CHALMERS
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Quality management of critical activities with a large number of subcontractors

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

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ABSTRACT

The purpose of this thesis is to investigate the application of quality management in infrastructure projects, as well as the challenges, when a large number of subcontractors are involved. The challenges with quality management in infrastructure projects originate from a wide spectrum of factors such as the main contractors' lack of expertise in all the outsourced activities and a greater responsibility for the main contractor.

In order to achieve the purpose and objective of the thesis, the following research questions were formulated:

- Which processes and methods are available to assure and control the quality of critical activities executed by subcontractors?

- What are the challenges with quality management of subcontractors?

The empirical research also generated plans and suggestions for improvements in the studied contractor's quality management system, specifically when applying the system to activities and processes executed by subcontractors. Although two interviews were conducted with two different subcontractor representatives, the vast majority of the interviews were conducted with representatives from the studied main contractor. Therefore, the resulting suggestions and ideas are primarily related to the studied contractor, as their specific processes and procedures have been studied.

The studied contractor is a construction and development company and the activities studied are in the civil engineering projects under their responsibility. The critical activities performed by the subcontractors are in the technical areas of concrete structures, steel constructions, installations and railway works. The empirical background concentrates on the contractor's quality management system, processes and operations regarding subcontractors in two bridge projects.

The methods for quality assurance and quality control in both projects have been studied. The problems that emerged and their causes have also been studied and collected. The methods have been compared to distinguish the differences between quality assurance and quality control in the two projects. Interviews have been conducted with the contractor's projects actors in the two projects as well as two representatives from two different subcontractors. These interviews have included both unstructured and semi-structured interviews with the aim of extracting the full experience from the respondents.

The results show that the studied contractor handles quality management of concrete works and steel works rather well: there were/are clear methods for quality assurance and quality control in both projects. This could largely be attributed to the fact that the

contractor possesses expertise in these activities. The railway works had only been completed on one of the projects, and the contractor faced considerable problems in this field. The problems stemmed from the contractor's lack of knowledge and experience; the procurement route; insufficient communication between contractor and subcontractor, and; insufficient integration of the design and construction of the railway. The documentation management is more planned on one of the projects, with the active involvement of a quality manager. The procurement process is organized and well described in the contractor's management system. The procurement process includes subcontractor prequalification analysis. Issues inte the procurement process includes integrating the quality requirements of all project actors as well as establishing all quality requirements early in the project.

The study has generated several recommendations and suggestions for improving the contractor's quality management of subcontractors' activities. The procurement stage benefits from transparency between contractor and subcontractor, strategic cooperation and early integration of the different requirements. The procurement route of a subcontractor should be chosen based on the contractor's knowledge and abilities to control a certain activity. The subcontractors perform their activities more efficiently if they are given the adequate pre-conditions and the time they need. The use of method statements, inspection test plans and flowcharts may give the contractor a tool in generating effective process descriptions from the subcontractor. The study affirms that communication is paramount and the contractor and subcontractor should strive to sustain regular meetings/technical briefings. The contractor's use of visual and illustrative guidance is a powerful tool in assuring that subcontractors perform according to the quality requirements. The activities for which the contractor lacks knowledge and experience can be solved by using a competent and experienced coordinator. The coordinator should integrate design and construction while also coordinating the activities in question with the activities of other subcontractors and project actors.

Key words: quality management, quality assurance, quality control, civil engineering, subcontractors, critical activities, process quality

Contents

Preface

I would like to thank all people that have contributed to the creation of this thesis. First and foremost I would like to thank my supervisor, Christian Koch, for his support and guidance throughout this endeavour. I would also like to thank my supervisor in Skanska Gothenburg, Christer Nordberg, as he has guided me through the process with his invaluable experience and knowledge. All the participants in the interviews have challenged heavy workloads and shortages of time in order to contribute with their own knowledge and experience; I am extremely grateful for this.

And finally, I would like to thank my family for the support that can only come from home.

Göteborg June 2017

Edo Sijaric

Notations

AMA – Allmän material- och arbetsbeskrivning
ISO – International Organization for Standardization
SRA – Swedish Rail Administration
STA – Swedish Transport Administration

1 Introduction

1.1 Background

The construction industry in Sweden is seeing an increase in large-scale projects, which encompass more complex structures and technical content. Construction companies have reduced their core operations and are increasingly relying on subcontractors for executing key processes with the latter expected to deliver according to legal requirements, customer expectations, standards and norms (Warsame et al 2013, Warsame 2012).

Manshadi et al. (2014) state that medium and large size construction enterprises are increasingly adopting quality management systems for dealing with the assurance, control and inspection of quality, which includes the operations of the subcontractors. This is crucial as the final point of responsibility for the delivered project falls on the contractor.

1.2 Purpose

The purpose of the thesis is to investigate the application of quality management in infrastructure projects, as well as the challenges, when a large number of subcontractors are involved. The challenges with quality management in infrastructure projects arise from the contractors' lack of expertise in all the outsourced activities, differences in work procedures and a greater point of responsibility on the contractor. Contract requirements, standards and norms must be satisfied while the final product must fulfil the client's expectations.

The construction company, which will be the focus of this thesis, is Skanska AB, more specifically the office and operations in Gothenburg. In detail, the study will revolve around Skanska's quality management system, processes and operations involving subcontractors, using several projects as case studies.

1.3 Objective

The objective of the thesis is to generate plans and suggestions for improvements in Skanska's quality management system, specifically when applying the system to activities and processes executed by subcontractors. The thesis should also open possibilities for further research in this area.

The critical activities performed by the subcontractors are in the fields of concrete, steel, installations and railway infrastructure.

1.4 Research question formulation

The following questions are to form the basis of the research in order to achieve the purpose and objective:

- Which processes and methods are available to assure and control the quality of critical activities executed by subcontractors?

- What are the challenges with quality management of subcontractors?

1.5 Delimitation

The thesis will focus on the construction company Skanska AB, specifically on their office based in Gothenburg and the civil engineering projects under their responsibility in that area. The empirical background will concentrate on Skanska's quality management system, processes and operations regarding subcontractors in two bridge projects: the South Marieholm Bridge and the Hisingen Bridge.

The customer in project South Marieholm Bridge is the Swedish Transport Administration while Trafikkontoret is customer in the ongoing Hisingen Bridge. Trafikkontoret is Gothenburg municipality's office responsible for traffic administration and development. South Marieholm Bridge is a Design-Build contract while Hisingen Bridge has a more complex contract form, i.e. the middle-part of the bridge is under a design-bid-build contract while the abutments are under a design-build contract.

2 Methodology

2.1 Research approach

An abductive research is initiated by a surprise or unexpected observation inciting the need to explain it. The deviation found in the phenomenon cannot however solely be explained by theoretical data, instead relying on a back-and-forth engagement between theoretical data and empirical sources. The empirical sources generate theoretical ideas used to explain the phenomenon. (Kovács and Spens 2005).

Kovács and Spens (2005) describe an abductive research starting, similarly to an induction, with a real-life observation. It is important to note that the researchers conducting the research usually have some pre-perceptions and previous knowledge, which renders the phenomenon found in the observation not entirely surprising.

As mentioned earlier, theoretical data and empirical sources are tools to explain this observed phenomenon. The abductive reasoning starts as soon as an observation in the empirical sources emerges which the prior theoretical sources fail to explain. In order to explain this deviation, Kovács and Spens (2005) as well as Dubois and Gadde (2002) describe a creative iterative process of "systematic matching" in which the theoretical sources are extended. The studied cases provide new theory and illuminate new inconsistencies between theory and real-life observations. This iterative process continues until new theory or frameworks emerge which explain the phenomenon.

Dubois and Gadde (2002) state that the back-and-forth play between theory and empirical sources constitutes the foundation of "systematic matching".

In order to achieve the objective of this study a contractor's quality management of subcontractors was examined. As subcontractors are increasingly delivering considerable parts of civil engineering projects the quality of their services account for substantial levels of the projects' costs and time. Big contractors have simultaneously reduced their core-operations and the study will encompass both subcontractors operating in fields in which the specific contractor has knowledge in as well lacks knowledge in. Answering the research questions formulated for this study required an explorative approach and thus a qualitative research strategy was most suitable.

Qualitative research mainly focuses on words contrary to the concern with numbers found in quantitative research (Bryman and Bell 2015).
Furthermore, Bryman and Bell (2015) discuss several traditions in qualitative research. The authors describe naturalism as the endeavor of understanding social reality in its own terms, or "as it really is". The application of this tradition sees people and interaction in natural settings.

Although quality management systems and routines in the construction industry aim to give a predictability, the reality is much more complex because of the dependance on the individuals, settings (both geographical, topographical and social), project conditions as well as legislative regulations, predictability in civil engineering projects becomes unlikely. The author of this study therefore recognizes the need for a qualitative research.

2.2 Research process

This thesis is the final part of the Design and Construction Project Management master programme at Chalmers University of Technology. The study and research necessary for its emergence was realized between January 2017 and June 2017.

The theme for the thesis originated in Skanska. It is important to note that Skanska has given permission for the company name to be used in this study. The multinational construction and development company has moved to procuring services from subcontractors instead of keeping large numbers of skilled laborers. This trend has been more prevalent in housebuilding, however in recent years the civil engineering sector has adopted the same concept. With this, contractors dismantle certain core processes in favor of procuring subcontractors. Without expertise in these works, Skanska has had issues following and controlling the activities of the subcontractors. The backlash has appeared in the form of defects, often detected in the final inspection, as well as the need for rework.

Experiences from project South Marieholm Bridge, as well as earlier projects, prompted Skanska's infrastructure division in Gothenburg to launch a thesis concerning the quality management of critical activities with a large number of sub-contractors involved.

The theme was at the outset very broad. During the period of January-February 2017, eleven interviews were conducted with district managers, project managers, production managers and design managers from Skanska's infrastructure division, in order to establish a picture of the state of quality management in projects as well as the ensuing challenges. These eleven interviews formed the foundation for the problem formulation and research questions as it became clear that the quality management of subcontractor activities constituted a challenge.

Simultaneously as the initial interviews were held, a literature review was conducted in order to examine existing literature in quality management. The literature review covered not only general quality management definitions and concepts but also quality management applied in civil engineering and structural engineering. Quality management concerning sub-contractors in the construction industry forms a part of the literature review.

A brief period, spanning a couple of weeks in February and March, followed during which the interviews were analyzed and the problem formulated. The preliminary research questions, which had been very broad, were narrowed down and specified. In consultation with the supervisor from Chalmers, the theoretical background developed by complementing the literature review with new sources and insights focusing more on the specific topics relevant for the problem. The section regarding quality management of subcontractors in the construction industry was extended.

A suitable research strategy was necessary in order to generate an empirical background, thus the last weeks of February were also used for examining the methodology of the study. After studying research strategies, a qualitative research strategy was chosen. Open question interviews were most appropriate for generating the data, which would constitute the empirical background. This was deemed most

appropriate, as the examination of interactions in natural settings was necessary for understanding the social reality.

The purpose with the data, in combination with the theoretical data generated, was to provide sufficient understanding for answering the research questions.

The following part of the study saw a new round of interviews, which would form the greatest part of the empirical background of the study. Twenty interviews were conducted in a period spanning March and April, and one interview carried out in May. All of the interviews were carried out face-to-face with a wide variety of Skanska employees occupying a wide variety of positions in any of the projects forming the cases as well as representatives from two of Skanska's subcontractors. These positions included project managers, production managers, design managers, block managers and supervisors.

The employees interviewed were chosen in consultation with a supervisor for the thesis from Skanska. The supervisor, an assisting project manager on one of the projects forming the case studies, had extensive knowledge about the projects and the positions. He knew several of the interviewees personally having worked closely with them on projects.

The aim was to generate descriptions of Skanska's quality management procedures regarding subcontractor activities and the existing challenges in these procedures. Furthermore, the literature review had illuminated the weight of the procurement of subcontractors. The research questions were thus expanded adding questions about the quality assurance procedures in the procurement stage.

An interview was conducted with one of Skanska's subcontractors employed on both projects, while another was interviewed in May.

Different questions were asked depending on the position. The questions were open end and most often used to ignite discussions and make the interviewees share their knowledge and experience about the topic.

Finally, in May, the data assembled from the interviews was analyzed with the discussion focusing on connecting the empirical findings to the theoretical background. The findings were summarized in a conclusion, ending with a recommendation for future research.

2.3 Literature review

The empirical findings, research questions and discussions in the study were connected to a theoretical background consisting of data collected from scientific articles, books and standards. Bryman and Bell (2015) state that this is an effective way of validating the credibility of research.

Bryman and Bell (2015) stress existing literature's importance by regarding it as a crucial element in all research. Furthermore, in the research of a topic or issue, the authors describe the elements that need to be determined as:

- Already established findings about the topic,

- Concepts and theories that have been applied to the topic or issue,
- The research methods applied in the study of the topic or issue,
- Existing controversies about the topic or issue,
- Any existing clashes of evidence and,
- The key contributors to research on the topic.

The following key words were used in the literature search; *construction, civil engineering, quality management, quality assurance, quality control, subcontractors, defect, rework* and *process quality*. The scientific articles were obtained from Google Scholar, SCOPUS and Web of Science while Chalmers' school library as well as Gothenburg University's school library provided the specialist literature. The scientific articles were mainly selected with respect to the aim and purpose of the study.

The year of publication, place of publication (geographically as well as the institution), number of citations and the breadth of the bibliography were the focus when evaluating and selecting sources. Not all literature focused on the topic of the study as certain literature was concerned with research strategies, qualitative research methods and the abductive reasoning used in the study.

The case studies in this study are conducted in a Swedish context, as both projects took place/are taking place in Gothenburg, while the literature is not limited to Sweden. To be specific, several of the scientific articles used in the theoretical background are based on case studies and research conducted in the USA, Great Britain, Slovakia, Australia, Hong Kong, Singapore and Jordan. The literature search was conducted between January and May 2017 and included 28 scientific articles, two books and sources from standards and laws.

2.4 Data collection

The empirical background in this study is the result of a qualitative research strategy. Two methods were mainly used, i.e. semi-structured interviews and unstructured interviews. Bryman and Bell (2015) identify these two methods as constituting qualitative interviews.

2.4.1 Interviews

The interview is probably the most extensively applied method in qualitative research (Bryman and Bell, 2015). This study saw the use of two types of qualitative interviews: semi-structured interviews and unstructured interviews.

The **semi-structured interview** refers to a situation in which the interviewer has a list of questions guiding the interview. The sequence of the questions are not strict and can be altered as the interview proceeds. The questions are more or less general giving the interviewer leeway to ask further questions in response to the interviewee's significant replies to the main questions. (Bryman and Bell, 2015).

The **unstructured interview** is usually based on a list of topics or issues called an interview guide or aide-memoire. The interviews are usually informal and the phrasing of questions, as well as the sequence, varies from interview to interview. An unstructured interview may only consist of a single question asked by the interviewer,

allowing the interviewee to respond freely. The interviewer may then respond to points noted as relevant. (Bryman and Bell, 2015).

Eleven unstructured interviews were conducted with employees from Skanska in the beginning of the study. The purpose of these interviews was to form an understanding of the general application of quality management and the biggest challenges for its effective implementation. Most of the interviewees occupied a position in the project organization of one of the two projects that were to be studied. The interviews were conducted with one district manager, four project managers, two production managers, two design managers, one procurement manager and one block manager.

Twenty-one semi-structured interviews followed the unstructured interviews. All but two of the interviewees were representatives from Skanska. Two of the interviewees were representatives from enterprises working as subcontractors to Skanska on the two projects forming the base for the case studies.

The positions of those interviewed in Skanska were as follows: two operative managers, one district manager, two project managers, three production managers, one procurement manager, one purchaser, two design managers, one project manager, one steel group manager, one production manager/railway expert, three supervisors, one quality manager.

The interview process in this study can be summarized in eight steps that include:

1. *Formulating questions for the interview guide* – The first step in the interview process was to formulate the open-end questions that would steer the course of the initial interviews.

2. *Selecting interviewees* – The interviewees were selected in consultation with the Skanska supervisor. The factors determining the choice was position in projects and experience.

3. *Performing the interviews* – The interviews were usually conducted in the offices of the interviewees with a duration of about 45 minutes per interview. One interview lasted for 1 hour and 30 minutes. All of the interviews were conducted according to the interview guide, with follow-up questions emerging during the interviews. The interviews were recorded in order to facilitate the analysis and reflection of the content.

4. *Summary and analysis of interviews* – The records and notes produced during the interviews were transcribed after each interview. The transcriptions were analyzed, with respect to the problem formulation, summarizing the challenges inhibiting quality management in projects.

