quality management activities, project management activities (Yasamis *et. al*. 2002)	● Price, quality, previous experience ● Improvements ● Project management activities ● Non-linear	● Price, SHEQ; ● No predefined measures ● Experts ● Project team
2.1 Selection criteria			
2.2 Scoring	● Absolute vs. relative scoring (Waara & Bröchner 2006) ● Quality-to-price or Price-to-quality (Bergman & Lundberg 2013) ● Performance measures (Mateus et. al. 2010)	● Relative scoring ● No predefined performance measures	● Relative in terms of price ● Experts for SHEQ
3. Weighting	● Relative importance (Mateus *et. al.* 2010) ● Experts (Alsugair 1999) ● AHP (Abbasianjahromi *et. al.* 2018) ● Weighted sum (Mateus *et. al.* 2010; Lorentziadis 2010); ● Plausible tenders (Mateus *et. al.* 2010)	● Price (1), Quality (2) ● Client stipulated weight distribution ● No full understanding of weight distribution impact ● Failed to express the relative importance	● Risk-value matrix ● Experts ● Weight distribution according to project characteristics
4. Selection method	● Bespoke (Holt 1998) ● EMAT (Lundberg & Bergman 2017) ● Transaction costs (Lundberg & Bergman 2017) ● Complexity & uncertainty (Bergman & Lundberg 2013)	● Bespoke approach ● EMAT	● BSC method (EMAT)

Prequalification and shortlisting

Supplier prequalification was suggested to be used for shortlisting and forming a set of suppliers participating in tendering (Ng & Skitmore 2001), implementing project specific requirements (Kumaraswamy 1996) or to include quality factors and rooting out suppliers with inferior quality (Yasamis *et. al.* 2002). From the original set of suppliers invited to participate in HVAC tendering, only half had approved prequalification status. In addition, the prequalification information was in many cases considered to be outdated (more than a year old) and provided little support both in terms of shortlisting suppliers, or as a solid selection criterion. The problem of outdated prequalification information was also reported by Jennings & Holt (1998) and Holt *et. al.* (1995). Requalification of contractors involved with critical parts of project, suggested by Jennings & Holt (1998), is appropriate when prequalification successfully measures criteria for which decision is based, *i.e.* criteria are aligned with evaluation and selection criteria (Ng & Skitmore 2001).

When prequalification measures are inappropriate for decision making (Holt *et. al.* 1995), prequalification loses its value, as is the case based on empirical evidence. Aurora's prequalification questionnaire does not include attributes directly applicable to supplier evaluation nor is it designed to act as such, instead it is used as a supply chain risk management tool providing basic information of given supplier. Closest criteria might be the possible use of different certified management systems (health and safety or quality), proposed by Waara & Bröchner (2006) and Holt *et. al.* (1995). However, statistics (appendix 2) prove that this would result in unnecessarily limiting the number of participants. Also, according to HVAC procurement manager, formally certified quality management systems are an invalid measurement for quality in subcontractor selection of HVAC systems. As Aurora does not yet have established multi-criteria selection method for subcontractor selection, the development of prequalification criteria to align them with selection criteria is yet too early, since before alignment the evaluation criteria must be determined. The idea is novel, but it needs to be balanced with the fact that prequalification does not include too many criteria, becoming too costly (Ng & Skitmore 2001).

In addition to prequalification, selected minimum requirements to participate in tendering can be used to shortlist suppliers (Mateus *et. al.* 2010), for which existing management systems *seem* feasible. The use of formal management systems as a prerequisite to participate in tendering (Waara & Bröchner 2006; Holt *et. al.* 1995) is suggested in studies written from the perspective of client – main contractor, not from a perspective of a main contractor selecting a subcontractor, and this might explain why these are somewhat inapplicable in this case. In addition, quality of HVAC subcontracts is somewhat measurable during or after the delivery (ex-post quality, Lundberg & Bergman 2013), meaning that prequalification has a limited applicability in terms of contributing to quality aspects. The used shortlisting criteria were project team's implicit knowledge of suppliers, contract sum, and payment defaults through automated supplier credit rating. In the company subsidiary, prequalification was applied as a part of tender compliance and in addition to disruptions in payment, ongoing or previous lawsuits were checked to ensure supply of purchased good or service.

