CHALMERS
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Proactive Quality Management in a Multi Residential Housing Project

Master's thesis in Design and Construction Project Management

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DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se

Master’s Thesis acex30

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Research Group Name
Chalmers University of Technology

Göteborg, Sweden 2021

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Examensarbete ACEX30
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Chalmers tekniska högskola, 2021

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Abstract

Costs of lacking quality, errors, and defects regarding housing projects within the Swedish construction industry account for up to 111 billion Svenska kronor yearly. A proactive approach towards quality management has been found facilitate a reduction in these costs. In this study literature regarding causes of errors and defects and measures to improve the proactivity towards quality management in housing production is studied. This is done in combination with a case study of a multi-residential housing projects to identify potential error and defect causes and how to manage the identified causes more proactively in the specific project. The method of the study is a qualitative, abductive case study where empirical material is gathered through interviews and a workshop in the case project. The primary causes of errors and defects identified is a lack of motivation, a lack of planning, time pressure, and a lack of knowledge or knowledge generating processes. They are found to be mutually dependent in relation to each other. Measures of improvement identified and recognized as prioritized action of improvement within the case project include:

- *Quality rounds,* to allow for earlier detection of errors and defects.
- *Development of routines and standardization regarding digital tools for quality management,* to facilitate the error management project of specific projects and provide groundwork for organizational learning from defect data.
- *Adapted work preparation for uncomplex work activities,* to facilitate the development work preparations by being less extensive and time consuming. Potentially leading to mitigation of errors and defects during the performing of the prepared activity.
- *Part-completion controls,* to facilitate earlier detection of errors and defects, while they require less rework to be corrected, while potentially also mitigating the recurrence of errors and defects.
- *Initial quality meeting,* a meeting held early in the project to facilitate knowledge transfer regarding risks potentially causing costly and extensive errors.

Key words: Defect management, error management, proactive quality management, multi residential housing project

Proaktivt kvalitetsarbete i ett flerbostadshusprojekt

Examensarbete Examensarbete inom masterprogrammet *Design and Construction Project Management*

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Chalmers tekniska högskola

Sammanfattning

Kostnader för kvalitetsbrister, fel och byggskador i bostadsprojekt inom den svenska byggbranschen kostar upp till 111 miljarder svenska kronor årligen. Ett proaktivt angreppssätt gällande kvalitetshantering kan bidra till en minskning av de kostnaderna. I den här studien studeras litteratur som behandlar orsaker till byggfel och kvalitetsbrister samt åtgärder för att förbättra proaktiviteten gällande kvalitetshantering vid produktionen av husprojekt. Litteraturstudien kombineras med en fallstudie av ett flerbostadshusprojekt för att identifiera potentiella orsaker till byggfel och kvalitetsbrister samt hur dessa kan hanteras mer proaktivt i det specifika projektet. Metoden som används i studien är en kvalitativ, abduktiv fallstudie där det empiriska materialet samlas in genom intervjuer och en workshop i fallprojektet. De främsta orsakerna till byggfel och kvalitetsbrister identifierade är bristande motivation, bristande planering, tidspress och bristande kunskap eller kunskapsgenererande processer. De identifierade huvudsakliga orsakerna är beroende av och påverkar varandra. Åtgärder identifierade för att minimera huvudorsakerna och som fallprojektet har beslutat att prioritera framöver inkluderar:

- *Kvalitetsronder,* för att främja tidigare upptäckt av byggfel och kvalitetsbrister.
- *Utveckling av rutiner och standardisering av digitala verktyg för kvalitetshantering,* för att främja felhanteringsprocessen i specifika projekt och bidra till grundarbete för lärande på organisationsnivå från byggfelsdata.
- *Anpassade arbetsberedningar för okomplicerade arbetsmoment,* för att underlätta framtagandet av arbetsberedningar genom att vara mindre omfattande och tidskrävande för att sedan möjligen leda till en minskning av byggfel och kvalitetsbrister när den arbetsberedda aktiviteten utförs.
- *Delutförandekontroller,* för att underlätta tidigare upptäckt av byggfel och kvalitetsbrister, när de kräver mindre omfattande åtgärder, och potentiellt minska antalet återkommande byggfel och kvalitetsbrister.
- *Inledande kvalitetsmöte,* ett möte som hålls tidigt i projektet för att främja kunskapsutbyte om potentiella kvalitetsrisker som kan leda till byggskador och kvalitetsbrister som kan kräva omfattande och kostsamma åtgärder.

Nyckelord: Byggskador, byggfel, kvalitetsbrister, proaktivt kvalitetsarbete, flerbostadshus

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Preface

This Master's thesis of 30 credits was written during the spring of 2021 as the last part of the Master programme Design and Construction Project Management at Chalmers University of Technology. The Master thesis was written at the Department of Architecture and Civil Engineering, more specifically the Division of Construction Management. It was also written in collaboration with the construction company Skanska, at the region Hus Göteborg.

I would like to thank my supervisors at Chalmers University of Technology, Professor Christian Koch, and Assistant Professor Dimosthenis Kifokeris for valuable input, insights, and discussions that have helped improve both the research process and the written report.