5. *Formulating questions for the second round of interviews* – The findings from the first round of interviews formed the basis when establishing the questions for the second round of interviews. The second round was to be performed as semi-structured interviews. The questions would be general, although more guiding and specific when compared to those in the unstructured interviews.

6. *Selecting interviewees* – This was again done in consultation with the Skanska supervisor. This new list included two representatives from enterprises that had worked as subcontractors for Skanska during the South Marieholm Bridge Project. They were also to participate in the ongoing Hisingen Bridge Project.

7. *Performing the second round of interviews* – Performed in the same manner as the first round of interviews. The interviews with the subcontractors were conducted in the offices of the representatives.

8. *Summary and analysis of interviews* - The records and notes produced during the interviews were transcribed after each interview. The transcriptions were analyzed, with respect to the problem formulation. These summaries formed the base for the empirical background.

2.5 Data analysis

Bryman and Bell (2015) affirm that when audio-recording interviews a large amount of raw data is produced. The raw data has to be managed and an effective way is to transcribe the interviews. The authors noted that the most commonly used tool in the analysis of transcribed data is *thematic analysis* i.e. the search for recurring patterns or themes in the acquired data. The thematic analysis was used in this thesis.

After the summary and structuring of the audio-recordings in this thesis, the consequential data was reviewed in order to disclose themes between the obtained data. Due to the large amount of data retrieved, it was necessary to catch the most important themes and points in every interview, while the interviews and data not relevant was not taken into consideration into the report. Therefore, not all of the data obtained from the 32 interviews is incorporated in the following report.

2.6 Quality of the study

Bryman and Bell (2015) state that the most notable principles for evaluating any kind of research are reliability, replication and validity. As this study is part of a master thesis, its replication will not be discussed. However, reliability and validity are of unwavering importance.

Authors such as Lincoln and Guba (1985) introduce an alternative way of determining the reliability and validity of a qualitative research. What the authors conclude is that trustworthiness represents the criterion suitable for assessing a qualitative research. Further on, trustworthiness consists of four aspects that can be applied to qualitative research when determining its reliability and validity, i.e.:

- Credibility – How credible are the results?
- Transferability – Are the results implementable to other situations?
- Dependability – What is the possibility of the results being implementable at other times?
- Confirmability – Has the investigator allowed his or her values to impair the impartialness of the study?

Bryman and Bell (2015, p.52)

Evaluating the study according to these aspects is thus an appropriate way of judging the reliability and validity of the results.

Looking at the first aspect, credibility, Bryman and Bell (2015) state that by establishing the credibility of results attained assures that the principles of good practice have been respected. This is important, due to the fact that the social reality studied may manifest itself in different interpretations and accounts. Lincoln and Guba (1985) describe several techniques that can be used in order to establish credibility. *Prolonged engagement* means that the researcher spends considerable time in the environment of the research target in order to gain understanding of the social setting. This study was conducted in a period of six months during which relationships were formed with many of the interviewees. Furthermore, a certain trust was established between researcher and the respondents, which Lincoln and Guba (1985) also identify as a result of prolonged engagement.

The next aspect is the transferability of the study. Qualitative studies are described by Bryman and Bell (2015) as typically aligning to the uniqueness of the specific situation and the influencing factors from the social setting. So the question for this study is, are the results implementable to other situations? Lincoln and Guba (1985) argue that this is an empirical issue. The authors suggest that a *thick description* is a technique the researcher can implement for assuring the transferability of a study. Using this method, the author provides extensive descriptions of the social settings and interactions being studied. However, Lincoln and Guba (1985) affirm that the final judgement of the studies transferability to other studies can only be made by the authors responsible for those studies. In this study, the interviews have been described in detail as recorded. Furthermore, the semi-structured and unstructured interviews complement each other by providing accounts of the studied target as well as the social settings.

Nevertheless, there are certain factors that have to be taken into account when discussing the transferability:

- The study was conducted in Skanska and the case studies were projects that Skanska were/are operating.

- The projects are civil engineering projects seeing the construction of bridges. The topic concerns the implementation of quality management of critical activities executed by subcontractors.

- No laborers/workers were interviewed. This would have been appropriate because of the fact that they perform the processes and they are those responsible for achieving the right quality.

All of these factors should be taken into consideration in any further implementation of these findings.

Lincoln and Guba (1985) propose that dependability may be established by following an ‘auditing’ approach i.e. to maintain a complete documentation of all the stages of the research process. This includes problem formulation, selection of interviewees, fieldwork notes, transcriptions of interviews and data analysis decisions. The researcher should keep these documentations available and transparent for peers who

will act as auditors. This has been done in this study, as all interviews have been transcribed and are available.

Bryman and Bell (2015) claim that confirmability is of such importance in research that its establishment should be assured by auditors. Personal values or theoretical leanings should not be allowed to mar the reliability and validity of the study. The abductive reasoning used in this study should sustain its credibility. The theoretical background has been updated continuously in relation to the empirical findings in order to establish credibility and negate any inclinations or false data pervading the achieved result.

2.7 Limitations

In the study, references have been made towards the end client in projects and their importance for decreeing the quality of the final product. Still, none of the clients of the two projects studied have been interviewed. This is due to their unwillingness to participate in the studies as both of the clients are government agencies. Their will and requirements have thus been manifested in the agreements and technical descriptions that have been available.

The study focuses on the contractor-subcontractor relationship when assuring and controlling the quality of critical activities. However, out of 32 conducted interviews, only two interviews were conducted with representatives from two different subcontractors. Thus, the focal point has fallen on the studied contractor and the processes, methods and challenges as experienced by its employees. However, the subcontractors are those actually performing the processes and those responsible for achieving the right quality. It would have been suitable to interview more representatives from the subcontractors performing the critical activities in the chosen technical areas.

In the theoretical background, the majority of the data is from scientific articles dealing with quality in civil engineering projects, which has been desired. However, a few of the sources have also dealt exclusively with quality in structural engineering projects. Although similar, different conditions prevail in these types of projects and however small they have to be taken into consideration. Based on this, a certain influence may therefore be present in the theoretical background.

2.8 Ethics

The ethics of the research puts focus on the integrity of values in the research process (Bryman and Bell, 2015). The definition of ethics in this context relate to several issues and to which extent the research has transgressed upon them.

Diener and Crandall (1978) define these issues into four main areas:

- Whether there is damage to the research participants;
- Whether there is an absence of informed consent from the participants;
- Whether there is an violation of privacy;
- The use of deception for attaining data from the participants.

The discussion of the ethics of this study may be put in relation to these areas. Before doing so however, clarification is necessary regarding the first point, i.e. what is

damage in this case? Citing Diener and Crandall (1978), Bryman and Bell (2015) state that damage to a participant concerns damage to the individual's physical well-being, self-esteem, prospects of further career-development or causing stress.

In order to avoid any of the four issues discussed above, precautionary actions were taken in the following ways:

- The Skanska supervisor reviewed all of the questions asked during interviews and gave his consent for them to be asked.

- Before each interview, every participant was informed about the intended use of the resulting data.

- The participants were given the produced data from their respective interview for confirmation. This method is known as member validation (Bryman and Bell 2015).

3 Theoretical background

3.1 Quality in the construction industry

3.1.1 Definition of quality

The concept of quality has constantly developed throughout history, with the last hundred years seeing different definitions emerging and complementing each other. Therefore, this section will only describe the most recent definitions.

Rajendran et al. (2012) define quality, in relation to the construction industry, as follows:

"Conforming to the plans, specifications and applicable codes and standards; conformance to the requirements (i.e., meeting the owner's requirements)" (p. 40).

This relates to the more general definition of quality by Crosby (1979) which describes quality as *"conformance to requirements"* and Deming (1986)*"quality should be aimed at the needs of the customer, present and future"* (p.5.).

These definitions represent the prevailing view, namely that quality is requirements which are set before production and which should be fulfilled. In addition, to note, Rajendran et al. (2012) stress the owner's/client's importance as the party setting the requirements.

These definitions also integrate an important element, i.e. the client, and all product characteristics and abilities should be put in relation to what the client wants and needs, knowingly and subconsciously.

3.1.2 Quality assurance and quality control

Quality assurance is the part of quality management aimed at assuring the fulfillment of quality requirements during the pre-production phase, i.e. design stage and procurement stage (Rajendran et al. 2012, ISO 9000:2008).

Quality control is the part of quality management aimed at verifying the achievement of quality requirements during the production phase and also includes inspections and testing (Rajendran et al. 2012, ISO 9000:2008).

3.1.3 Processes

The word process originates from the Latin words *processus* and *procedure* meaning "advancement" or "move ahead".

The ISO 9000 standards defines it as a "set of interrelated or interacting activities that use inputs to deliver an intended result" (ISO 9000:2008).

When describing the different processes constituting an organization, it may be preferable to do so according to the questions "who is the customer and who is the supplier". Thus, processes are often classified in the following categories:

- *Main processes,* whose function is to satisfy the needs of the external customers and to create value for external customers by refining the products provided by suppliers. The main processes produce output, which creates the organization's income. The main processes serve external customers (Bergman and Klefsjö, 2010).

- *Support processes,* whose function is to provide support and resources for the main processes. The support processes serve internal customers (Bergman and Klefsjö, 2010).

- *Management processes,* whose function is to make decisions on the organization's strategies and goals as well as carry out improvements in the different organizational processes. The management processes serve internal customers (Bergman and Klefsjö, 2010).

3.1.4 Standards and standardization

The Swedish Standards Institute defines standards as mutually agreed solutions for recurring problems. A more complete definition includes documentation, erected in consensus and finalized by an acknowledged authority, providing rules for public and frequent usage, guidelines or features for activities or their result, with the purpose of achieving the greatest possible order in a certain context (SiS 2014).

The main purpose with standardization is to determine optional technical specifications or quality specifications with whom existing or future products, productions processes or services can conform. Standardization is playing an increasingly important role in international trade and the opening of markets (SiS 2014).

Independent standards organizations acting on national, European and international level establish standards. The implementation of standards is voluntarily. If, however, government regulation refers to a certain standard/standards its implementation becomes compulsory (SiS 2014).

In the Swedish construction industry, there are several prevailing standards, which contractors and laborers must take into consideration. These are the Eurocode standards and the AMA.

Eurocode is an umbrella term for the standards regulating the design and construction of structures within the European Union. The Eurocodes applied in Sweden are adapted to the prevailing local conditions. (SiS 2014).

The General Material and Workmanship Specifications (*Allmän material- och arbetsbeskrivning* in Swedish, abbreviation: AMA) are series of Swedish reference documents that serve as support documents for the regulated standards. Although not legally mandatory, it becomes so if the contract between the client and contractor refers to AMA. It is a tool, which the client can use to specify demands regarding execution of activities, including critical activities. (SiS 2014).

3.1.5 Quality management systems and the ISO series

ISO 9000:2008 defines a quality management system as "*a management system to direct and control an organization with regard to quality*".

A quality management system is primarily a tool for the control and improvement of an organization's product and service quality (Bergman and Klefsjö 2010). A crucial factor for achieving an efficient quality management system is documentation. The documentation supports both the continuous improvement of the system as well as serving as the foundation for the quality audit of the organization and its methodologies.

3.1.6 Quality management in construction

Rajendran et al. (2012) describe quality management as the implementation of a quality management system in operating a process with the aim of maximizing client satisfaction at the lowest overall cost to the organization while simultaneously conducting continuous improvement of the process.

The construction industry has seen an increased interest in the application of quality philosophies and methodologies originating in the manufacturing industry (Jraisat et al. 2016). With a worldwide boom in construction, especially among developed countries, the large increase in construction has put a strain on management in construction companies. This has prompted the management in many countries to study and apply quality management methodologies previously limited to the manufacturing industry. The globalization and the construction boom have forced construction firms, even the more established ones, to use quality management as a means for improving the efficiency of their processes in order to stay in business.

Rajendran et al. (2012) describe the consequences of faulty quality in the US construction industry. According to the authors, construction defect claims constitute $5 billion of what the US insurance industry pays annually in settlement deals. Infrastructure is one of the branches of the construction industry where most construction defect claims are reported.

Lundkvist et al. (2012) state that in the Swedish construction industry, defects and nonconformities induce costs and delays in construction projects. In the study, the authors discuss construction defect management in the Swedish construction industry with a focus on compulsory third party inspections, which have a crucial role in the management of defects in Swedish construction projects.

Jraisat et al. (2016) state that contractors often neglect the profits available from quality work by focusing exclusively on cutting direct costs and project duration. In their study, the authors sent out questionnaires to 243 contractors and 85 architectural/consulting firms in Jordan. The firms studied focused on improving financial measures instead of concentrating on the quality measures, which has proven to be inefficient. Furthermore, they state that contractors can benefit from implementing quality work in the form of increased customer satisfaction, enhanced product quality and higher market shares.

Management practices are crucial for the success of quality management in construction (Jraisat et al. 2016). The authors continue with describing several practices, i.e.:

- The contractor's senior management must motivate the entire project organization;

- The project organization's top management must commit to site management by offering support and interest in the site activities, and;

- The top management must integrate continuous improvement activities into the strategic goals of the project thus assuring its implementation on all levels of the project organization.

It is important to stress that this is true for countries where the construction industry focuses on a "top-down approach".

When looking at the three project dimensions cost, time and quality, construction management usually focus on time and cost as they are usually clearly stated in the form of project durations and budget (Aichouni et al 2014, Warsame et. al 2013).
Quality management depends on continuous improvement work encompassing all the members of an organization. Thus, many construction companies working with quality management have developed long-term relationships with their customers and subcontractors.

Aichouni et al. (2014) and Pheng and Teo (2004) argue that not only does customer satisfaction improve but also employee satisfaction, in the form of lower rates of sick leave and injuries. Other resulting benefits are reduced quality costs, reduced rework, subcontractors applying quality management systems in line with the main contractor's system and closer relationships between contractors, subcontractors and customers.

3.1.7 Product quality and process quality

There are two different types of quality usually identified in, but not limited to, the construction industry, i.e. product quality and process quality.

The product quality is the physical product and in construction, it corresponds to the quality of materials, equipment and technology that form a part of a structure (Jraisat et al. 2016).

The process quality is the quality of the management of the construction processes intended to deliver the physical product. The processes managed constitute the main phases of the construction processes, i.e. design phase, construction phase and, operation and maintenance phase (Jraisat et al. 2016, Arditi and Gunaydin 1998).

The concept of Total Quality Management aims at improving the processes delivering the product. Thus, the processes are paramount while the inspection of the final product is secondary and used to assess the efficiency of the processes. Arditi and Gunaydin's (1998) listed in their study the factors deemed as most important for the quality of the construction processes. Arditi and Gunaydin (1998) focused on the

design and construction phases of construction projects, both for structural and infrastructural projects.

Looking at the design phase, the design consultants and construction managers participating in the study stated that projects specifications were of great importance (Arditi and Gunaydin 1998). Project specifications are documents containing quality requirements, performance requirements and technical information on materials. Project specifications should correspond to the client's requirements. The authors also found that the project management should communicate the specifications to all projects actors in a clear and consistent way.

Furthermore, both construction managers and clients participating in the study stated that the design consultant responsible for generating the design had to have considerable experience, expertise, capabilities and financial balance. Design consultants have the potential of becoming the most effective problem-solving tool in the project by implementing constructability in the design and thus preventing rework and defects later in the construction phase and even operation phase (Arditi and Gunaydin 1998).

The participants deemed communication between the client, the construction management and design crucial. The client was responsible for giving clear and consistent information but the construction management/project management had to assure that the information and requirements reached all project participants (Arditi and Gunaydin 1998).

3.1.8 Documentation and quality in construction

Kozlovska et al. (2016) state that the management of information flows is a decisive part of construction projects. The authors affirm that the documentation of a construction project is a substantial source of information for the planning and administration of the processes comprising the total project and is necessary for all stakeholders including the client, contractor, subcontractors, suppliers and government administrators.

Kozlovska et al. (2016) study is part of a broader study, with a focus on the processing of construction documentation in the Slovak construction industry, initiated by the Slovak government in which representatives from different Slovak constructions companies were interviewed in 1996, 2003, 2008 and 2013. The construction companies were a mix of structural engineering and civil engineering companies. 64 respondents were interviewed in 1996, 48 respondents were interviewed in 2003, 159 respondents in 2008 and 59 respondents in 2013.

The resulting documentation of any construction process originates in the planning phase and is a powerful tool for the different managers operating a project to evaluate their ability to meet the project deadlines. The documentation is fundamentally concerned with the time, cost and quality of the project. (Kozlovska et al. 2016).