Selection criteria and scoring

As Bergman & Lundberg (2013) described, the selected scoring method was price-to-quality. Bergman & Lundberg (2013) suggested using quality-to-price whenever possible, but in this case measured quality aspects were difficult to directly convert into monetary values, thus obstructing the possibility to use quality-to-price scoring. For example, it is difficult to say how much more value (in this sense monetary value) is created through increase in one point in any of the questions asked in quality plan, increase of one point in overall quality plan, better previous experience, better customer satisfaction or quality score overall. To illustrate the relation between price and quality, replacement ratios were calculated, from which it is clear that the ratios are non-linear. Whether the non-linearity presents buyer's preferences or not, stays unclear.

As stated, quality of HVAC procurement packages can be to some extent ensured in the contract as well as during the installation phase at latest, making quality verifiable (Vassallo 2007) with aspects of both *ex-ante* and *ex-post* quality (Bergman & Lundberg 2013). However, as stated by the procurement manager, sometimes

the quality is more on the shoulders of an individual on-site worker, leaving room for quality uncertainty described by Bergman & Lundberg (2013). As Lundberg & Bergman (2017) revealed, in an uncertain environment, more complex scoring rules become more likely. However, there exist no clear description *when* an environment becomes so uncertain that it requires complex scoring, or *what* counts as complex.

The notion of main contractors being unwilling to compromise on price, made by Hartmann & Caerteling (2010), holds true in the case tendering. According to Harald (2013), if quality degradation poses an economical threat, price premiums are possible, which proved also to be true as the buyer was willing to pay more to ensure better level of quality. For scoring price, case project chose relative scoring. Arguably, this seems appropriate, as tender prices varied significantly, suggesting that there existed uncertainty in range of values, pointing towards use of relative values (Waara & Bröchner 2006). Absolute values were only used with suggestions for improvement.

As clients certainly use quality criteria in selecting main contractors (see *e.g.* Albano *et. al.* 2017; Bergman & Lundberg 2013; Waara & Bröchner 2006; Yasamis *et. al.* 2002 and Holt *et. al.* 1995), it surprising that Aurora has not yet established quality aspects in tender evaluation and has a limited experience on applying quality attributes as evaluation criteria. In this sense, there is a gap of demanded quality between buyer and its subcontractors as clients demand quality from main contractor, but main contractor does not demand it as strongly from subcontractors. Based on the evidence collected, it is likely that the level of demanded quality diminishes as the level of observation moves from client to main contractor and further towards the end of upstream suppliers. This becomes even more troublesome, as the subcontractors are responsible of delivering majority of the project (Hinze & Tracey 1994).

Yasamis *et. al.* (2002) divided construction project performance indicators to quality control activities, quality management activities and project management activities (table 5). The evaluated quality criteria of HVAC procurement fit into the category of project management activities such as integration-, scope-, time-, cost- and risk

management, while leaving the other two categories of subcontractor's quality control activities and quality management activities largely unexamined. There was a large variation in document quality, suggested to be a cause of subcontractors being unfamiliar with quality criteria, but also of buyer giving too large freedom in terms of document form. In one instance a subcontractor submitted insufficient number of answers even if points were obtainable with relative ease. Mateus *et. al.* (2010) suggested deconstructing broad themes of quality or price into more comprehensible subsections. Such an approach would benefit both the buyer and subcontractor, as the buyer would need to define criteria in more detail, while for the subcontractor the criteria would appear as more precise. This was not done, and the determination of relative differences between the bids was transferred to markets (Mateus *et. al.* 2010). Transferring the responsibility of determining differences between evaluation criteria was one criticism towards relative scoring by Mateus *et. al.* (2010), but it seems that relative scoring is convenient for the buyer as it requires less effort when detailed performance measures are not needed for scoring.

Previous experience and past project performance were reported as evaluation criteria by *e.g.* Harald (2013); Jennings & Holt (1998); Singh & Tiong (2006), see table 2. Buyer's supplier feedback database failed to provide information of subcontractor's past performance, and instead the information was collected through a separate questionnaire. Buyer considered this to be a successful practice, as every subcontractor was able to provide scores from similar projects. For measuring previous performance in future, supplier feedback can be utilized through individual feedback question such as contract compliance, compliance with health and safety regulations, overall delivered quality, or by using the average value of the supplier feedback as a whole. In order for this to be successful, supplier feedback needs to have consistency.