Kozlovska et al. (2016) identify time, cost and quality in the following documents generated during construction projects:

- Time – time schedules of the different construction activities,

- Cost – budget plans,
- Quality – quality control plans and checklists for construction realization,
- Building site - construction site layout planning, as-built drawings, drawings, plan for occupational safety and health.

The quality control plan includes:

- Technical descriptions provided by the end client describing the intended product and requirements which the client expects to be fulfilled.

- Control plans describing the different critical activities executed in order to realize the construction phase with each critical activity supported by a checklist.

- Checklists describing the different controls required for each critical activity, the responsible surveyor and the reference standards/norms/regulations.

3.1.9 Defects and rework in the construction industry

Rajendrat et al. 2012 define a construction defect claim as "any claim for property damage that is progressive in nature, and arises out of the construction of any project and occurs after construction operations have been completed" (p.38).

Quoting the Construction Industry Development Authority (1995), Love (2002) defines rework as "the process by which an item is made to conform to the original requirement by completion or correction" (p.138).

3.1.10 Challenges with quality management in structural and infrastructure projects

Although construction management is implementing quality management practices originally used in the manufacturing industry, there are fundamental conditions in construction and civil engineering making quality management more difficult. Warsame et al. (2013) identifies three factors in infrastructure projects aggravating quality management:

- Site-based production, where supervision differs significantly and where external factors may have a profound effect on the quality of a particular structure.

- The project organization responsible for the production changes from project to project. This has a lot to do with the use of subcontractors and the fact that construction companies are typically decentralized.

- The products in infrastructural projects, e.g. roads, bridges, etc. are such that it takes a rather long time to detect quality problems. The warranty period may span several decades.

Warsame et al. (2013) affirm that the client must have a certain expertise or knowledge when procuring services as it is not sustainable to rely on market feedback.

Love (2002a, 2002b) states that costs, originating from defects and rework, may constitute as much as 12.4% of the contract value in civil engineering projects. Love bases his statement on a study from Burati et al. (1992) focusing on nine major civil engineering projects in the USA. In the nine projects, Burati et al. (1992) found that deviations in the design documentations and execution of construction activities constituted the majority (93.6%) of deviations reported. The other deviations reported by the project representatives originated in fabrication, transportation and operability.

In another study, Love (2002a) studied a mixed housing-civil engineering project in Australia consisting of two, six-story residential apartment buildings and an underground parking. Love found in his study that rework leading to costs, in this particular project, was due to deficient contract documentation and poor workmanship.

Barber et al. (2000) conducted a study in the UK construction industry focusing on two road construction projects. Both of the studied projects included the construction of bridges, tunnels, sign gantries and culverts. The authors focused on the costs caused by non-conformities to contract requirements and functional performance requirements, including drawings, technical specifications and process descriptions.

The authors concluded that the few major errors accounting for most of the costs usually had their origin in undiscovered or unamended small errors from the early stages of the construction process. With it, Barber et al. (2000) suggests that there is a need to trail the supply chain of a project in order to identify critical activities, which affect the forthcoming activities.

3.1.11 The client's role in structural and infrastructure projects

In Warsame´s survey (2011), members of construction companies involved in infrastructure projects responded to questions about the biggest reasons for inferior quality. Of the respondents, 81% answered that a lack of public client competence was a decisive factor for inferior quality. In Sweden, the Swedish Transport Administration (*Trafikverket* in Swedish, abbreviation: STA) is responsible for procuring the vast majority of infrastructure projects, thus making them the biggest client for infrastructure products.

Both Warsame et al. (2013) and Manley (2006) stress the role of client leadership for improving the quality of products in construction and infrastructure projects. Manley (2006) describes the importance of the client taking an active role in construction projects in order to assure its delivery according to standards and specifications set by the client itself. Drawing from a wide range of literature, Manley (2006) summarizes the activities the client can promote in assuring high quality outcome of projects as:

- demanding notable project results,
- implement economic incentives within contracts,
- focusing on the quality of project relationships,
- establishing value-based selection of tenders,
- designing pre-qualification systems that evaluate innovation history,
- applying performance-based standards and regulations,
- divide risks, and;
- delegating authority to stimulate more site-based ideas for improvement.

Manley (2006) focuses on the role of innovation in the improvement of quality, specifically on public clients in Australia. In her study, Manley sent out questionnaires to contactors, consultants and clients involved in civil- and housebuilding projects in which the client was a public institution.

Public clients need to possess adequate skill, competence, expertise and experience in their employed personnel and management in order to enable efficient risk management and protect public interest in infrastructure projects (Warsame et al. 2013).

3.1.12 The impact of subcontractors on quality work

The construction industry has seen an increase in large-scale projects where often one main contractor has a contractual obligation to deliver the whole project. This in turn craves special expertise, advanced equipment and a large workforce, often for several different labors. (Yoke-Lian et al. 2012).

Cantarelli et al. (2013) defines large-scale projects as major infrastructure projects with project budgets exceeding US$1 billion. This is nonetheless a relative figure and different countries may define this sum differently. There are, according to the authors, other conditions prevalent in large-scale projects as a high level of public attention, political interest and indirect impacts on the economy, society and environment of a community. Thus, a project's size should be put into relation to the area and conditions where it is delivered.

The construction industry in Sweden has seen the trend of large construction organizations reducing their core processes and in-house expertise in the favor of subcontracting specialist subcontractors depending on the project (Warsame et al. 2013).

Yoke-Lian et al. (2012) describe a subcontractor as a construction firm with specialist knowledge in the execution of a specific activity that contracts with a main contractor for performing a part of the main contractor's work. The subcontractor usually provides the process, knowledge, workforce and equipment needed for the execution of the activity.

Warsame et al. (2013) state that contractors in Sweden, as well as in many other countries, are shifting to procuring design services from external consultants as opposed to the earlier use of in-house expertise. The authors list several explanations for this shift; variations in the number of projects produces challenges with employing an in-house workforce fully committed to design and steady incentives are hard to create with an in-house organization.

Warsame (2012) discusses the use of subcontractors in the Swedish housebuilding industry in the context of integration and differentiation of construction organizations. An integrated construction organization refers to a main contractor that keeps a large number of labor specialists. A differentiated construction organization refers to a main contractor procuring specialist subcontractors in fields where the main contractor lacks expertise.

The two factors affecting the choice between integration and differentiation are risk allocation and the organization's capability to respond to economic changes (Warsame 2012, Winch 1989).

The integration of a main contractor with labor specialists, i.e. to have in-house expertise in different technical areas will increase the organization's competence, but it might simultaneously impair the organization's ability to adapt to economic changes (Warsame 2012). Contrary to this, a main contractor procuring specialist subcontractors will be able to conform competitively to prevailing economic factors and allow for a better risk distribution. The downside however is that the main contractor will be dependent on others' expertise.

According to Arditi and Chotibhongs (2005) main contractors in the USA do not have sufficient activities and projects in order to afford the full-time employment of workforces specialized in specific activities nor is it feasible for them to own, operate and maintain equipment related to specific activities due to its limited use during a project. These views are in line with Warsame (2012). They also state that another important reason for subcontracting is that subcontractors are usually able to perform their specific activity faster and to a lower cost.

Based on the conditions prevalent in the Hong Kongese construction industry, Yoke-Lian et al. (2012) state that the large presence of subcontractors generates a diverse project organization with a disintegrated group of subcontractors spread across the organization. Thus, the construction management is compelled to coordinate the different competencies towards the same project goals regarding time, cost and quality.

Futhermore, Yoke-Lian et al. (2012) identify two factors determining the success of a construction project, i.e. the main contractor's ability to select suitable subcontractors during the bidding process and the main contractor's ability to manage the subcontractors during the construction phase.

Yoke-Lian et al. (2012) also state that the main contractor's construction management needs to understand the subcontractor's scope of work and the probable dependencies between the different activities in order to assure the long-term successful delivery of the entire project. Jraisat et al. (2016) further lists subcontractor involvement in quality management as a crucial quality factor.

Arditi and Gunaydin (1998) have conclusions similar to Yoke-Lian et al. (2012). Their study focused on the factors that affected process quality in the design phase, construction phase and operation phase. The authors conducted the study by sending out a questionnaire to design firms, construction companies, property management firms and construction management firms. All of the companies/firms operated in the USA and were a mix of structural engineering and civil engineering firms with some specializing in both areas. They found that the process in the construction phase, which most construction managers found to be crucial, was the contractor's supervision of the subcontractors. The subcontractors on the other hand thought that lack of information and overlapping activities were the cause of low quality performance, reworks and costs in general. The connection here is obvious, as the subcontractors need guidance and clear, consistent information while executing the

activities for which they are responsible and the contractor has to be the one providing this.

Sovacool et al. (2016) studied the risk of cost overruns and underruns arising during the construction of 51 onshore and offshore windfarms authorized between 2000 and 2015, spanning 13 countries. The authors discuss the trend of 'technological learning' meaning that most contractors develop certain knowledge and gain experience during projects increasing the efficiency when performing later projects. The contractors performing the construction of these civil engineering-classed structures rely on a changing host of small and medium companies throughout the construction phase of the wind farms i.e. subcontractor. The authors affirm that one of the factors impeding the ability to learn is the subcontractors. The dynamic market in which the subcontractors operated contributed to the difficulties concerning learning from projects.

Cantarelli et al. (2013) investigated cost overruns on transport infrastructure projects in the Netherlands. The authors define transport infrastructure projects as projects involving the construction of roads, rail lines, channels, (extensions of) airports and harbors, bridges or tunnels. The study revolved around all transport infrastructure projects completed in the Netherlands after 1980. Cantarelli et al. (2013) concluded that the projects that actually achieved cost underruns, as opposed to overruns, where those with facilitating factors in the pre-construction phase. This includes planning and setting up necessary arrangements with subcontractors.

In Arditi and Chotibhongs' (2005) study about issues in subcontracting, the authors sent out questionnaires to the top 450 specialty contractors, the top 300 general contractors, and the top 250 owner firms in the United States, obtained from lists provided by Engineering News-Record (ENR 2001a,b,c). The authors received responses from 124 subcontractors, 66 general contractors, and 33 owners.
They point out that the procurement of subcontractors is one of the most important processes of structural- and civil engineering projects. The authors identify it as the stage in which the main contractor decides which subcontractors are suitable for the execution of certain activities, including the activities deemed as critical for the overall project. The main contractor has the potential to assure the fulfillment of quality specifications and requirements in this stage.

However, Arditi and Chotibhongs (2005) point out that the practice of post-award bid shopping is widespread among main contractors in the USA, i.e. the main contractor will try to get a subcontractor to lower the submitted bidding price or procure another subcontractor willing to perform the same activity for a lower price. In order to be able to procure the lowest bidding subcontractor the main contractor may have to lower the quality standards required in the selection.

Arditi and Chotibhongs (2005) list several possible consequences of this practice:

- The encouragement of lower standards of work performance,
- A decrease in the general quality of the project,
- The formation of an adversarial relationship between the parties,
- The incitement of legal disputes,
- Promotion of unjust competition,

- Decline of overall jobsite safety.

Furthermore, Arditi and Gunaydin (1998) found in the same study, which was mentioned earlier, that the selection of appropriate subcontractors constituted a decisive activity in the pre-construction phase. The subcontractor's expertise, financial situation, technical equipment, workforce capacity and reputation could have a direct effect on the quality of the project. Contractor prequalification analysis is the process used by contractors when procuring subcontractors as well as clients procuring contractors. The aim of the analysis is to assure that the subcontractor possesses sufficient expertise in order to meet the specific requirements for the execution of an activity.

Jraisat et al. (2016) and Pheng and Teo (2004) stress the importance of the main contractor and subcontractors working integrated with the quality process. Jraisat et al. (2016) describes the importance of the contractor providing the subcontractors with input complying with the end client's requirements.

Pheng and Tao (2004) goes into depth in the contractor-subcontractor relationship's impact on the quality management of processes in two construction companies based in Singapore. Both companies formed long-term relationships with a few subcontractors and suppliers stretching throughout several projects. This gave time for a quality culture to evolve with the companies and subcontractors committing to a constant quality process. This process included establishing project quality plans for each activity and a mutual commitment to continuous improvement. The subcontractors and suppliers developed an understanding of their respective client's quality needs, facilitating their delivery of services in later projects. It is important to note that the construction companies, although based in Singapore, each had a Japanese top management.

3.1.13 Procurement route

The chosen procurement route regulates the risk distribution; design strategy, including the employment of design consultants, and; project management structure in construction projects. It directly affects the level of integration between design and construction. (Potts and Ankrah 2013).

The two most common procurement routes, or project delivery methods, between client and contractor, as well as the main contractor and subcontractor, are the design-bid-build and design-build agreements. There are however, several forms of arrangements, such as joint venture, consortium and partnering that are commonly used in combination with the more traditional procurement arrangements. In the studied projects of this study, the most commonly used procurement routes were the design-bid-build and design-build arrangements. Therefore, only these two arrangements will be described.

Design-bid-build
The design-bid-build route divides the design and construction. The client assigns the design consultants and is responsible for the detailed design. A main contractor is appointed to perform the construction according to the detailed design generated by the client's design consultants. (Potts and Ankrah 2013).

Potts and Ankrah (2013) describe the advantages of the design-bid-build method to include:

- Clear responsibility,
- High level of cost certainty,
- Contractors and subcontractors can be chosen in a competitive bidding,
- Opportunity to acquire the best design and construction skills in clearly established relationships, and;
- Space to establish the detailed design and technical specification up to the procurement stage of the contractor/subcontractor.

The authors describe the disadvantages of the method to include:

- Potentially adversarial relationship between client and contractor,
- Client cannot include the contractor or subcontractor in the design stage,
- The overall project time may be longer due to the clear separation of the design and construction stages, no overlap of the stages is possible,
- No possibility for the contractor or subcontractor to influence the design documentation, which in turn might affect the buildability in construction process, and;
- Divided responsibilities, with the client having direct contact with all different parties but the contractor/subcontractor being limited to the client; this may pose as a major weakness in case of defects or issues in the construction process.

Design build

The design build route obliges the contractor/subcontractor to assume overall responsibility of both design and construction. The client may assign a project manager, or build manager, to join the contractor's project management in order to secure their interests. The client provides the contractor with a technical description according to which the contractor is supposed to design and build the project. The contractor is then free to assign design consultants, subcontractors and suppliers who have to complete the project according to the established technical description. (Potts and Ankrah 2013).

Potts and Ankrah (2013) describe the following advantages of the design-build method:

- The overlap of the design and construction stages enables early completion of the project.
- The single point of responsibility falls on the contractor/subcontractor.
- The client is free to demand quality and performance specifications for the whole project.
- The contractor/subcontractor can directly influence the buildability of the project through the design.
- The contractor/subcontractor can communicate directly to the design consultants.
- It carries less adversarial opportunity than the design-bid-build method.

- The integration of design and construction mitigates variations in the construction stage.

The authors describe the following disadvantages of the design-build:

- The completed project may not be cheapest.
- The client cannot control and integrate the required quality in the design stage.
- The technical description must clearly describe and state the intended product and functions.
- Any alternations after the project is initiated may be expensive.

3.2 Summary

Infrastructural projects are seeing a rise of subcontractors performing parts of the project activities. Construction companies are reducing their in-house expertise in different technical areas in favor of procuring subcontractors. The process quality of the subcontractors' activities depends on multiple factors appearing in the different stages of the projects. The main contractor's procurement of subcontractors is identified as a crucial stage in which the quality of the process and product can be secured. The design documentation combined with project specifications provide the fundamental information for performing any of the project activities and therefore requests a level of quality and clarity. The main contractor is recognized as being instrumental in coordinating the subcontractors as well as communicating the end client's requirements and expectations. The documentation of any construction project is a substantial source of information for the planning and management of the processes comprising the total project and is necessary for all stakeholders including the contractor and subcontractors.

In this thesis, a main contractor's application of quality management in assuring and controlling the critical activities of subcontractors has been studied. The objective is to generate suggestions for improvements in the studied contractor's quality management procedures.

4 Empirical background

4.1 Projects

During the course of this study, interviews have been conducted with employees from Skanska and subcontractors working on the South Marieholm Bridge project and Hisingen Bridge project. These two projects have been central in the endeavor of answering the research questions and achieving the aim of the study as it revolves around the quality management of the subcontractor's critical activities.

The interviews have been fundamental for shaping the description of both Skanska's quality assurance and quality control of the different technical areas. Skanska's management system has provided support for understanding parts of the documentation although company restrictions have limited the possibility of using parts of the management system directly in this study.