Mateus *et. al.* (2010) suggest determining level of performance for each evaluation criteria, similar to absolute scoring (Waara & Bröchner 2006). However, the perspective of questions in quality plan was more of a descriptive one, instead of assessing what would be required in addition to existing standard quality

requirements. This was also noted by the buyer, as during an interview it was suggested that in the future the perspective should be revised. When revising measures, other than quality aspects can be included in the evaluation criteria, as in the case of BSC method used by buyer's subsidiary. They key to success seems to be the involvement of project team and different experts in procurement process through determining scores and evaluating submitted tenders. Through use of multi-selection criteria, evaluation criteria and weighting are possible to align with corporate goals, which was suggested by Griffith & Headley 1997 and Watt *et. al.* 2010.

Both client and buyer sought additional emphasis to be put on scheduling, joint-operations and removing obstacles, although these were not further elaborated. They were simply interpreted as client seeking smooth delivery of the project and partly included in the quality plan. From this, it was discussed that subcontractor's ability to manage resources might be one critical selection criterion and a separate resource plan might have complimented the already existing quality plan, putting more emphasis on smooth execution and delivery of the subcontract. In addition, existing bonus system of permitting any major accidents or fatalities, supports the use of health and safety as selection criteria. Health and safety question was merged into the quality plan, consisting of only one question. As reportedly subcontractors have failed due to lack of adequate safety consideration at work sites (Singh & Tiong 2006), the theme might have required scoring.

Reportedly, post contract haggling over prices has occurred in construction when fixed-price contracts have been used with insufficient level of plans and specifications (Tadelis 2012; Waara & Bröchner 2006). Partly as a solution to avoid this, letting subcontractors suggest improvements to existing plans is a feasible method. By giving out tender points, buyer diminishes the risk of subcontractor deliberately agreeing to the contract only to later haggle additional income caused by design and plan changes obvious for the subcontractor from the very beginning (Tadelis 2012). Through exploiting faulted plans, subcontractor exposes itself to lose the whole tendering if no suggestions are made.

Weighting

Considering all important HVAC procurements, client stipulated the weighting between quality and price factors to be 70% for price and 30% for quality. Client stipulation also solidified that no other factors in addition to price and quality were to be applied in evaluation and scoring of tenders, although client did not define precisely what quality should or should not include, thus leaving a certain degree of freedom. In the project, price was without a doubt considered to be the most important selection criterion followed by quality. This is in line with previous academic literature of main contractors selecting a subcontractor using price as the most influential selection criterion (Harald 2013; Hartmann & Caerteling 2010; Harald 2009; Hartmann *et. al.* 2009; Proverbs *et. al.* 1997). However, an incident of price being secondary and non-price criteria having a heavier weight was reported by the company subsidiary, proving that even for main contractor's situations where non-price criteria are deemed more important indeed exists.

According to Mateus *et. al.* (2010) weights should reflect their relative importance. In the case tendering, weighting function to some extent failed to reflect relative importance of selection criteria, as the client stipulated the weight distribution and in the end quality weighting was considered to be too heavy. However, this must not be misunderstood, as the buyer was pleased with quality aspects being included as evaluation criteria and reckoned quality to increase the value of tendering process. Surprisingly, this had relatively little effect on final subcontractor selection, as the buyer was able to select a proficient subcontractor excelling both in terms of price and quality. However, both the client stipulating the weighting distribution as well as the buyer might have not had a comprehensive understanding of the effects of weighting and replacement ratios presented previously. Even if weighting had represented the relative importance from *client's* perspective, it is naive to presume that the same distribution would apply to the buyer as well, and even more so to every HVAC procurement package. As Waara & Bröchner (2006) state, a typical weighting in public procurement has been a 70% price weight combined with non-price criteria, which was the case. Reportedly, buyer had no insight of how the stipulated weighting was formed nor what it was based on. All this implies that

neither the client nor the buyer had a full understanding of how applying weights affected the final selection or how relative importance should be determined.

Selection method

Bespoke approaches are occasionally used in supplier evaluation and selection (Holt 1998), and such an approach was designed for the case project. As the company did not have an existing multi-criteria selection method, the used bespoke approach was more of a pilot method for the company. Lundberg & Bergman (2017) argue for using more complex scoring rules and selection methods such as EMAT in complex environments, which is close to the used method in the project. However, there is a contradiction between Lundberg's and Bergman's (2017) proposition and empirical evidence: in the case project, the client stipulated quality to be involved in tendering with a certain weight, affecting directly the weighting and scoring, and as so, the method itself. Thus, the selected method was not completely formed to answer procurement environment, complexity of the procurement or the uncertainties involved. Even if the HVAC procurement packages were deemed not to be the most complex ones, with relative low levels of uncertainty associated to the purchase, scoring was more complicated compared to an alternative procurement decision made solely based on price.

The company subsidiary's approach is an application of EMAT, as it measures overall economic value in more than only price criteria (Lorentziadis 2010). Compared to the bespoke approach, the BSC method used is more sophisticated and an implemented part of subsidiary's procurement process with solid backing from the line organization. Considering future projects in Finland, there is no point of each project developing their own quality-adjusted supplier selection method, but instead the method used in the case project combined with the experience of the BSC method existing in the subsidiary, should be enough to provide tools for further development.

SQ2: *What are the steps of quality-adjusted subcontractor selection?*

Overall the construction of this research is based on logical process of tendering presented in figure 3. This was further enhanced with the framework presented first in figure 12 and even further in the empirical part (chapter 3.6, figure 21). The framework was based on previous academic research, with applications of real-life procurement. When choosing to use a quality-adjusted supplier selection, buyer needs to shortlist supplier (phase 1), determine evaluation and selection criteria (phase 2), apply weighting (phase 3) and select appropriate method (phase 4). Contract design (phase 5) is not directly associated with quality aspects, but instead with uncertainty and complexity (Lundberg & Bergman 2017; Bergman & Lundberg 2013) as well as completeness of plans and specifications (Tadelis 2012; Waara & Bröchner 2006), all of which influencing selected design. Unfortunately, the effects of tender design to delivered quality could not be examined as the data was yet unobtainable.

Even though this study did not comprehensively examine motives of main contractor's applying quality criteria in subcontractor selection, it is noteworthy to examine the perspective of using quality. Based on the empirical evidence collected, client organizations can indeed stipulate main contractor to use quality in its subcontractor selection. However, currently the practice implicates that main contractor uses quality criteria when *needed,* not consistently. As client organizations have been moving towards applying other than price criteria in main contractor selection (Watt *et. al.* 2010; Watt *et. al.* 2009; Singh & Tiong 2006; Waara & Bröchner 2006; Wong *et. al.*; 2000 Jennings & Holt 1998), a notion which also supported by empirical evidence (Tiehallinto 2003), the consistency might help main contractors in winning future contract and projects. The shift of perspective is also one of the steps proposed (figure 27).