The construction of the South Marieholm Bridge had already finished when the study begun while the construction of the Hisingen Bridge had just started in January 2017. A short description of both projects will follow.

4.1.1 Project South Marieholm Bridge

The South Marieholm Bridge is a railway bridge, over the Göta Älv River, in Gothenburg. The construction of the South Marieholm Bridge started in 2014 and completed in May 2017. It is located south of the Marieholm Bridge, an older railway bridge that was until the completion of the new one the only railway link over the river. The bridge also has lanes for bicycle and pedestrian traffic. Similarly, to the old bridge, the South Marieholm Bridge is a lift-swing bridge i.e. a type of moveable bridge.

The project was a joint venture between Skanska Sverige AB and MT Højgaard under a design-build contract. Skanska was the lead contractor responsible for 70% of the contract while MT Højgaard had responsibility for 30%. More specifically, MT Højgaard was responsible for all steel works and the procurement of subcontractors in this area. Skanska was responsible for the rest, i.e. the earthworks, geotechnical works, concrete works, railway works and the procurement of subcontractors related to all these works. The estimated cost of the project was SEK 790 million. The client is the Swedish Transport Administration.

The aim of the project is to decrease the vulnerability of rail transport over the Göta Älv River and to increase the capacity of the railway to the Port of Gothenburg. The adjacent Bohus line should also benefit from the additional bridge.

4.1.2 Project Hisingen Bridge

Project Hisingen Bridge is an ongoing construction project to replace the existing Göta Älv Bridge with a new bridge, i.e. the Hisingen Bridge. The new bridge will be located to the east of the existing bridge. The construction of the Hisingen Bridge started in January 2017 and is planned to conclude in 2021. The project completion should coincide with Gothenburg's 400 anniversary. The Hisingen Bridge is part of the greater Project Älvstaden i.e. an urban development project that will see the rise of

new residential and commercial areas in the core area of Gothenburg. After its completion, the old Göta Älv Bridge is to be demolished.

This project is a joint venture between Skanska Sverige AB and MT Højgaard. For this endeavor, Skanska and MT Højgaard have formed a partnership under the name Skanska-MTH Hisingsbron HB. The client is Gothenburg municipality's office for transportation (*Trafikkontoret* in Swedish). The contract price is SEK 1.97 billion.

The Hisingen Bridge project is divided into two sections:

- The middle-part of the bridge is to be delivered under a design-bid-build contract, with the client being responsible for the zoning/detailed design and the contractors (Skanska and MT Højgaard) being responsible for the construction of the structure.

- The abutments of the bridge are to be delivered under a design-build contract, with Skanska and MT Højgaard being responsible for both the zoning/detailed design and construction of the abutments.

4.2 Subcontractors

This part of the empirical background describes two of Skanska's subcontractors and the subcontractors' activities in project South Marieholm Bridge. The first subcontractor, Actemium, is providing the same service for Skanska in the Hisingen Bridge project.

The other subcontractor, Infranord, worked as a subcontractor for Skanska on the South Marieholm Bridge project but not on the Hisingen Bridge.

No interviews were conducted with representatives from subcontractors responsible for concrete works and steel works.

4.2.1 Subcontractor background –Installations

Actemium's business activities includes solutions to improve and optimize customer systems and processes in the electrical and automation engineering sectors.

The subcontractor was responsible for the design, programming and installation of the control system for the lift-swing mechanism of the bridge. Similarly, the subcontractor will be responsible for the above-mentioned activities for the Hisingen Bridge. The Hisingen Bridge is however a vertical-lift bridge.

4.2.2 Subcontractor background – Railway works

Infranord is a government-owned corporation whose business activities include the construction and maintenance of railway infrastructure.

Infranord worked as a subcontractor on the South Marieholm Bridge project with Skanska as client. Skanska procured Infranord under a design-bid-build agreement meaning that Infranord was solely responsible for the construction of the railway tracks and connecting installations. Skanska hired Sweco, an engineering consultancy company, for the design of the railway.

4.3 Processes in projects

4.3.1 Quality assurance in the procurement stage

The procurement unit establishes a procurement plan at the start of the project. The procurement plan includes:

- a list over planned procurements,
- the purchasers responsible for each procurement, and
- which procurement strategy is suitable for the service in question.

The procurement strategy can be a framework agreement sent out to the sub-contractors, simple mail inquiries or the identification of the need to establish a strategic cooperation with a certain subcontractor because of the nature of the service. (Procurement manager 2017).

The purchasers evaluate each procurement according to the complexity of the service and the result of the service to the overall project result. (Procurement manager 2017).

In the next phase of the procurement, the procurement unit cooperates with the design and production staff. In this phase, the scope and aim of each service is determined. The design and production staff are crucial in generating the requirements sent to the potential subcontractors. The documentation sent also includes drawings and lists of exact activities that the subcontractor is to perform. (Procurement manager 2017).

Skanska has an electronic portal for subcontractors. This portal has a record of all subcontractors that Skanska has worked with in earlier projects. The subcontractors are pre-qualified using this portal as it describes certain conditions of the subcontractors. (Procurement manager 2017).

The procurement unit provides the subcontractors wishing to apply for the job a login to this portal. The sub-contractors answer questions in this portal including their economic status, number of employees, resources and certifications. (Procurement manager 2017).

The portal then compares their answers to the project requirements already set in the portal and marks the subcontractors red, yellow, green and dark green. Red means that the subcontractor in question does not sufficiently fulfill the project requirements. Yellow means that there is something doubtful with the sub-contractor. Green means that the subcontractor fulfills the requirements while dark green means that the subcontractor in question exceeds the requirements. The purchasers also review the candidates' economic status. The Swedish Tax Agency provides the procurement unit with the candidates' tax history and credit rating. (Procurement manager 2017).

Based on the information generated in the portal, the procurement unit compiles a list of final candidates appropriate for the service and project in question. The procurement unit then produces a draft of the agreement and send it out to the potential sub-contractors. This constitutes a preliminary agreement containing the requirements that the subcontractor must oblige to. Ideally, this draft should be a final

agreement but usually it covers around 50% of the final requirements. This draft constitutes the foundation of the final agreement. (Procurement manager 2017).

The requirements sent to the candidates also include the technical description provided by the client. These requirements include quality requirements. (Procurement manager 2017).

The candidates respond with an offer to this draft. This offer describes the candidate's planned process in delivering the service and fulfilling the requirements. The offer also includes the price for the service. The procurement unit, design staff and production staff evaluate these offers according to how they fulfill the requirements and their price. (Procurement manager 2017).

The procurement unit, design staff and production staff then invite candidates, based on their offers, to interviews. The staff asks the candidates to present how they will meet the requirements and what the candidates include in their prices. The offers do not often describe how the candidates plan to fulfill each and every requirement thus the interview is a chance for each candidate to complement their offers. (Procurement manager 2017).

The procurement unit, design staff and production staff then choose a final candidate based on the interviews. The candidate signs the final agreement and becomes the subcontractor to Skanska. (Procurement manager 2017).

The project management invite the sub-contractor to a starting meeting shortly before the subcontractor starts to work. The project management update the management of the subcontractor regarding requirements and agreements. The project management has a chance to inform the subcontractor about new requirements. (Procurement manager 2017).

The agreement describes the final documentation and drawings that the subcontractor must deliver at the end of their service. (Procurement manager 2017).

Challenges in the procurement stage

The client, production management and design staff all set different requirements for the product as well as the processes delivering the product. The procurement manager (2017) states that the greatest challenge is to identify and integrate all these requirements, from the different project actors, early in the procurement phase. The procurement of subcontractors occurs early in the pre-construction phase while most requirements, technical descriptions and drawings are completed at the end of the design stage. The procurement manager (2017) further states that initiating the procurement of subcontractors after the design stage is too close to construction start. The benefit for the purchasers is the longer time they have to evaluate the candidates. The drawback however is the small amount of established drawings and requirements.

According to the procurement manager (2017), the procurement unit in Skanska is moving towards establishing strategic cooperation with those subcontractors providing services and performing critical activities that contribute a considerable amount of value to the delivered products. The aim is for Skanska to involve these subcontractors in the early stages of the projects. The procurement manager (2017)

describes the aim of integrating the subcontractors in the design stage in which they will have a chance to influence the drawings. This will also give the design staff and production management an opportunity to understand the activities in which they usually lack expertise. This will also give the purchasers an opportunity to partake in the design stage.

Furthermore, Skanska is moving towards integrating the design, production and client in projects using a procurement manager early in the projects (Procurement manager 2017). The design manager, production manager, procurement manager and client's resident engineer will in this set-up work closely in the procurement of sub-contractors.

This team will evaluate the strategic subcontractors' performance with follow-up meetings held after their completion. The follow-up meetings would include:

- performance evaluation,
- a compilation of the process, and
- a description of how the subcontractor has fulfilled the requirements.

(Procurement manager 2017)

This is still not a routine or common practice in Skanska projects. It is often up to the individual procurement manager or production manager to organize these meetings. The procurement manager would then compile and store the experiences generated with the subcontractors in Skanska's procurement portal, available for latter projects.

The incumbent situation is such that projects often overlap. Project staff will move on new projects once they conclude their undertaking on the old project. Therefore, follow-up meetings and evaluations will lose priority. Similarly, subcontractors participating in the early production stages will leave once they execute their work. (Procurement manager 2017).

Procurement routes

The procurement route, or the project delivery method, is established in the agreement between the contractor and subcontractor. The procurement route establishes the main contractor's ability to influence the design and execution of the subcontractor's activities as well as the payment method. The most common procurement routes established between Skanska and its subcontractors in the two projects were design-bid-build and design-build agreements. The subcontractors responsible for the concrete works were procured under a design-bid-build agreement in both projects. Skanska's joint venture partner is responsible for the steel constructions in both projects. The activities and procedures of Skanska's steel, group that has not been involved in the South Marieholm Bridge but will support the joint venture partner during the Hisingen Bridge project, will be described later in the "Quality control" section of the empirical background. The following section will describe the impact of the procurement routes chosen by Skanska for two technical areas in which Skanska lacked expertise, installations and railway works.

Installations

The production manager (2017b) concluded that the procurement route had a fundamental effect on the subcontractor's ability to perform their work. Skanska

procured the subcontractor under a design-build contract in the South Marieholm Bridge project. Thus, the subcontractor was responsible for generating a detailed design of the control station.

Skanska provided the subcontractor with a technical description to enable them to generate the detailed design. Therefore, the technical description had to be adequate in its description of the expected functions of the product. This goes down to the end client who ultimately provided Skanska with the technical description. This worked well in the case of the South Marieholm Bridge because the end client had procured a consultant who could deliver the expected technical description.

Furthermore, the subcontractor and consultant had worked together earlier on other bridge projects, which meant that the subcontractor understood the drawings and descriptions provided by the consultant. The technical description must be sufficient in its description of what the client wants/expects.

Railway works
As mentioned earlier, Skanska procured Infranord under a design-bid-build agreement, with Infranord being responsible for the construction of the railway while Sweco was responsible for the design. This meant that Skanska was responsible for the detailed design and providing Infranord with sufficient drawings and descriptions. (Design manager 2017, Production manager 2017d).

The subcontractor's production manager (2017d) stated that Skanska lacked the expertise or deeper knowledge about railway infrastructure in order to undertake a design-bid-build agreement for the railway works. This became a considerable challenge and recurring issue in the project. This put Skanska in a difficult seat, as they had to understand the questions coming from both the subcontractor (Infranord) and design consultant (Sweco) in order to function as a medium between the two. Skanska also had a responsibility of conveying the end clients wishes and requirements to both the design consultant and subcontractor.

4.3.2 Quality control in the construction phase

Concrete works
The following activities that will be described include Skanska's processes and procedures for monitoring and controlling the concrete subcontractors' activities. The procedures were identical in Project South Marieholm Bridge and Project Hisingen Bridge.

During the procurement stage, the production management and procurement unit eyes the price of the subcontractor. The subcontractors competing for the job are called in to meetings during which the production management presents what they expect during the project regarding quality, health and safety. The production management shows 3D illustrations of what they expect from the subcontractors i.e. the planned structures the subcontractor is supposed to construct. The subcontractors are then sent home to calculate a new price with these conditions included. The production management, procurement unit and design management review the new prices until it is sensible. The subcontractor that has shown best ability to fulfill the requirements and price is awarded the contract. (Production manager 2017c).

The management of the subcontractor's enterprise is invited to a meeting in which Skanska's project management presents the conditions of the project i.e. rules, expectations, requirements, regulations. The project management also shows 3D illustrations of the bridge and which parts/activities are most complicated to construct. Since it is a subcontractor responsible for concrete works in question, their contribution to the project is substantial. The project management aims to make the management of the subcontractor aware of their importance to the project. (Production manager 2017c).

The subcontractor participates in the design of the activities for which the subcontractor is responsible. Skanska's project management provides the subcontractor with supervisors from Skanska, in addition to the subcontractor's own supervisors. In project Hisingen Bridge the subcontractor responsible for concrete works is from Poland, thus the subcontractor supervisor is the only proficient in English. (Production manager 2017c).

The Skanska supervisor has meetings every morning with the subcontractor's entire operative team. These meetings are included in the contract between Skanska and the subcontractor. During these meetings, the supervisor informs the operative team about the project conditions and the importance of completing the works right the first time. The supervisor regularly shows the team pictures of common quality defects in bridge projects as well as pictures of how Skanska and the client expect it to look. Every Monday the supervisor hangs 3D illustrations on the announcement board, visualizing the structure or any other activity that the subcontractor is to finish during the week. The illustrations show what the subcontractor is to complete until Friday the same week. Skanska's supervisor does this every Monday. (Production manager 2017c, Supervisor 2017b).

The supervisor and block manager communicate and visualize any changes applied to the project by the design and production management. The subcontractor's operative team are also shown the illustrations of the bridge and the cost of the different parts of the bridge and the contribution of the subcontractor's activities to the entire project. (Production manager 2017c, Supervisor 2017b).

During the construction of concrete structures, Skanska supervisors performed quality monitoring of the subcontractors' critical activities according to control plans and checklists. Certain activities were quality monitored by the subcontractors' supervisors and there were usually Skanska supervisors present.

Steel works

Skanska has a group concerned with steel works consisting of six engineers and six skilled workers. This group is divided between major projects in the Stockholm area, Gothenburg area and Malmö area. The group is a part of Skanska's "Stora projekt" (Major projects) division although it participates in other projects as well. (Steel group manager 2017).

The steel group did not participate in the South Marieholm Bridge project since the steel works were the responsibility of Skanska's joint venture partner. They are however participating in Project Hisingen Bridge, working as support to the joint venture partner. (Steel group manager 2017).

The following description of the steel group's quality assurance and control procedures is not from any of the projects but a description of their general procedures when assuring and controlling the quality of steel structures from subcontractors.

Quality assurance and control of steel

The steel group actively participates in the procurement process including the choice and evaluation of candidates, often having the final decision in which candidate will be signed as a subcontractor. The group will invite each candidate and present the requirements for the steel works, as well as the group's expectations regarding the manufacturing process. The manufacturing process includes the scheduled time needed for the different parts as well as the client's expectations. (Steel group manager 2017).

The steel group manager stated (2017) that it is important to note that all steel constructions are pre-made in workshops and then delivered to the construction site where it is installed. Skanska purchases all major steel structures from workshops in Poland, Estonia and Finland. Therefore, the manufacturing proceeds in a manufacturing environment.

After the steel group, in collaboration with the procurement unit, chooses a candidate there is a technical briefing. If the steel group has never worked with the subcontractor then the briefing is quite detailed. The steel group invites the subcontractor's workshop management to a meeting where a design engineer participates. The steel group and design engineer present the project goals and their expectations from the subcontractor. The subcontractor is given the opportunity to present their work process and the critical activities in the process. The three parts discuss possible issues and challenges. (Steel group manager 2017).

Furthermore, the steel group manager (2017) described the technical briefings as including the following discussions:

- How control plans describing the quality monitoring of critical activities should be modeled and handled;
- How quality monitoring and inspections of critical acrivities should be performed, valid requirements;
- Handling of questions and answers;
- Possible issues and challenges;
- How to manage any changes in the process;
- What the final documentation should include.

The manager of the steel group (2017) stressed the design stage. The steel group examines the drawings and technical descriptions provided by the client in order to find possible errors. The group also surveys the drawings made by Skanska's own design consultants in order to prevent any possible defects in the construction phase. Thus, the group assures that any drawings and descriptions the subcontractor receives are correct and sufficient.