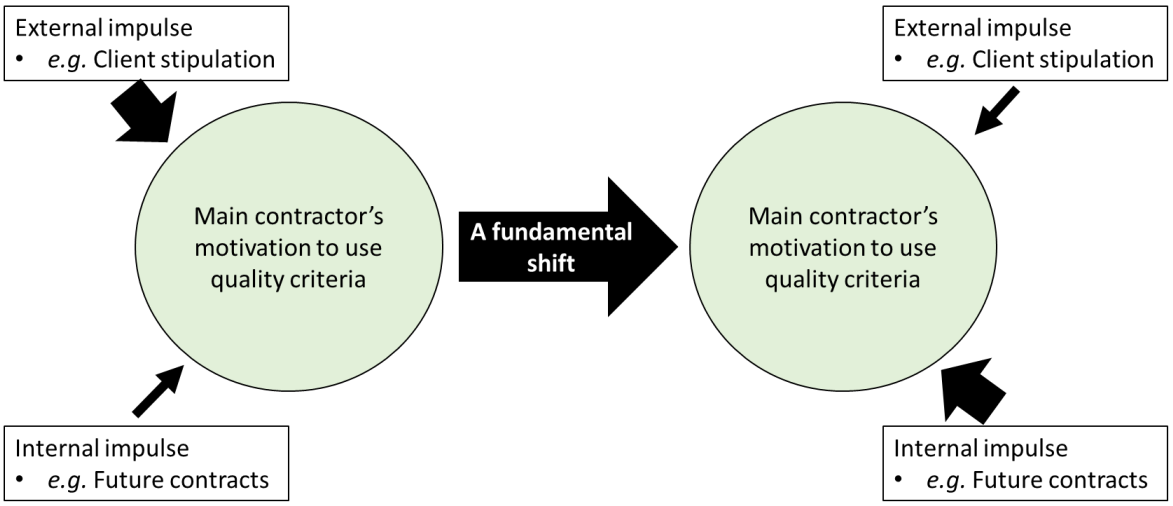


Figure 27. A shift from external impulse

4.1 Managerial implications

The results of this study have implications to those practitioners working with procurement in the construction, needing to apply non-price criteria in supplier selection. The study provides results especially for the buyer company as the data is collected from its project, subsidiary and internal processes. As this study is also an illustration of how quality is applied in subcontractor selection, to those who operate in a similar presumption of both buyer and supplier being unfamiliar with applying quality criteria, this study provides an insight of what can be done as well as how it can be done. An important notion for practitioners is that no method should unnecessarily be price nor quality dominant, the important aspect is to grasp the needs of the project and *adapt* to those either by reassessing the evaluation and selection criteria or by adjusting weighting. Involving other than procurement professionals in developing such a method, seemingly brings the most benefit through other experts having a say on criteria and project teams being able to adjust the weightings. Overall, quality-adjusted subcontractor evaluation and selection add complexity in procurement process, thus it is recommended to use in those subcontractors appearing in critical path of a project execution, possessing a high risk or high value to overall project success or exceeding a certain monetary threshold value. In addition, client organizations can evaluate main contractor's

ability to deliver quality, based on previous project success, thus making consistent quality level valuable in winning future contracts.

For future improvements, use of plausible fictional tenders to determine weights of selection criteria proposed by Mateus *et. al.* (2010) or utilizing project risk-value evaluations similar to the approach of the company subsidiary in its BSC method. Weight distribution within broad themes of for example price and SHEQ can be assigned through expert evaluation.

The writer's personal opinion is that applying non-price criteria to supplier and subcontractor selection is imminent in developing procurement practices in construction sector. The question is not whether this should be done, but instead *how* it should be done?

4.2 Reliability, validity and limitations of the research

According to Stuart et. al. (2002), the two primary concerns of case studies in general are construct validity and internal validity. Construct validity means that the measures used reflect the phenomena, while internal validity means that the relationships proposed in the study actually exist instead of being spurious (Stuart et. al. 2002). In addition, external validity is to be assessed, which means that the research succeeded to measure what was it was intended to (Metsämuuronen 2003, 86), and that the means of measures are valid despite the form of selected case study (Stuart et. al. 2002).

The choice of case study limits the generalizability of the research, however the objective from the very beginning was not to conduct with generalizable results but instead shed light on how quality-adjusted supplier selection is or can be done. The sample size of one case limits the study, as no reflection between two or more alternative cases can be done. As construction projects and their organizations are temporary constructs, it is immensely hard to obtain reliable data of quality-adjusted supplier selection attempts from companies. The obstacles of obtaining data are also limited by the companies' unwillingness to give out information regarding

ongoing or previous tenderings as they contain confidential information. In this regard, this study has been fortunate. The external validity is somewhat limited, but the measures are valid. In this sense the measures are previous literature, case project and BSC method, through which applications of quality-adjusted selection were assessed.

As the objective was to obtain deeper understanding of quality-adjusted selection, it was achieved through carefully analyzing tendering in case project, BSC method and reflecting findings to theoretical background. The objective was not to investigate universal nor optimal criteria in any way, but rather illustrate *how* quality criteria can be used. In a way, BSC method acted as a benchmark of a successful multi-selection method, which was reflected to the used bespoke approach of the project. However, this research lacks the subcontractor perspective, and their input on validating used quality measures, although the used criteria could be found from previous research. The sample size of subcontractors participating in tendering has an effect on the proposed conclusions, especially regarding the suppliers' familiarity with non-price criteria in supplier selection as the sample might not fully represent the suppliers. This is proposed due to the fact that some of the larger suppliers with implemented quality management systems declined to participate in tendering.

Regarding construct validity, examining project tendering and BSC method were considered appropriate ways of assessing quality-adjusted selection in a real-life procurement environment, done by practitioners. The used evaluation criteria were in line with the academic literature and similarities were found, suggesting that the selected criteria successfully measured quality. However, as the procurement method was bespoke, so were the evaluation criteria and project specificity affected the criteria selection. Thus, there can be no direct generalization of the criteria to other projects or procuring other types of subcontracts. Even so, the broad themes and logic are still arguably applicable. What stays unclear, is whether the used criteria and method was successful in selecting a subcontractor excelling both in terms of price and quality, as in the scope of this study it is not possible to examine delivered quality.

4.3 Suggestions for further research

As stated, the impact of quality-adjusted evaluation and selection method to the delivered quality was not measured because the subcontractor's actual work had not yet started. It is suggested for future research to examine the effect and results of quality-adjusted supplier selection to delivered quality. In addition to this, the type or form of contract agreed by client and main contractor is likely to have an effect on how main contractors select their subcontractors. Currently the different types of contracts and projects, such as alliances and life-cycle projects affect the main contractors through evaluation criteria used by client organizations. Client organizations tendering different types of projects and contracts are likely to use different evaluation criteria and weight evaluation criteria differently. It would be logical that these have an effect on main contractor's subcontractor selection. Thus, the impact of project contract and/or project type to both contractor and subcontractor selection is suggested to be studied.

This study approaches the conversion of quality to monetary values through replacement ratio, examining the trade-offs of price points to quality points. This however is only one possible ways of handling conversion, and for future researchers determining quality measures able to be converted directly to monetary values might prove valuable for practitioners, if such is possible. In addition, the impact of quality-adjusted supplier selection to main contractor's own quality delivery is a prominent aspect of further research.

4.4 Summary

In this study, quality-adjusted supplier selection is examined, concentrating on subcontractor selection in construction sector. The objective is to examine how quality can be included in supplier selection, examine some of the practices and necessary phases. This is done through analyzing previous academic research to build a proposed framework, analyzing tendering of one HVAC procurement package and multi-selection method used by case company subsidiary outside of Finnish construction markets. Based on these, a suggestion for improving used bespoke approach is made.

Overall, quality is usually implemented through selection criteria, although implementation in prequalification and shortlisting phase is also possible. Shortlisting using predetermined quality criteria is however contextual and depends on the dimensions of quality and whether it can or cannot be assessed prior to delivery of a subcontract. Use of quality criteria as an evaluation and selection criteria is interlinked with weighting of the criteria as well as with the selection method. Commonly, the most economically advantageous method (EMAT) is used, utilizing a weighted sum approach. Evidence from empirical data support the previously made observation in academic research that main contractors use price as the most influential selection criteria, as well as having limited experience of applying quality in supplier selection. Also, in practice the effects of scoring and weighting might not be fully understood, concerning both buyer and subcontractor.

The use of multi-selection method, which utilizes experts of selected themes under evaluation as well as project team in weight determining is emphasized over applying client stipulated weighting directly to every procurement package. Applying quality as a selection criterion is also emphasized due to the fact that there seems to be a gap in client required quality not transferring further to the supply chain, pass the main contractor. In other words, client uses quality to select main contractor to execute a project, but main contractors do not actively use quality in their subcontractor selection.

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APPENDICES

Appendix 1. Requirements in subcontracting: requirements given by client

Quality plans

Sub- and side contracts are required to provide quality plans and documentation (electronically) regarding their own work to main contractor (case company) and to client (authority ordering the project).

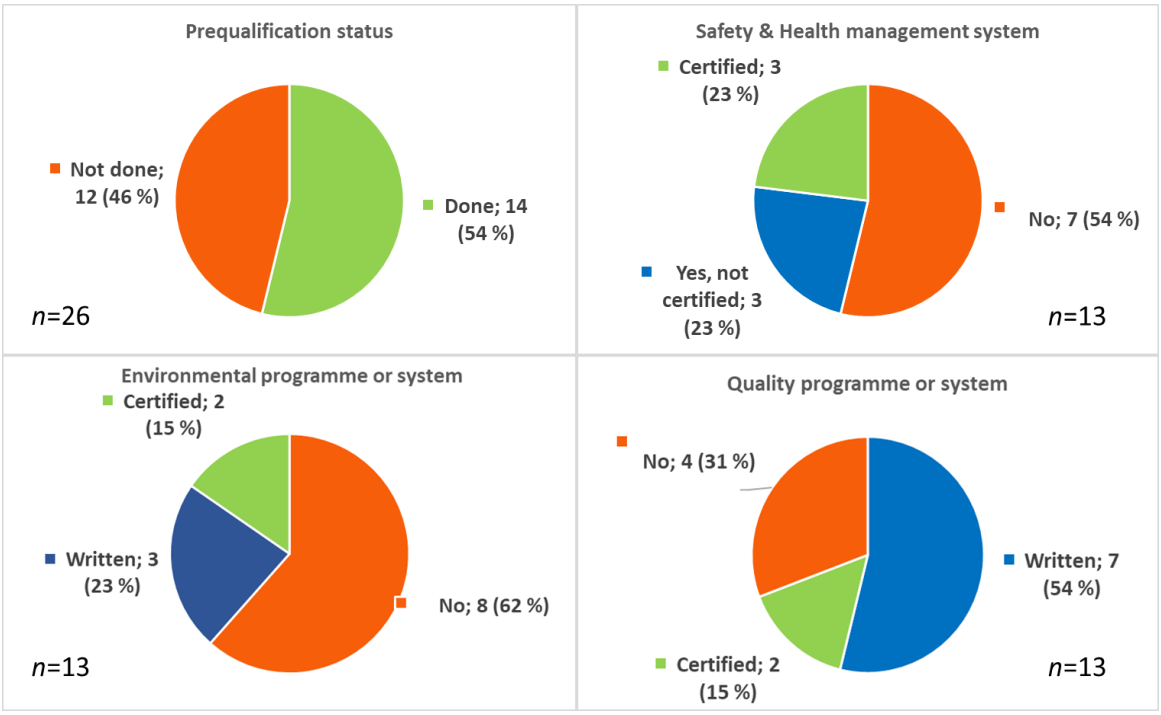
Quality plan is required to include at least the following:

- Security of information
- Description of project organization
- Responsibilities and mandates of quality management
- Process of quality control (throughout the project)
- Documentation
- Defect reporting and correcting measures
- Possible special requirements for certain tasks
- Self-inspection of work/contract
- Connection to construction site owner's quality systems, incl. internal audits
- Schema of quality plan for different work stages

Safety

Client has set a target of 0 casualties or fatalities in the project. This number also includes 3rd party casualties, which are caused by work site activities to persons outside of work site (e.g. traffic accident)

Appendix 2. Project's supplier prequalification status overview



Appendix 3. Project's quality plan

Quality plan	Supplier
How subcontractor ensures feasibility of plans before start of the contract?	
For which parts of the contract (referring to different phases of work) buyer defines a specific plan of work and installation instructions?) Proper and safe installation procedure)	
How the subcontractor guides its own as well as its (sub)subcontractor's employees to work tasks, ensuring implementation of subcontractor's plans?	
How subcontractor ensures joint-operations of its own work with other parties (building and subordinate side contracts)?	
How the subcontractor contributes to overall quality requirements of the complete project?	
How the subcontractor executes and documents inspection of its own work?	
How the subcontractor ensures that detected defects and faults are fixed and corrected?	
How the subcontractor, by its own actions, ensures successful operability testing between different contractors?	
How the subcontractor ensures that its employees are all working according to client's safety and health regulations?	
Total	
Quality plan final score [compared to others]	

Appendix 4. Price evaluation and scoring of received bids

$$\textbf{\textit{Price score}} = S(x) = \frac{P(min)}{P(x)} \times 70\ pts.$$

$$S(x) \leq 70\ pts.$$

$$P(x) \geq P(min)$$

Where

$P(min)$ = 87 024 €

$P(x)$ is the bid for which price score is being calculated

$$\textbf{\textit{Price score}} = S(x) = \frac{87\,024€}{P(x)} \times 70\ pts. \rightleftarrows S(x) = \frac{6\,091\,680}{P(x)}$$

Pts.	Price equivalent to points	Difference to previous [€]	Pts.	Price equivalent to points	Difference to previous [€]
70	87 024 €	- €	46	132 428 €	2 818 €
69	88 285 €	1 261 €	45	135 371 €	2 943 €
68	89 584 €	1 298 €	44	138 447 €	3 077 €
67	90 921 €	1 337 €	43	141 667 €	3 220 €
66	92 298 €	1 378 €	42	145 040 €	3 373 €
65	93 718 €	1 420 €	41	148 578 €	3 538 €
64	95 183 €	1 464 €	40	152 292 €	3 714 €
63	96 693 €	1 511 €	39	156 197 €	3 905 €
62	98 253 €	1 560 €	38	160 307 €	4 110 €
61	99 864 €	1 611 €	37	164 640 €	4 333 €
60	101 528 €	1 664 €	36	169 213 €	4 573 €
59	103 249 €	1 721 €	35	174 048 €	4 835 €
58	105 029 €	1 780 €	34	179 167 €	5 119 €
57	106 872 €	1 843 €	33	184 596 €	5 429 €
56	108 780 €	1 908 €	32	190 365 €	5 769 €
55	110 758 €	1 978 €	31	196 506 €	6 141 €
54	112 809 €	2 051 €	30	203 056 €	6 550 €
53	114 937 €	2 128 €			
52	117 148 €	2 210 €			
51	119 445 €	2 297 €			
50	121 834 €	2 389 €			
49	124 320 €	2 486 €			
48	126 910 €	2 590 €			
47	129 610 €	2 700 €			

Appendix 5. Interview form of BSC based supplier selection method by company subsidiary

1. For what type of subcontracting / material purchases BSC based supplier selection tool is designed? (Assumption is that for trivial procurement tasks rarely such a tool is used since it consumes resources) Is there a certain risk threshold for procurement; or money value; overall importance for the project?