The steel group manager (2017) described three quality controls during the manufacturing of the steel, i.e. basic controls, impartial controls and production monitoring.

The workshop performs the basic controls. The basic controls are conducted based on control plans that include descriptions of each critical activity. There is a separate checklist attached for each critical activity that describes every control that has to be made for that activity. The basic controls are the equivalent of quality monitoring of critical activities on the building site. (Steel group manager 2017).

A third party performs the impartial controls. Some subcontractors have an internal control unit that is separated from the workshop, usually working directly under the management. Another company most often performs the impartial control. The company is required to have accreditation, certain certificates and vouchers to confirm their competence. The impartial controls include ultra sound tests, magnetic particle inspection and x-ray scanning of the material. (Steel group manager 2017).

Skanska's steel group performs the production monitoring. The steel group usually hires a local company to visit the workshop once a week and write reports. The reports include descriptions of the production process and performed activities, progress of generating documentation and the execution of basic controls. The production monitoring and ensuing reports are not a mandatory activity obliged by Skanska's agreement with the subcontractor or end client. This is an independent monitoring activity in order to ensure the progress of production. The steel group will be aware of all activities, changes and even standstills in the workshop.

The end client receives the control plans and checklists from the basic controls as well as the documentation from the impartial controls as a part of the final documentation. Although not obliged in the agreement Skanska always provides the client with the reports from the production monitoring. (Steel group manager 2017).

Installations

The production manager (2017b) stressed the importance of how the contractor views the subcontractor and relates to them i.e. are they just a temporary unit there to do a job and be paid or are they a part of the total project organization.

The production manager (2017b) stated that his organization's quality management system provides a description of the process of fulfilling quality requirements. The subcontractor in question has a database where all documentation is compiled from the different projects the subcontractor has participated in.

Each project has a unique quality plan in which the subcontractor describes the plan of fulfilling the quality requirements for the specific project. This quality plan includes control plans for each activity i.e. construction and installation. In the pre-construction phase of the South Marieholm Bridge project, the subcontractor submitted the quality plan and control plans to Skanska's project organization after signing the contract. It is important to note that Skanska submitted the quality plan and control plans to the end client to give them an opportunity to understand how the quality requirements would be fulfilled for the installation of the bridges lift-swing mechanism. The end client had to approve the quality plan and the control plan. (Production manager 2017b).

The subcontractor was responsible for performing the quality monitoring of their activities. The quality monitoring was based on control plans that the subcontractor established before the start of their work. Checklists, that include what controls the subcontractor will conduct during the quality monitoring for each activity, supplemented the control plans. The subcontractor was not obliged to present these checklists to the contractor before the start of production. However, the subcontractor had to submit all checklists to Skanska as a part of the final documentation. Skanska's project organization had the right to demand checklists from the subcontractor on specific activities during the project. The subcontractor's production manager was responsible for controlling all of the checklists and for signing them as a verification that the responsible operators had conducted the quality monitoring of their activities. The end client's surveyor eyed the documentation during the inspection phase as to be sure that all quality requirements established in the beginning and referred to through standards and drawings had been delivered. The final documentation was submitted the Swedish Transport Administration's database called IDA. (Production manager 2017b).

The subcontractor was responsible for the design, programming and installation of the control system and electrical installation in the South Marieholm Bridge. The contractor only had quality requirements in the technical description for the subcontractor's activities. The subcontractor's production manager (2017b) assured that this was more than sufficient for the subcontractor to deliver their service. Skanska relied on the experience the subcontractor had from similar projects, as Skanska did not understand much of the technical description but relied on the subcontractor. This put Skanska in a position where they relied on the subcontractor's skill and knowledge, with no way of fully controlling that process. (Production manager 2017b).

The subcontractor's production manager (2017b) affirmed that they enjoyed this type of conditions as they were certain of their ability to deliver what Skanska and the end client desired. However, the production manager (2017b) felt that the backside of this was that other subcontractors operating in these settings could use it against Skanska. Thus, trust is extremely important in this scenario.

The production manager (2017b) states that Skanska has employed an installations coordinator for the Hisingen Bridge project. This is due to the experiences from Project South Marieholm Bridge: Skanska felt that they did not have the control they wished over the activities executed by the subcontractor.

The coordinator in question is an experienced employee of the subcontractor possessing considerable knowledge about the processes and services that the subcontractor provides. (Production manager 2017b).

Railway works

Both the production manager (2017a) and design manager described the railway works as being the most complex activities Skanska's project organization had to manage during the construction of the South Marieholm Bridge. The Hisingen Bridge will have tram tracks, which fall in railway works, but these works have not initiated yet and will therefore not be discussed in this study.

The subcontractor was responsible for performing the quality monitoring of their activities. The quality monitoring was based on control plans that the subcontractor established before the start of their work. Checklists, that include what controls the subcontractor will conduct during the quality monitoring for each activity, supplemented the control plans. The subcontractor was not obliged to present these checklists to the contractor before the start of production. However, the subcontractor had to submit all checklists to Skanska as a part of the final documentation. The subcontractor's production manager (2017d) stated that Skanska did not participate during the quality monitoring of the railway works. The subcontractor solely performed the controls included in the quality monitoring.

The subcontractor responsible for the construction of the railway over South Marieholm Bridge, as well as Skanska's own design manager (2017) affirm that Skanska lacked any knowledge or competence in the design and construction of railway infrastructure. This had a profound effect on Skanska's ability to assure and control the quality process for the subcontractor's activities.

Skanska did not have any procedures or processes to control the subcontractor's activities when constructing the railway. Skanska's design manager (2017) stated that he did control and audit the design documentations received from the design consultant but in a limited capacity. Solely the subcontractor (Infranord) performed the controls of activities using their own supervisors and without much influence from Skanska's personnel. The subcontractor's production manager (2017d) concluded that a lack of understanding of the works negated Skanska's supervisors from fully controlling or surveying the activities of the subcontractor's operative team. Therefore, the challenges faced during the design and construction of the railway infrastructure will be described in this section.

- **Communication** – Skanska's design manager (2017) as well as the subcontractor's production manager (2017d) affirmed that Infranord had a great relationship with the Swedish Transport Administration, the end client, throughout the project. Infranord often came with certain questions directly to the STA in order to speed up the process. However, Infranord had an agreement with Skanska and not STA. The issue when taking questions to the end client (STA) via Skanska was that it could take considerable time before Infranord received an answer. Therefore, Infranord went outside the hierarchy of the project organization. Infranord did establish the questions and answers with Skanska but often after they already had talked to STA. (Design manager 2017, Production manager 2017d).

  During the project, there were occasions when Infranord had to halt the railway traffic in order to perform their activities. These occasions were important and every second week preceding them Skanska, Infranord and STA had meetings revolving around the coming stops. The production manager (2017d) explained that issues and questions between Skanska and Infranord where not suited for these meetings due to the presence of the end client.

  The production manager (2017d) felt that it would have been appropriate for Skanska and Infranord to have meetings every two weeks in order to discuss all railway works. These meetings should also have included the design

consultant (Sweco). This was actually happening in the beginning of the project but after a couple of meetings, the Skanska representative stopped attending.

- **Documentation** – Throughout the project, Infranord had notes on the drawings from Sweco. These notes had to go through Skanska and the resulting discussions often required Skanska's opinion. This sometimes led to deadlocks and drawn out discussions as Skanska could not mediate effectively due to their lack of knowledge in the field.
  (Design manager 2017, Production manager 2017d).

  The production manager (2017d) stated that Infranord had to alter the bill of quantities for the project several times. As Infranord and Sweco often had meetings to solve issues and questions, it often led to changes in the methods or course of action. Infranord had to add these changes in the bill of quantities leading to new costs. As Skanska did not attend the meetings, there would often be discussions about the changes in costs.

- **Block manager** – The railway works consist of four technical areas: track, electricity, signal and telecommunication. Infranord have a supervisor for each work area in order to divide the workload. On the South Marieholm Bridge project, one block manager from Skanska was responsible for coordinating all the railway works. This block manager was also responsible for all questions emerging from the different technical areas included in the railway works. (Design manager 2017, Production manager 2017d).

  The one block manager from Skanska handled all the questions arising in the different railway areas and had to convey questions about design documentation to the design manager. It was the design manager and block manager's task to differentiate the errors caused by the consultants and those caused by deficient technical descriptions from the end client. This proved hard due to the earlier mentioned lack of expertise. (Design manager 2017, Production manager 2017d).

  The production manager (2017d) concluded that the block manager on South Marieholm Bridge had a too large workload.

4.3.3 Documentation

In every Skanska project, the project organization establishes a project plan. The project plan is an application of Skanska's management system to the conditions of the project. Thus, every project plan is unique. This part of the empirical background will focus on the documentation in projects South Marieholm Bridge and Hisingen Bridge and describe the common documents for the projects as well as project-unique documents. Interviews and the project plans for each project form the basis for the description of the documents.

In Project South Marieholm Bridge, the design manager was responsible for establishing the documentation management. During the project, the subcontractors' supervisors and Skanska's own supervisors were responsible for providing Skanska's block managers with the work statements and control plans (including checklists for

controls) for every activity. The block managers were responsible of collecting these documents at the end of the project. The design manager was responsible of collecting all of these documents from the block managers as well as consolidating it into the final documentation.

In project Hisingen Bridge, Skanska's project organization provides the subcontractors with several documents. The quality manager, a position in Skanska's project organization, is responsible for generating these documents. The block managers are then responsible for distributing them to the subcontractors and informing them about the details. Skanska includes these documents as a requirement in the agreements with their subcontractors working on project Hisingen Bridge. The client, Trafikkontoret, gains these documents as a part of the final documentation. (Quality manager 2017).

The quality manager is responsible for establishing the process for finalizing the documentation. Several months before the final documentation needs to be gathered, the quality manager will book a meeting with the block managers to establish what documents they have to retrieve from the subcontractors. (Quality manager 2017).

The documents are specifically concerned with subcontractors and the critical activities they perform. Other documentation regarding other project activities are not included here.

Common documentation

- **Technical description** (both projects) – Drawings and descriptions regarding the projects technical functions. The client provides the contractor with this document. Subcontractors often gain the entire technical description or the parts relevant to their activities.

- **Statement of work** (both projects) – According to provisions provided by the Swedish Work Environment Authority (Building and civil engineering work, (AFS1999:3Eng), provisions), every contractor and subcontractor must provide a statement of work for activities impacting the health and safety, environment, quality, time schedule and cost of the project. The AFS1999:3 upon which statements of work are drawn is first of all concerned with health and safety.

- **Control plans** (both projects) – The Planning and Building Act (*Plan och bygglagen* in Swedish), states that contractors and subcontractors must establish control plans for every activity (Plan- och bygglag (2010:900) 10 kap 6-8 §§). A control plan is a compilation of the activities that comprise an overall activity e.g. concrete works, steel works, railway works, etc. Every activity must have a checklist containing controls and inspections of the different activities.

  A checklist comprises the following data:
  - Controls and inspections
  - Approval of execution (Yes/No) for every control/inspection
  - Deviations in execution

    - Origins of criteria (EN, AMA)
    - Signature of responsible surveyor

- **As built drawings** (both projects) – Drawings visualizing the projects state after completion. These drawings reflect all alterations made by the contractor and sub-contractor during the construction process and are usually submitted as part of the final documentation.

Different documentation

Method Statement (unique for Hisingen Bridge) - In this document, the subcontractors are to describe the following parts:

- Scope of work
- Organization and responsibilities
- Resources - equipment, built-in materials and chemicals
- Permits
- Survey - survey works and how the subcontractors incorporate surveys in their works.
- Environmental conditions
- Health and safety
- Related design documents
- Procedures - The main chapter that in detail describes the operations/procedures/activities required for the implementation. All procedures related to environment are also incorporated here.
- Temporary constructions and special design involvement
- Risk assessment and contingency plan
- Reference documents – refers to Inspection Test Plans, drawings, etc.
- List of attached documents

Inspection Test Plan (unique for Hisingen Bridge) – The purpose of this document is for the subcontractor to describe the following parts:

- Scope of work (same as in the Method Statement)
- Reference documents (same as in the Method Statement)

- List of attached inspections and test documents
- Lis to of test plans
- Plans – Includes activity to be inspected/tested, type of inspection/test, requirements, including tolerances, frequency, responsible supervisor, inspection documents, verified self-inspection (limited to some activities), origin of criteria (EN, AMA, technical description).

Flowcharts (unique for Hisingen Bridge) – The quality manager establishes flowcharts concerning the process of generating complete Method Statements and Inspection Test Plans from the subcontractors. The block managers responsible for providing the subcontractors with the MS and ITP brief the quality manager who then updates these flowcharts.

5 Analysis

5.1 Quality assurance in the procurement stage

Several authors conclude in their studies that the procurement of subcontractors is one of the most decisive stages in the quality process. Yoke et al. (2012) identifies the procurement stage in combination with the management of subcontractors as the factors determining the success of a construction project. Arditi and Chotibhongs (2005) affirm this as well, by studying both structural- and civil engineering projects.

The procurement manager, as well as the production and design staff, describe the procurement process in Skanska as being extensive. Skanska's use of a subcontractor portal, in which the candidates answer questions regarding their economic status, number of employees and certifications, constitutes what Arditi and Gunaydin (1998) describe as a contractor prequalification analysis. Arditi and Gunaydin (1998) state that the aim of the analysis is to assure that the subcontractor's competence meets the specific requirements for the execution of a service. Reflecting back to Skanska's practice, the portal is updated with the project requirements that are compared to the candidates' answers. The candidates are labelled in different colors with respect to their suitability for performing the service. Furthermore, the candidates proceeding to the next stage are given the exact requirements and technical descriptions for the activities for which they are competing to sign an agreement. The procurement unit, design staff and production staff also analyze the offers the candidates return, in which they describe their plan for delivering the service and in which manner they will fulfill the requirements. The procurement process is supported by framework agreements, process descriptions and Skanska's own partnership form, all of which are described in Skanska's management system. It can be concluded that contractor prequalification analysis is applied in Skanska's procurement processes.

The procurement manager states that challenges in the procurement process persist. There are still issues with integrating all of the requirements set by the client, production staff and design staff early in the pre-construction phase. There are many requirements from several different actors to consider. The design staff, production staff and client have different quality requirements that the subcontractors need to fulfill as well as standards and regulations that the subcontractors must oblige to. Thus, the procurement unit is responsible for conveying a considerable amount of quality requirements to the subcontractors early in the pre-construction stage.

This is related to the another issue i.e. that all requirements are usually established late during the pre-construction phase and sometimes even in the beginning of the construction phase. The procurement manager stressed that it is unsustainable to initiate the procurement of subcontractor's during these stages.

Skanska is moving towards establishing strategic cooperation with those subcontractors performing services deemed as critical for the overall project result. The procurement manager acknowledges that this has been achieved with certain subcontractors but that it has to be implemented in several other areas. The subcontractors with whom Skanska has a strategic cooperation are included in the early stages of projects and are integrated in the design process for their activities. Both projects South Marieholm Bridge and Hisingen Bridge have seen Skanska's

subcontractors, responsible for concrete works, procured early and involved in the design process of the concrete structures. This practice goes into agreement with Pheng and Tao's (2004) findings in their study about the impact of contractor-subcontractor relationships on the quality management of construction projects. The studied companies formed long-term relationships with some subcontractors, spanning several projects. The result was improved quality processes, mutual understanding of each other's processes and improved client satisfaction.

Furthermore, Skanska is moving towards integrating the design, production and client in projects using a procurement manager early in the projects (Procurement manager 2017). The design manager, production manager, procurement manager and client's resident engineer will in this set-up work closely in the procurement of sub-contractors. This aligns with Jraisat et al. (2016) as well as Pheng and Tao's (2004) studies in which they stress the importance of the main contractor and subcontractors working integrated.

This team will evaluate the strategic subcontractors' performance with follow-up meetings held after their completion. The follow-up meetings would include:

- performance evaluation,
- a compilation of the process, and
- a description of how the subcontractor has fulfilled the requirements.

Procurement route

The challenges Skanska experienced with the documentation and the coordination of the design and construction of the railway infrastructure during project South Marieholm Bridge originates from their choice of procurement route. The choice would have been suitable if Skanska possessed knowledge and experience in the design and construction of railway infrastructure. This was however not the case and the consequences of the choice were visible in their handling of the design documentation discussions between the subcontractor and consultant as well as their ability to quality monitor the activities of the subcontractor. This was also the opinion of the subcontractor's production manager. A design-build agreement would have been much more suitable and beneficial for Skanska as well as the subcontractor and consultant.