2. Was the tool developed inside the company or in association with some client organization (or other party, *e.g.* consultant)?

3. Is the tool used by an individual or a group of people? How subjective the scoring is?

4. Is the tool intuitive / easy to use? (Received feedback)

5. Has it been used in multiple projects? Is the tool widely in use? If not, are there any plans in place to use it other projects?

6. How was the tool perceived when it was announced to be used in the project? (Resistance or other forms of implementation barriers)

7. Presumably lowest price is not always economically most advantageous tender since non-price criteria have a great impact on project success. Has this tool promoted the use of more "*able"* suppliers / subcontractors instead of focusing on price and face difficulties later? Has the tool proved to be valuable?

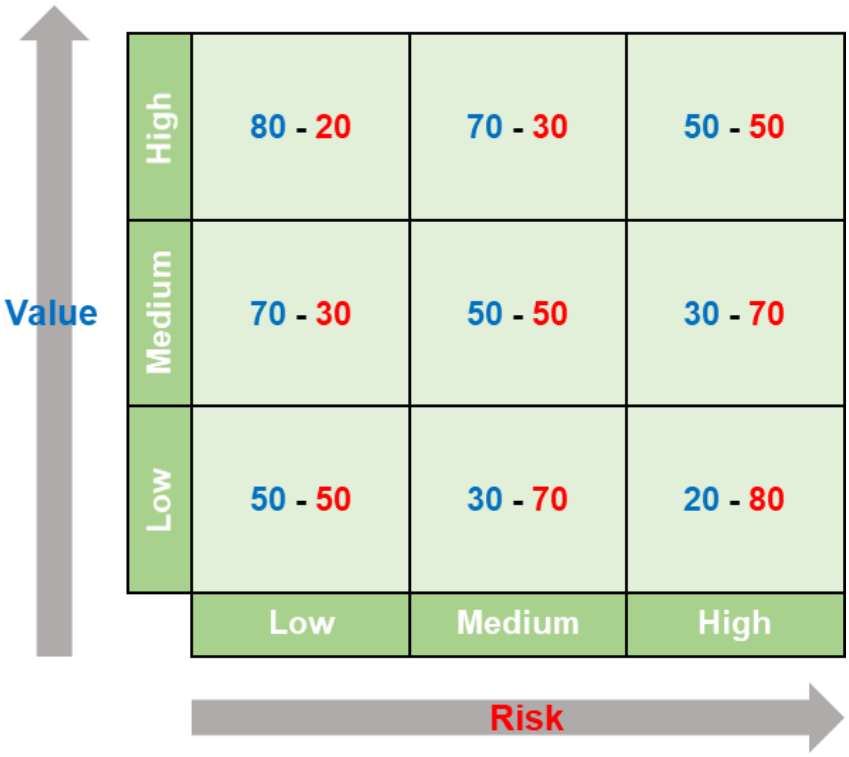
8. What is the strength of this model compared to previous way of supplier selection?

9. What is the weakness of this model?

10. Assumption is that previously final tender price was a major discriminating factor in supplier supplier/subcontractor selection. How drastically this tool affects supplier selection? Do the same suppliers / subcontractors excel in bidding as before?

11. Specifics: What is *'Delivery Total Score'*? Consists of three separate questions of clarification and compliant bid; Programme / resource management and optimization; Previous Experience --> Why is this so heavily weighted?

Appendix 6. Quality questions from BSC approach

Number	Question
	1. Managing Quality
1.1	Please provide a copy of ISO9001 Certification.
1.2	Please identify the Senior Management Team member responsible for quality systems and control.
1.3	Please provide a copy of your company Quality Policy.
1.4	Please provide Excellence for Quality Management (EfQM) Certification.
1.5	Please provide example of Commissioning Plan (Stored Energy, Mechanical, Electrical, Control / Instrumentation contractors only)
1.6	Please provide example of Quality Inspection / Test Plan (Civil, Structural, Mechanical contractors only)
1.7	Please provide example of Quality Audit Plan.
1.8	Quality Leading Indicators, please provide evidence/examples (preventative: Pre-planned inspections, Tests, Tender Queries).
1.9	Quality Lagging Indicators, Please provide evidence/examples (monitoring activity: audits, event reporting).
	2. Training
2.1	Please provide a quality focused Training Plan.
	Total Scores
1	Managing Quality
2	Training

Appendix 7. Risk-value weighting matrix of BSC