As Skanska was the client towards the subcontractor it is appropriate to relate this to Potts and Ankrah's (2013) description of possible disadvantages with design-bid-build agreements, i.e.

- The client cannot include the contractor or subcontractor in the design stage,
- No possibility for the contractor or subcontractor to influence the design documentation, which in turn might affect the buildability in construction process, and;
- Divided responsibilities, with the client having direct contact with all different parties but the contractor/subcontractor being limited to the client; this may pose as a major weakness in case of defects or issues in the construction process.

These disadvantages manifested during the railway works on the South Marieholm Bridge project. Skanska did not include the subcontractor in the design and this led to the lack of influence from the subcontractor on the design and resulting buildability of the railway infrastructure.

Skanska had direct contact with the design consultants and subcontractor, but according to the agreement, all communication between the subcontractor and design consultants had to be conveyed through Skanska. The numerous issues that arose prompted the subcontractor to communicate directly to the design consultant in order to save time. This was however, outside the chain-of-communication. This is also a result of the design-bid-build agreement. Therefore, the claim that a design-build agreement would have been more appropriate for the railway works becomes more justified.

The installations subcontractor's production manager concluded that the procurement route had a fundamental effect on their ability to perform their work. Skanska lacked any knowledge or competent personnel in the field of installations during the South Marieholm Bridge. This motivated Skanska's choice of procuring the subcontractor responsible for the installations under a design-build contract in the South Marieholm Bridge project. With the subcontractor providing both design and installations, the integration of these phases facilitated the installations subcontractor's performance. Comparing it to the railway works, this could strengthen the claims made by Infranord's production manager that a design-build agreement would have been more beneficial for the railway construction.

The production manager from the installations subcontractor remarked that even though the procurement route assisted the progress of the installations works, it could only be sustained through full transparency between Skanska and the subcontractor's operative team. As Skanska did not have knowledge about the works, the subcontractor explained meticulously their activities and their plans for achieving the required quality goals. Continuous communication was also helpful in informing Skanska of the progress and changes.

The procurement route is thus not enough for securing the quality of the subcontractors' activities, as it should be combined with transparency and continuous communication between contractor and subcontractor. The contractor would then be able to understand and follow the subcontractors' activities and performance. A strategic collaboration through several projects could help develop the trust needed to achieve transparency through a strategic collaboration.

5.2 Comparison of the chosen technical areas

Looking at the four technical areas that have been studied, the quality management of the critical activities included differ considerably. First of all the nature of the execution of concrete works, steel works, installations and railway works differ. Furthermore, the knowledge and resources Skanska possesses in the different technical areas diverges.

5.2.1 Concrete

A large number of skilled workers perform the concrete works on-site. The subcontractors are almost exclusively foreign and their workers have usually no

Swedish proficiency and often lack any English knowledge. They rely on interpreters acting as supervisors, although there is usually older workers who are the informal leaders. The cost of the concrete works also constitute a considerable percentage of the total contract price. Skanska possesses expertise in concrete works in the form of experienced production managers, block managers and supervisors who have worked in several bridge and road projects.

This is visible in the quality management of these subcontractors as Skanska actively participates in the procurement, design and construction phases involving concrete. Skanska's production managers, design managers and procurement unit have rigorous procurement proceedings in which they make clear what the candidates are expected to deliver. The chosen candidate, that becomes the subcontractor responsible for the concrete works, is included in the design phase. Skanska's block managers and supervisors work closely with the subcontractor's operative team, providing guidance and support. There are regular morning meetings where Skanska's supervisors and block managers update the subcontractor with changes in the process and what Skanska expects from the subcontractor. The subcontractor's operative team are shown illustrations of the future structures that they are expected to finish for each week. Skanska's supervisors also perform quality monitoring of the subcontractors' activities according to control plans and checklists.

This aligns with the statements made in several theoretical sources. Yoke Lian et al. (2012), Arditi and Chotibhong (2005), and Arditi and Gunaydin (1998) stress the importance of establishing quality requirements during the procurement of subcontractors. The authors deemed the candidate's expertise, financial situation, resources and reputation as important factors in the choice of a final subcontractor. The contractor also has the opportunity to convey the quality requirements with the future subcontractor as well as the existing project terms. This is very visible in Skanska's procurement process of the concrete subcontractors on both Project Hisingen Bridge and Project South Marieholm Bridge, with the production managers, block managers and supervisors being satisfied with the concrete works.

The same authors also state that the main contractor's ability to manage subcontractors is crucial for the overall quality of the product in both structural and civil engineering projects. Arditi and Gunaydin (1998) conclude that the construction managers in their study found main contractor's supervision of the subcontractors as the most important activity in the construction phase.

Jraisat et al. (2016) and Pheng and Teo (2004) stress the importance of the main contractor and subcontractors working integrated with the quality process. Jraisat et al. (2016) describes the importance of the contractor providing the subcontractors with input complying with the end client requirements. Thus, another part of the theory aligns with Skanska's practices concerning the concrete subcontractors, i.e. continuous management and supervision of the subcontractor. The method Skanska supervisors and block managers use where they show 3D illustrations of the expected results is a way of assuring that the end client's requirements are fulfilled.

5.2.2 Steel

The concrete works and steel works see certain similarities as well as differences. The steel structures used in and on the bridge are produced in a manufacturing

environment, as contrary to the concrete works' site based production. The production of the steel structures are performed with standardized procedures in a workshop and is thus a controlled environment as opposed to the dynamic environment on the building sites. The subcontractors are almost exclusively from Poland, Estonia or Finland and the workshops where the steel structures are produced are based in these countries.

Skanska possesses expertise in the steel area in the form of a steel group i.e. a team consisting of six engineers and six skilled workers. The group works on several Skanska projects all over Sweden, mostly in the Stockholm area, Gothenburg area and Malmö area. The team actively participates in the procurement process of steel subcontractors, establishing the quality requirements with the candidates. The steel group also have a start-up meeting with the chosen candidate, a technical briefing, where they discuss and establish technical descriptions, drawings, controls and inspections. The group also examined the technical descriptions and drawings from the end client in order to identify possible errors. It is clear that the steel group engages in the quality assurance of the steel works comparing this to the definition given by Rajendran et al. (2012) and ISO 9000.

Skanska's steel group also implements quality control in cooperation with the subcontractor's workshop. While the subcontractor is responsible for the basic controls of their own processes, Skanska's steel group conducts production monitoring. A local company hired by Skanska visits the workshop once a week to write reports on the progress of the subcontractor and if the subcontractor is executing the basic controls. Skanska is not obliged to perform the production monitoring according to their agreement with the end client, it is on the initiative of Skanska's steel group.

What is also important to note is that Eurocode standards require certain inspections to be performed by a certified third party. These impartial controls are also a part of the quality control.

Project South Marieholm Bridge did not see the engagement of Skanska's steel group because all steel works were the responsibility of Skanska's joint venture partner. The joint venture partner had their own procedures and routines for controlling the Polish subcontractor hired for the production of the steel structures. There were problems in the form of structures arriving on the construction site with the wrong steel quality as well as damages. Skanska is working with the same joint venture partner on the Hisingen Bridge project and the steel group will cooperate with and provide support to the joint venture partner. This is a measure taken to avoid the problems experienced on Project South Marieholm Bridge.

As mentioned above, Skanska possesses expertise for steel works but the contractual agreement for the South Marieholm Bridge was such that they were not included in the project organization. This study has not gone into the depths of the joint venture partner's procedures and processes for securing the quality of the steel structures they were responsible for on South Marieholm Bridge and are now again responsible for on Project Hisingen Bridge. This has not been considered due to the delimitation of the study. It is sufficient to say that the results on South Marieholm Bridge prompted

Skanska and their partner to include Skanska's steel group in the construction of the Hisingen Bridge.

5.2.3 Installations

The installation of the control system for the lift-swing mechanism of the South Marieholm Bridge proceeded during the final stages of the construction phase. Skanska procured the subcontractor, Actemium, under a design-build agreement. The installations of this control system constitute activities that Skanska did not have knowledge in, at least not during Project South Marieholm Bridge. The subcontractor's production manager states that several factors were decisive in their ability to deliver their service according to requirements.

Firstly, the design-build procurement route was appropriate as Skanska lacked the capacity to control the design while the subcontractor had experience from an earlier, similar project. The quality requirements, from the end client, were only specified in the technical description. This was sufficient, as the subcontractor was familiar with the standards to which the technical description referred.

Secondly, the subcontractor's management had continuous communication with Skanska's project management during the subcontractor's time on the project. Skanska's project management and the subcontractor's management discussed issues that arose as the subcontractor was carrying out the activities. The subcontractor's production manager praised Skanska's production manager on the South Marieholm Bridge project for showing understanding and dedication for all works including the installations.

Something that was prevalent during the involvement of the subcontractor responsible for the installation of the control system was transparency. Actemium's production manager affirmed that already in the procurement stage they had been fully clear over the activities and services that were included in the price they were offering. They had listed all activities and described them to Skanska's procurement unit and project management. The production manager concludes that this helped thee performance.

Interestingly, Skanska has hired an installations coordinator for Project Hisingen Bridge. The coordinator is a former employee at Actemium. Actemium's production manager that had been responsible for their activities at the South Marieholm Bridge recognizes Skanska's doubt over transferring the full control of the installations activities to the subcontractor. He states that even though there was trust, Skanska's project management felt displeasure with not being able to follow the quality requirements that had to be achieved. With the installations coordinator, Skanska wishes to be able to follow the subcontractor's process of fulfilling the quality requirements described in the technical descriptions and standards. The coordinator will be able to ask questions and confirm that the subcontractor is performing as agreed in the contract.

The subcontractor's production manager (2017b) stated that the installation works were affected by the delays in other preceding activities as well as the joint venture partner's failure to complete an activity directly linked to the installations works. The production manager's (2017b) experience related to this led to the conclusion that the contractor has to provide each subcontractor with adequate pre-conditions to perform

their activities. Yoke-Lian et al. (2012) state that the main contractor's construction management needs to understand the subcontractor's scope of work and the logical dependencies between the different activities in order to assure the long-term successful delivery of the entire project. This aligns with the production manager's statement and it is possible to draw the conclusion that Skanska needs to understand all their subcontractors' scope of works as well as the dependencies between the different activities. This means that the main contractor must actively work with all of their subcontractors and work to understand their needs.

5.2.4 Railway

Railway infrastructure made up a considerable part of the completed South Marieholm Bridge while the ongoing Hisingen Bridge has not yet reached that stage. Therefore, the discussion will revolve around the railway works during the South Marieholm Bridge, much like the empirical background. Contrary to the concrete and steel works, the railway works fall into the technical area in which Skanska lacks knowledge and expertise. There are no employees in Skanska's Gothenburg office with extensive knowledge or experience from the area of railway infrastructure. The procured subcontractor responsible for the railway construction as well as the consultant responsible for the design were both Swedish in the South Marieholm Bridge project. This removed the language difficulties often experienced in the work with foreign subcontractors. Subcontractors for concrete works and steel works are almost exclusively foreign.

In the procurement stage, Skanska only conveyed the quality requirements found in the end client's technical description as well as the drawings and specifications generated by the design consultant. Skanska provided no other specific information or procedures during the procurement.

Throughout the South Marieholm Bridge project, the subcontractor responsible for the construction of the railway had notes of errors on the drawings and technical descriptions. Skanska's block manager had to convey this to Skanska's design manager who in turn conveyed it to the design consultant. Certain errors were due to faults in the end client's technical descriptions that the design consultant had integrated in the drawings. This craved considerable railway knowledge from Skanska's block manager and design manager in order to understand the difference and origin of the errors.

Arditi and Gunaydin (1998) stress the importance of project specifications as a medium to convey the end client's quality requirements. The authors conclude that the contractor's project management needs to communicate the project specifications, including quality requirements, performance requirements, drawings and technical descriptions to all project actors. The subcontractor's production manager for the railway works states that this was not achieved during the construction of the South Marieholm Bridge. Skanska's design manager states that this was a result of Skanska's insufficient knowledge in the area of railway design and construction.

Burati et al. (1992) identify design documentation, in the form of drawings and additional descriptions, as a crucial part of the project specifications. Their study showed that 93.6% of defects found in nine major civil engineering projects were the result of deviations in the design documentation and the construction activities.

Skanska's design manager and the subcontractor's production manager in South Marieholm Bridge stressed the importance of the project specifications, including design documentation, and the role of the design consultant.

This leads the discussion into another topic namely communication. Both Skanska's design manager and the subcontractor's production manager described that there were regular meetings between the subcontractor and the design consultant. Skanska's representatives attended these meetings at first but stopped after a while. There were regular meetings between Skanska, the end client (the Swedish Transport Administration) and the subcontractor concerning railway stops. The subcontractor's production manager felt that these meetings were not sufficient. The production manager stated that the subcontractor should have had regular meetings about the railway works with Skanska and the design consultants.

This reflects Arditi and Gunaydin's (1998) views on communication as the authors affirm that communication between the client, construction management and design management was crucial for achieving the required quality during a project. The subcontractor's production manager's remarks about meetings, and the fact that Skanska and the subcontractor did not have any meetings together is peculiar as this is described in several theoretical sources as a fundamental quality control tool. Skanska's quality control of the railway subcontractor's activities was next to non-existent. Skanska's design manager was active in controlling and examining the design documentation generated by the consultant, but lack of experience and knowledge inhibited much of the quality assurance possible in the design documentation.

The challenges Skanska experienced with the documentation and the integration of the design and construction of the railway originates from their choice of procurement route. The design-bid-build agreement Skanska had with Infranord would have been suitable if Skanska possessed knowledge and experience in the design and construction of railway infrastructure. This was however not the case and the consequences of the choice were visible in their handling of the design documentation discussions between the subcontractor and consultant as well as their ability to control the activities of the subcontractor. Skanska was not able to examine the design documentation properly and judge whether errors were due to the design consultant or the client's technical description. The integration of design and construction was a challenge, which Skanska never solved, and there were issues until the end of the railway works. This was also the opinion of the subcontractor's production manager. A design-build agreement would have been much more suitable and beneficial for Skanska as well as the subcontractor and consultant.

The project organization regarding the railway works was also an issue in the South Marieholm Bridge project. Skanska had one block manager that was responsible for the railway works. This block manager had the task of coordinating all the different technical works comprised by the railway works, i.e. tracks, electricity, signal and telecommunication. This was however not a small task. Each technical area mentioned earlier that constitute railway works have their own design, supervisors and technical specialists. The one block manager from Skanska handled all the questions arising in the different railway areas and had to convey questions about design documentation to the design manager. It was the design manager and block

manager's task to differentiate the errors caused by the consultants and those caused by faulty technical descriptions from the end client. This proved hard due to the earlier mentioned lack of expertise.

Interestingly, both the subcontractor's production manager and Skanska's design manager recommended the same solution to these problems in future projects. They suggested that Skanska should employ a coordinator of railway works. This coordinator should have considerable knowledge and experience about railway design and construction, thus integrating the two activities while also coordinating the railway works with the activities of other subcontractors and project actors.

5.3 Documentation

A recurring topic during the interviews was the documentation management during projects. There was consensus among Skanska's district managers, operative managers, project managers, production managers, design managers and quality manager about the importance of project documentation. Many interviewees from Skanska felt that the documentation handling could be improved and taken more seriously. A block manager stated, "It is always more fun to build than to sit with the administrative work afterwards" and that this might be a factor to why it has often been sidelined. The clients for major civil engineering projects are usually either the Swedish Transport Administration or a municipality's transport office. As state actors, these clients require extensive documentation in the final documentation in order to prove that the contractor has fulfilled the quality requirements established in the beginning of the project.

Skanska has had issues with documenting the quality throughout the construction process and during the final phase of the projects, in the inspection, there has often been issues with insufficient final documentation. The reason is due to the above stated fact that many block managers and supervisors prefer constructing but the task of sitting down afterwards and filling in checklists and control plans is not yet an appreciated routine. This is a part of the greater development in the construction industry where managers on all levels have much more administrative work and documentation to work with. The interviewees state that this is low-hanging fruit where Skanska can become better with not much effort.

The General Material and Workmanship Specifications (*Allmän material- och arbetsbeskrivning* in Swedish, abbreviation: AMA), are reference documents which include (among other processes) control activities and related documentation for critical activities. Project specifications usually refer to these documents and therefore the final documentation always includes control plans and checklists for critical activities performed both by the main contractor and the subcontractors. Important to note: the AMA also describes time schedules for the critical activities and budget statements from the subcontractors.

During Project South Marieholm Bridge, the crucial documentation involving quality controls were the control plans and checklists. The production manager for the construction of the South Marieholm Bridge stated that the documentation process went well but that there were some issues with assembling the control plans and checklists from certain subcontractors. Furthermore, the production manager stated that it was questionable if every subcontractor's control plan and controls in the

checklists were performed correctly, as human errors could mar the performance of the controls. Several of the interviewees also stated that a recurring issue was the collection of the final documentation. This reflects the above mentioned view that there still are issues in construction projects related to the documentation management.

The planning phase of projects is identified both by Kozlovska et al. (2016) as the stage where the final documentation should be established. The authors also describe a construction project's documentation as a tool to manage and evaluate the different processes that comprise the total project. Many of the interviewees share these views. The production manager (2017a), design manager (2017) and block managers (2017a, 2017b) state that in the pre-construction phase, the client is usually insecure and not clear about what they expect in the final documentation. There are certain documents that Skanska and the client always establish in the beginning of projects to be included in the final documentation. The client often adds new documents in the later stages of the project as it becomes clearer what will be required for the final inspections and commissioning. These documents may prove hard to generate, as they might be from already completed processes.

The Hisingen Bridge project has introduced certain new ways of documenting that could be interesting to include in other projects. The Method Statements, Inspection Test Plans and flowcharts are all tools that force the subcontractors to describe their processes and related information meticulously. The quality manager is responsible for providing the subcontractors with these documents and for coordinating the finalization of the documentation. The design manager, that is usually responsible for these activities, will thus be relieved of a quite extensive task. The subcontractors still have to provide the statement of work and control plans, with supporting checklists, as in other projects. However, this is an additional requirement from the subcontractor that is included in Skanska's agreements with all their subcontractors. This might be suitable to integrate in to Skanska's management system, as it will possibly improve the documentation management as well as the quality control of the subcontractors' activities.

5.4 Effects of privatization

It is necessary to discuss the reasons for this lack of knowledge in railway construction, as it is widespread among the main construction companies in Sweden. Formerly, the Swedish Rail Administration (*Banverket* in Swedish, abbreviation: SRA), a Swedish state administrative authority, maintained and constructed all railways in Sweden. This meant that the Swedish state had a monopoly on all railway maintenance and production with the SRA performing all bigger and smaller railway projects. Before 2010 during infrastructure projects in which several structures were built e.g. roads, bridges, railways, etc. the Swedish Road Administration (*Vägverket* in Swedish) used to procure the services for constructing roads and bridges from a contractor while procuring the SRA separately for designing and constructing the railway infrastructure. The railway works were never given to the contractor.

However, in 2010 the Swedish Government integrated parts of the Swedish Rail Administration into the newly formed Swedish Transport Administration while leaving Infranord as a government-owned corporation whose business activities include the construction and maintenance of railway infrastructure. With this the

government effectively privatized the railway sector with the aim of creating market competition. This has brought a new dynamic into the Swedish construction industry: the STA and municipalities often procure all services, including railway design and construction, from one contractor for major infrastructure projects. This adds to a new technical field that all major contractors, such as Skanska, must adapt to and be able to offer.

As the privatization occurred not a long time ago, many experts in railway infrastructure either work in Infranord or in some of the newly formed private railway contractors. Many experts in railway design work for engineering consultancy companies such as Sweco or ÅF. Therefore, contractors have been forced to take major infrastructure projects that involve railway works to stay competitive, even though they lack much needed knowledge and expertise in this field.

Both Skanska's design manager and Infranord's production manager pointed out that, during the South Marieholm Bridge project, Infranord was used to communicate directly with the end client, the Swedish Transport Administration. Certain decisions regarding the railway works were taken without consulting with Skanska and this seems to be a habit left from the days before 2010 when the STA procured the services of Infranord without any middle-hands. This is something that both the design manager and production manager thought needed to be altered with a clear knowledge of who the real client is with respect to the subcontractor. This could have been established with regular meetings between Skanska and Infranord where Skanska would have coordinated with Infranord and Infranord could have updated Skanska of any changes and dialogues held with the end client.

The STA have become the chief clients of major infrastructure projects in Sweden. There has also been an increase in Swedish municipalities being clients in infrastructure projects e.g. the Hisingen Bridge studied in this thesis.

Warsame (2012) discusses the differentiation and integration of construction organizations with a focus on the housebuilding industry. What the author states is that an organization can choose to keep a large in-house expertise in the form of skilled laborers in different technical areas that will increase the organization's competence but simultaneously impair the organization's ability to adapt to economic changes on the market. The other choice is that the organization procures services from specialist subcontractors and thus adapt competitively to the prevailing economic settings while also allocating risk to another party. The downside is however that the organization will depend on the expertise of others. Referencing to the empirical findings from this study this is clearly the case in the civil engineering sector as well. Although Skanska has dismantled much of their specialist laborers in almost all technical areas in their civil engineering sector they still have many project managers, production managers, design managers, block managers and supervisors who have experience and knowledge about concrete, foundations, steel and installations. This has enabled them to quality assure and control much of their subcontractor's activities as it is crucial to be able to monitor and follow the processes of the subcontractors.

Looking at Warsame's (2012) theory, there is a need for a balance in order to survive on the market: as a major construction and development company there is no need

either to keep a large in-house work force or to situate the company at the mercy of subcontractors. The coordinating managers that run the project must have some knowledge about the works the subcontractors perform.

The railway privatization will force the major construction and development companies to adapt by acquiring a certain degree of knowledge about the field. This is paramount if quality is to be achieved. As mentioned earlier, both railway subcontractors as well as Skanska's own staff have stated the need to hire coordinators competent in the field of railway works in order to quality assure and control the processes associated with this technical area.

6 Discussion

The research questions formulated in the introduction chapter will be answered and discussed in this chapter.

6.1 Research question No. 1

Which processes and methods are available to assure and control the quality of critical activities executed by subcontractors?

Skanska assured and controlled the critical activities of its subcontractors responsible for concrete works, steel works, installations and railway works in various ways. It is important to note that the methods and processes differed depending on the activity, and this will be taken into consideration in the answers below.

- Prequalification analysis – This analysis is performed in the procurement of all subcontractors and includes several steps. The first is the establishment of a procurement plan. Afterwards, the procurement unit cooperates with design staff and production staff in order to establish all quality requirements.

  Skanska's use of a subcontractor portal, in which the candidates answer questions regarding their economic status, number of employees and certifications, constitutes an important part of their subcontractor prequalification analysis. The purpose of the analysis is to assure that the subcontractor's competence meets the specific quality requirements for the execution of a service.

  Furthermore, the candidates competing to be signed as subcontractors are labelled in different colors with respect to their suitability for performing the service. Furthermore, the candidates proceeding to the next stage are given the exact requirements and technical descriptions for the activities for which they are competing to sign an agreement.
  The procurement unit, design staff and production staff also analyze the offers the candidates return, in which they describe their plan for delivering the service and in which manner they will fulfill the requirements.

- Technical descriptions – Drawings and descriptions regarding the projects technical functions. The client provides the contractor with this document. Subcontractors often gain the entire technical description or the parts relevant to their activities. The reason why this part of the documentation is different from the other documentation (described below) is that the end client provides it in the earliest stages of the pre-construction phase. In design-build projects, the technical description is often the basis for the detailed design the main contractor generates. This document is common in every project.

- Meetings – Skanska's supervisors and block managers had meetings every morning with the subcontractor's operative team responsible for concrete works in both of the studied projects. These meetings are included in the contract between Skanska and the subcontractor. During these meetings, the

supervisor informs the operative team about the project conditions and the importance of completing the works right the first time.

Skanska's supervisors and block managers communicate any changes in the design or procedures. The supervisor regularly shows the team pictures of common quality defects in bridge projects as well as pictures of how Skanska and the client expect it to look. Every Monday the supervisor hangs 3D illustrations on the announcement board, visualizing the structure or any other activity that the subcontractor is to finish during the week.

- Illustrations of defects – In both projects South Marieholm Bridge and Hisingen Bridge, Skanska's supervisors and block managers responsible for concrete works had morning meetings with the subcontractor's laborers/operative team. During these meetings, the supervisor regularly showed the team pictures of common quality defects in bridge projects as well as pictures of how Skanska and the client expect it to look.

- 3D illustrations – In both of the studied projects, every Monday the supervisors for the concrete works hanged 3D illustrations on the announcement board, visualizing the structure or any other activity that the subcontractor is to finish during the week. The illustrations show what the subcontractor is to complete until Friday the same week. Thus, the subcontractor always has visual and illustrative guidance of what to construct.

- Quality monitoring of critical activities – Both on the South Marieholm Bridge as well as the Hisingen Bridge, the critical activities that subcontractors performed for concrete works were always attended by Skanska's supervisors and sometimes even block managers. The supervisors followed the procedures and verified that the subcontractor's laborers carried out the critical activities according to the control plans and checklists. This was done to assure that the quality requirements were fulfilled.

- Coordinator – Skanska has hired an installations coordinator for Project Hisingen Bridge. This coordinator is tasked with managing the design consultant as well as supporting the subcontractor responsible for installing the vertical-lift mechanism on Hisingen Bridge. The coordinator would also be tasked with coordinating the installations subcontractor with the activities of other subcontractors and project actors.

  The installations subcontractor states that the coordinator should assure that discussions and ambiguity are avoided, regarding what is included in the price of the subcontractor's activities. During the procurement negotiations, the coordinator can ask the subcontractors, submitting requests for performing the job, what exactly is included in their price. The coordinator may also review the drawings in the technical description and ask how the subcontractor plans to execute the different parts.

  Interestingly, several Skanska representatives, i.e. the district manager for infrastructure, a block manager, and the design manager as well as the

production manager from Infranord have recommended that Skanska employ a coordinator for the railway works.

- Documentation – Documentation is used to specify quality requirements as well as verify that the requirements have been satisfied. The common documentation for both projects were as built drawings, statements of work, control plans and checklists. The Hisingen Bridge project includes Method Statements, Inspection Test Plans and flowcharts.

- Technical briefings – Skanska's production manager as well as responsible supervisors and block managers always invite subcontractors for a technical briefing before they are to start their work. The technical briefings include:

    - How control plans describing the quality monitoring of critical activities should be modeled and handled;
    - How quality monitoring and inspections of critical acrivities should be performed, valid requirements;
    - Handling of questions and answers;
    - Possible issues and challenges;
    - How to manage any changes in the process;
    - What the final documentation should include.

  These technical briefings are also held with Skanska's subcontractors responsible for steel constructions. However, because Skanska's steel group were not involved in the South Marieholm Bridge, this was not done in that project. The steel group will assist Skanska's joint venture partner on the Hisingen Bridge project and these briefings will be held with the steel subcontractors.

  Skanska also held technical briefings with the subcontractors responsible for the installations and railway works.

- Quality monitoring of manufacturing of steel structures – These controls are unique for the production of steel constructions as these works are performed in a manufacturing environment. Skanska's steel group has standard processes for the quality control of these activities and they include the following three controls:

    - Basic controls – The workshop, manufacturing the steel constructions, performs the basic controls. The basic controls are conducted based on control plans that include descriptions of each critical activity. There is a separate checklist attached for each critical activity that describes every control that has to be made for that activity. The basic controls are the equivalent of quality monitoring of critical activities on the building site.

    - Impartial controls – A third party performs the impartial controls. Some subcontractors have an internal control unit that is separated from the workshop, usually working directly under the management. Another company most often performs the impartial control. The

company is required to have accreditation, certain certificates and vouchers to confirm their competence. The impartial controls include ultra sound tests, magnetic particle inspection and x-ray scanning of the material.

- Production monitoring – Skanska's steel group performs the production monitoring. The steel group usually hires a local company to visit the workshop once a week and write reports. The reports include descriptions of the production process and performed activities, progress of generating documentation and the execution of basic controls. The production monitoring and ensuing reports are not a mandatory activity obliged by Skanska's agreement with the subcontractor or end client. This is an independent monitoring activity in order to ensure the progress of production. The steel group will be aware of all activities, changes and even standstills in the workshop.

The end client receives the control plans and checklists from the basic controls as well as the documentation from the impartial controls as a part of the final documentation. Although not obliged in the agreement Skanska always provides the client with the reports from the production monitoring.

6.2 Research question No. 2

What are the challenges with quality management of subcontractors?

- Integration of all quality requirements in the procurement stage – A great challenge is to identify and integrate all requirements, from the different project actors, early in the procurement phase. The procurement of subcontractors occurs early in the pre-construction phase while most requirements, technical descriptions and drawings are completed at the end of the design stage. Initiating the procurement of subcontractors after the design stage is too close to construction start. The benefit for the purchasers is the longer time they have to evaluate the candidates. The drawback however is the small amount of established drawings and quality requirements.

- Unsuitable procurement routes – Looking at the railway works in the South Marieholm Bridge, Skanska's choice to procure the subcontractor for the railway construction under a design-bid-build agreement proved problematic. Skanska lacked the expertise or deeper knowledge about railway infrastructure in order to control the design as well as integrating the design and construction of the railway infrastructure. This became a considerable challenge and recurring issue in the project as it was up to Skanska to integrate the design and construction of the railway infrastructure.

- Lack of suitable conditions for the subcontractors to perform their work – During the South Marieholm Bridge project, the contractor's joint venture partner was responsible for erecting the control station for the lift-swing mechanism of the bridge, as it was a steel structure. The partner had assured Skanska and the subcontractor's production manager that the control station

would be finished at the agreed time. This was however not the case and led to delays and the need to perform several activities simultaneously. The handling of the steel constructions affected the overall time schedule of the project. This shows the importance of providing the subcontractors with right conditions and the need to respect time-schedules.

- Lack of communication – The subcontractor responsible for the construction of the railway infrastructure affirmed that an issue in the construction of the South Marieholm Bridge was the fact that they did not have regular meetings or technical briefings with Skanska's project organization. This contributed to Skanska's limited knowledge about the proceedings of the railway construction. The subcontractor also came with questions directly to the end client in order to speed up the process. However, the subcontractor (Infranord) had an agreement with Skanska and not the end client. The issue when taking questions to the end client (STA) via Skanska was that it could take considerable time before Infranord received an answer. Therefore, Infranord went outside the hierarchy of the project organization.

- Quality of design documentation – The production manager (2017a) and design manager (2017) responsible for the South Mareiholm Bridge stated that the overall quality of design documentation, submitted by external consultants, has declined. This was prominent in the design documentation for the railway infrastructure. They believe that the engineering consultants have a lack of resources, including personnel, to be able to deliver the design documentation at the required pace and quality. Design consultants are often tied up in many projects, resulting in the consultants overstretching their personnel.

- Privatization – The privatization of the railway sector in Sweden has shed light upon a new phenomenon in the construction industry. Due to the increase in privatization of former state-operated sectors, the activities once monopolized by state-actors are being assigned to construction companies.

  It is forcing the major construction and development companies to adapt by acquiring a certain degree of knowledge in these fields, such as railway infrastructure. This is paramount if quality is to be achieved and sustained. As mentioned earlier, both railway subcontractors as well as Skanska's own staff have stated the need to hire coordinators competent in the field of railway works in order to quality assure and control the processes associated with this technical area.

7 Recommendations

The purpose of this chapter is to summarize the different suggestions and improvements that have been generated through the interviews. The suggestions are available methods in the different projects as well as ideas for new methods and practices with the aim of facilitating the assurance and control of the critical activities performed by subcontractors. This chapter is an extension of the empirical background. Some of the suggestions found in this chapter have already been described in the empirical background while others are mentioned here for the first time.

7.1 Procurement stage

Transparency – Both the procurement manager (2017) and the installations subcontractor's production manager (2017b) stressed the importance of transparency in the procurement process. During the procurement of the installations subcontractor, the subcontractor calculated the price for the work they were to deliver and which activities the subcontractor would perform in the technical description. This is due to transparency: the subcontractor wanted to be clear regarding what they would deliver and what Skanska was paying for. The subcontractor pointed out any activity demanded in the technical description that the subcontractor lacked skill in performing. This gave Skanska the possibility to procure another subcontractor for executing that specific activity. Furthermore, this is a way to avoid drawn-out discussions about point of responsibility during the execution-phase. (Production manager 2017b).

Strategic cooperation – According to the procurement manager (2017), the procurement unit in Skanska is moving towards establishing strategic cooperation with those subcontractors providing services and performing critical activities that contribute a considerable amount of value to the delivered products. The aim is for Skanska to involve these subcontractors in the early stages of the projects.

The procurement manager (2017) describes the aim of integrating the subcontractors in the design stage in which they will have a chance to influence the drawings. This will also give the design staff and production management an opportunity to understand the activities in which they usually lack expertise. This will also give the purchasers an opportunity to partake in the design stage. The subcontractor responsible for installations on both projects with whom Skanska has a strategic cooperation also described this.

Integration of the different requirements – Skanska is moving towards integrating the design, production and client in projects using a procurement manager early in the projects (Procurement manager 2017). The design manager, production manager, procurement manager and client's resident engineer will in this set-up work closely in the procurement of sub-contractors.

This team will evaluate the strategic subcontractors' performance with follow-up meetings held after their completion. The follow-up meetings would include:

- performance evaluation,
- a compilation of the process, and

- a description of how the subcontractor has fulfilled the requirements.

(Procurement manager 2017)

This is still not a routine or common practice in Skanska projects. It is often up to the individual procurement manager or production manager to organize these meetings. The procurement manager would then compile and store the experiences generated with the subcontractors in Skanska's procurement portal, available for latter projects.

Procurement route – The two interviewed subcontractors operated in technical fields in which the contractor did not have any knowledge. Both subcontractors' production managers stated that the procurement route was crucial in setting the conditions for their operative teams to deliver the services in question. This is established in the agreement between the contractor and subcontractor and therefore this falls in the procurement process. The design and construction of railway works is a specific technical area requiring extensive knowledge and resources. The subcontractor's production manager (2017d) recommended during the interview that Skanska should in the future procure the subcontractor under a design-build agreement as to put the responsibility of both design and construction on the subcontractor. This aligns with the views of the subcontractor responsible for the installations in both project. The production manager (2017b) concluded that the procurement route had a fundamental effect on the subcontractor's ability to perform their work. Skanska procured the subcontractor responsible for the installations under a design-build contract in the South Marieholm Bridge project.

7.2 Quality control during the execution of activities

Adequate pre-conditions - The production manager (2017b) stated that a contractor has to provide the subcontractor, whatever the project or task, with satisfying pre-conditions. This is especially true in the case of installations of control systems as it is usually in the end of projects. Any delays earlier in the project will manifest in the later stages. This also means that the time schedule of the different activities need to be respected by all project actors.

The contractor's joint venture partner was responsible for erecting the control facility for the lift-swing mechanism of the bridge, as it was a steel structure. The partner had assured Skanska and the subcontractor's production manager that the control facility would be finished at the agreed time. This was however not the case and led to delays and the need to perform several activities simultaneously. The handling of the steel constructions affected the overall time schedule of the project. The production manager (2017b) further states that there were considerable delays in the steel works for other parts of the bridge.

Coordinator – The production manager (2017d) for railway works, Skanska's design manager (2017), a block manager (2017a) and the district manager (2017) for the infrastructure department in Skanska stated that the use of a coordinator of railway works would facilitate the execution of the critical activities. The coordinator should have considerable knowledge and experience in railway design and construction, thus integrating the two activities. This coordinator would manage the design consultant and support the subcontractor responsible for the construction. The coordinator would also be tasked with coordinating the railway works with the activities of other subcontractors and project actors. Skanska's design manager (2017) and the

subcontractor's production manager (2017 d) especially stressed the importance of having a coordinator for the railway works.

The production manager (2017b) for installation suggested that Skanska could avoid discussions and ambiguity regarding what is included in the price of a subcontractors activities by employing an installations coordinator. During the procurement negotiations, the coordinator can ask the subcontractors, submitting requests for performing the job, what exactly is included in their price. The coordinator may also review the drawings in the technical description and ask how the subcontractor plans to execute the different parts. The coordinator will be able to understand when the subcontractor tries to avoid performing an activity or argue that it is not included in the agreement for the reason that the subcontractor wishes to receive payment separately for the activity in question. These activities, and the cost of performing them, may amount to considerable sums. Therefore, the installation coordinator is in this case quite valuable. In fact, Skanska has employed an installations coordinator on the Hisingen Bridge project that was once an employee for the subcontractor, and the production manager (2017b) as well as a block manager (2017a) states that this has worked well so far in the project.

Meetings – Several interviewees describe meetings as a fundamental tool in the construction process. In both projects, Skanska's supervisors had morning meetings with their concrete subcontractor's operative team every day. These meetings are included in the contract between Skanska and the subcontractor responsible for the concrete works. During these meetings, the supervisor informs the operative team about the project conditions and the importance of completing the works right the first time.

Skanska's steel group, when included in projects, have most meetings with their subcontractor in the pre-production phase. This includes technical briefings right before production start. Engineers from the steel group visit the workshops producing the steel constructions during production in order to meet the subcontractor's operatives as well as meet the management.

The subcontractor responsible for installations described having regular meetings with Skanska's project organization and the subcontractor's production manager (2017b) concludes that this was efficient in coordinating the installations works with the activities of other subcontractors.

The railway subcontractor's production manager (2017d) felt that it would have been appropriate for Skanska and Infranord to have meetings every two weeks in order to discuss all railway works. These meetings should also have included the design consultant (Sweco). This was actually happening in the beginning of the project but after a couple of meetings, the Skanska representative stopped attending.

Illustrations of defects – In both projects South Marieholm Bridge and Hisingen Bridge, Skanska's supervisors and block managers responsible for concrete works had morning meetings with the subcontractor's laborers/operative team. During these meetings, the supervisor regularly showed the team pictures of common quality defects in bridge projects as well as pictures of how Skanska and the client expect it to look.

3D Illustrations – In both of the studied projects, every Monday the supervisors for the concrete works hanged 3D illustrations on the announcement board, visualizing the structure or any other activity that the subcontractor is to finish during the week. The illustrations show what the subcontractor is to complete until Friday the same week. Skanska's supervisor does this every Monday on Project Hisingen Bridge and the same procedures were used during the construction of the South Marieholm Bridge. (Production manager 2017c, Supervisor 2017b).

The supervisor and block manager communicate and visualize any changes applied to the project by the design and production management. The subcontractor's operative team are also shown the illustrations of the bridge and the cost of the different parts of the bridge and the contribution of the subcontractor's activities to the entire project. (Production manager 2017c, Supervisor 2017b).

Skanska's production manager (2017c) responsible for the Hisingen Bridge project concludes that this is a strong tool for guiding the subcontractors in their execution and assuring that the quality requirements are obliged.

The reason for this being described in the recommendations is due to fact that it could be applied for the critical activities in other technical fields. Important to note is that Skanska, as the contractor, must have the capacity and resources to generate these illustrations for other structures and activities, e.g. railway works.

Documentation – The documentation management as well as the documentation of quality differs in the two studied projects. All subcontractor's participating on Project Hisingen Bridge are obliged in their agreements with Skanska to fill in certain documents that Skanska's quality manager provides. These are the Method Statement and Inspection Test Plan. Both documents are described in detail in the empirical background in the "Documentation" section.

The Method Statement is a document in which the subcontractor describes its activities and how the quality requirements of the project are fulfilled. Drawings and technical descriptions are attached in the document.

The Inspection Test Plan is a document in which the subcontractor describes the quality controls relating to the activities in the Method Statement as well as according to which standards and drawings they are controlled.

The quality manager also generates flowcharts in order to track the progress of the collection of the Method Statements and Inspections Test Plans. This is described by the quality manager (2017) as helpful in the overall process of generating the final documentation.

Regulations and standards oblige subcontractors to provide the contractor with statements of work, control plans and checklists. The statements of work are mostly concerned with health and safety. Subcontractors always provide control plans and checklists after they have completed their activities. The Method Statement is however, a document focusing on the subcontractor's process and quality while the Inspection Test Plan is the main document for describing quality controls. During

Hisingen Bridge, Skanska's agreements with their subcontractors compel the latter to provide Skanska with these documents before they start their work on the project. Thus, Skanska gains a description of what exactly the subcontractors are to perform and how they will satisfy the quality requirements.

8 Conclusion

The purpose of this thesis was to investigate the application of quality management in infrastructure projects when a large number of subcontractors are involved. The study was performed from a main contractor's point of view, and the focus has been largely on the contractor-subcontractor relationship. In order to delimit the area of study, subcontractors' performance of critical activities in four technical areas were examined and two projects formed the cases.

The objective of the thesis has in turn been to generate plans and suggestions for improvements in the studied contractor's quality management system, specifically when applying the system to activities and processes executed by subcontractors.

The studied contractor used prequalification analysis, technical descriptions, meetings, 3D illustrations, coordinators, documentation, technical briefings as well as direct monitoring and control of the critical activities in order to assure the fulfillment of quality requirements set by both the client as well as the contractor's own project staff. The common documentation for both projects includes statements of work, control plans, checklists and as built drawings while one of the projects had specific documentation in the form of Method Statements, Inspections Test Plans and Flowcharts.

Furthermore, the use of a quality manager fully committed to the quality management and documentation process facilitates the coordination of subcontractors and the generation of the final documentation. It is also important to note that the production setting of the activities affects the quality control, i.e. site based production (concrete constructions) and manufacturing-based production (steel construction).

The findings produced in the thesis show that the challenge with the management of subcontractors has many facets, and include:

- Difficulties with integrating all quality requirements in the procurement stage,
- unsuitable procurement routes,
- the main contractor's lack of knowledge in the technical areas,
- lack of communication,
- quality of design documentation, and;
- privatization.

Depending on the technical area as well as the contractor's knowledge in the area, different methods are available to assure the quality of the processes the subcontractors deliver.

The findings from the one of the studied projects regarding railway works and installations show that different measures are required in the technical areas in which the contractor lacks knowledge and experience. These type of activities require a suitable procurement route, usually a design-build agreement, as the contractor may have considerable challenges in controlling the design as well as coordinating the subcontractor and design consultant. Furthermore, communication between contractor-subcontractor-design is crucial and should be constant. Representatives

from the contractors and both subcontractors affirm the need for the contractor to acquire coordinators in the discussed technical areas in order to enable coordination and control.

The contractor studied in this thesis has proved to have rigorous procurement procedures in order to assure the subcontractors' suitability for delivering the services. There are still issues with integrating all of the requirements set by the client, production staff and design staff early in the pre-construction phase. The studied contractor's procurement unit is moving towards establishing long-term strategic cooperation with certain subcontractors as well as integrating design, production and client in the early stages of projects.

The findings in the study include recommendations and suggestions for improving their quality management of subcontractors' activities.

During the procurement stage, it is important for the contractor to achieve transparency as to be fully informed about the activities the subcontractors include in their prices. The choice of establishing a strategic cooperation with the subcontractors delivering the most critical services for projects has the potential to integrate them into the design stage, facilitating the construction stage. The procurement units should strive to integrate all quality requirements, set by all project actors, early in the project. The contractor's procurement route of subcontractors should depend on the contractor's own knowledge and experience in the respective technical fields for which the subcontractors are procured.

In the construction stage, the contractor must be able to secure the adequate pre-conditions for every subcontractor. Site conditions must be suitable and the time schedule respected in order to secure the subcontractors performance. The contractor would benefit from employing coordinators for activities were the contractor usually lacks knowledge. The coordinator should have considerable knowledge and experience in the technical field in question, thus integrating the design and construction. The coordinator would also be tasked with coordinating the activities with the activities of other subcontractors and project actors. Communication between the contractor and the subcontractors' laborers/operative teams is found to be crucial and should be continuous throughout projects. This is best achieved through meetings. Subcontractors constructing complicated structures or objects benefit from being shown 3D illustrations of the expected structure. This is an effective way for the contractor to show what is expected and secure the quality of the end result. Documentation is used to specify quality requirements as well as verify that the requirements have been satisfied. The contractor may integrate certain documentation in the agreements with subcontractors that oblige the subcontractors to describe their processes and procedures in fulfilling the quality requirements set by the contractor and end client. The documentation should also include test plans of how controls and monitoring are conducted. The contractor could gain a considerable understanding of the subcontractors' procedures by requiring this documentation before the subcontractors' activities even start.

In conclusion, the main contractor must constantly monitor and guide subcontractors performing critical activities. It is important that the contractor provides the subcontractors with guidance through; supervisors, regular meetings, and; illustrations

of the desired results. In cases where the main contractor lacks knowledge and experience in a technical area, the findings affirm the need for main contractors to acquire coordinators with sufficient expertise to coordinate the activities while also integrating the design and production phases. Furthermore, the contractor, subcontractor and design consultant should attend regular meetings in order to sustain communication. Quality assurance in the procurement stage benefits from long-term cooperation between the contractor and certain subcontractors. In order to establish and encompass all quality requirements, the procurement process should integrate requirements from design, production and client.

8.1 Possibilities for further research

This thesis has focused on a contractor's quality management of critical activities performed by subcontractors. During the course of the study, several other areas have been touched upon which have the potential of being further examined. The client's impact on the quality process as well as the product has been limited in this research. A study of the end client's influence on the quality is thus appropriate in future researches.

Furthermore, several interviewees in this study state that design consultants' impact on quality, through the design documentation they produce, needs more attention as the overall quality of design documentation is decreasing. The integration of design and construction is crucial with faulty design documentation directly affecting the quality of the product. The design consultants should be viewed as subcontractors procured specifically for providing the design.

The findings in this study also conclude that the privatization of several sectors in Sweden, such as railway construction and maintenance, adds to the dynamic market of the construction industry. Construction and development firms are forced to bid for large infrastructure projects involving technical areas previously limited to state-organizations. This new dynamic and the following challenges would certainly be interesting to study further.

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Appendix A – List of interviews

Block manager (2017a), Mattias Liewendahl, Skanska Sverige AB, 2017-01-31.
District manager (2017), Henrik Nilsson, Skanska Sverige AB, 2017-02-02.
Block manager (2017b), Erik Westerlind, Skanska Sverige AB, 2017-02-03.
Project manager (2017a), Kenneth Wahlqvist, Skanska Sverige AB, 2017-02-06.
Design manager (2017), Gunnar Holmberg, Skanska Sverige AB, 2017-02-06.
Production manager (2017a), Björn Nordgren, Skanska Sverige AB, 2017-02-09.
Project manager (2017b), Henrik Gerber, Skanska Sverige AB, 2017-02-16.
Steel group manager (2017), Markus Glaas, Skanska Sverige AB, 2017-03-21.
Technical manager (2017), Per-Ola Svahn, Skanska Sverige AB, 2017-03-22.
Quality manager (2017), Mattias Kvistenberg, Skanska Sverige AB, 2017-03-28.
Production manager (2017b), Peter Granlund, Actemium Nordic, 2017-03-29.
Supervisor (2017a), Jakob Tholén, Skanska Sverige AB, 2017-03-30.
Production manager (2017c), Peo Halvarsson, Skanska Sverige AB, 2017-03-31.
Supervisor (2017b), Daniel Keinvall, Skanska Sverige AB, 2017-04-04.
Procurement manager (2017), Andreas Lindblom, Skanska Sverige AB, 2017-04-28.
Production manager (2017d), Emelie Dahlén, Infranord AB, 2017-05-09.

Appendix B – Interview guide: unstructured interviews

1. How is quality management being applied in Skanska?

2. What challenges do you recognize when working with quality in projects?

Appendix C – Interview guide: semi-structured interviews, questions to Skanska employees about quality management during the construction phase

1. Does Skanska require any process descriptions from the subcontractors?

2. How did Skanska quality manage the subcontractors in Project South Marieholm Bridge/Project Hisingen Bridge?

3. Are there any quality controls in order to assure the quality of critical activities?

4. Does Skanska supervisors participate during quality controls/quality monitoring?

5. What challenges are there when quality managing concrete/steel/installtions/railway subcontractors?

6. What possible solutions are there to these challenges?

7. Who was the responsible for establishing the documentation management during Project South Marieholm Bridge/Project Hisingen Bridge?

8. Does Skanska establish some kind of list over what documentation the subcontractors must submit?

9. What documentation are subcontractors usually obliged to present?

Appendix D – Interview guide: semi-structured interviews, questions for purchasers about procurement process

1. Are there any quality assurance processes when procuring subcontractors?

2. What project actors participate in the procurement process?

3. What are the challenges when conveying quality requirements to subcontractors in the procurement stage?

Appendix E – Interview guide: semi-structured interviews, questions for subcontractors

1. How did you quality manage your activities during the South Marieholm Bridge project?

2. What is decisive for your ability do achieve quality requirements?

3. How did communication work with your client (Skanska)?

4. With regard to the South Marieholm Bridge project, do you think that you had enough support from your client?

5. What challenges are there when quality managing your activities?

6. What applicable solutions are possible to the challenges?

7. How did the procurement process proceed?

8. Is the client clear when formulating their quality requirements?