I would also like to thank my company supervisor from Skanska, Peter Samuelsson for his guidance, input on both the research process, the written report and future application of the results as well as providing valuable feedback and a possibility to bounce ideas. I would also like to express my gratitude for him believing in my ability to conduct this Master's thesis on my own.

A big thank you to my opponent Tom Bergström as well for valuable feedback to help improve the report and continuous discussions during the research period.

Finally, I would like to thank the project members of the case project for taking time from their time-pressured workdays to participate in the research with open minds. I would also like to express my thanks to all other employees at Skanska that have contributed to this study in a variety of ways.

Carl Jansson
Gothenburg, June 2021

1 Introduction

In the following chapter a background to the researched problem is presented to put it into context and perspective within the construction industry and the studied organization. Further the purpose of the study and the four research questions is presented. Lastly limitations of the study are presented.

1.1 Background

In 2018 a report written on behalf of Boverket, a Swedish government authority on the built environment was released. The purpose of the report was to map defects, errors and lacking quality in the Swedish construction industry and the impact of these defects, errors, and lacking quality. In the research they found that direct costs connected to defects and their correction account for 59-73 billion Svenska kronor every year (Boverket, 2018). When taking indirect costs for defects, errors, and lacking quality into account the cost rises to between 83-111 billion Svenska kronor every year. During the last 10-year period the research found the amount of defect, error and lacking quality occurrences has remained relatively unchanged within the Swedish construction industry. It was concluded that the industry actors hold the main responsibility for coming to terms with and solve these problems. They also found that the government have some influence as well by funding company independent research to raise knowledge on the subject.

Finding and correcting problems earlier in construction projects or mitigating them before they occur can help reduce the impact and severity of the problems and lead to lower costs for quality related problems in construction (Love *et al.*, 2016). With the right detection processes and routines in place it is possible to detect, and correct construction errors earlier and therefore lower the costs of lacking quality and reducing construction time (Love and Josephson, 2004).

At Skanska, one of Sweden's largest construction companies measures and routines have been developed to work with quality and errors more proactively by either detecting them earlier or avoiding their occurrence. Since errors still occur in the production phase of construction projects and are often detected and corrected later than could have been possible there appear to be room for improvement, either by changing the current quality processes or by implementing new ones.

There is previous research conducted on the topics of defect causes, defect management and to some extent how construction quality can be managed more proactively. Much of the research is written by a few authors and some of it is written some years ago. Many previous studies on quality management improvement point towards general problem factors such as leadership, culture change or the role of human error that may come across as a bit unsubstantial regarding concrete measures of improvement in the context of specific construction projects. This study will contribute to an in depth understanding of how quality issues can be managed more proactively within the context of a specific construction project and perhaps work as inspiration for actions to impliment in similar construction projects facing similar issues to improve their proactivity in terms of quality management. The problem with significant defect and error costs within the Swedish construction industry is a complex and multifaceted one with no single solution. The intention of performing this particular research is not to

solve the problem in its entirety, but rather to provide groundwork for steps to be taken in the right direction as part of one solution of several.

1.2 Purpose

The purpose of this thesis is to investigate how a project organization within the context of a specific construction project can work more proactively in terms of quality management through an analysis of what causes defects and errors as well as how these causes can be managed more proactively.

Causes for errors and defects and potential actions for an improved proactivity in terms of quality management is examined through a literature review and a current situation analysis of the studied case project.

The objective of the study is finding actions, processes, or routines to improve a proactive quality management in a specific construction project that could also potentially be transferred to other projects and improve the quality of projects potentially leading to an improved final product when turning it over to clients and reduced costs for lacking quality.

1.2.1 Research questions

1. What causes for errors and defects can be identified in theory and practice in the context of a multi residential housing project?
2. How can the identified causes be managed in a more proactive way in theory and practice in the context of a multi residential project?
3. What measures can be tried in the studied project to promote a more proactive quality management?
4. How does the identified measures of improvement promote a more proactive way of working with quality?

Research question	Studied through literature review	Studied through case study
1	X	X
2	X	X
3		X
4		X

Table 1: How the research question will be answered

1.3 Delimitations

The case study in this thesis is limited to a single project, only members of this project employed by the studied organization is interviewed. The case project is a multi-residential housing project located in Sweden. When possible Swedish literature on the topic and literature concerning housing, projects is prioritized.

The study is limited to the production phase of construction projects and therefore other phases such as the design and facility management phases are not studied in depth.

The research is conducted with a contractor perspective and therefore phenomenon concerning other actors such as clients or consults for example is not in-depth examined.

2 Method

In the following chapter the method of the thesis is presented and discussed. The nature of the study is a qualitative single case study of a multi residential housing project in the Gothenburg area in Sweden. The method regarding the development of the theoretical framework is abductive, iterative, and circular. The study is divided into two parts, the first being a current situation analysis of the project based on literature and empirical material, the empirical material consisting mainly of interviews with project team members. The second part of the study is about finding, implementing, and evaluating measures to improve the proactivity regarding quality in the case project. This is done through a quality workshop where causes for defects and errors are discussed along with how to manage them more proactively leading to a few potentially improving measures being decided by the project. They are then implemented by the project team and evaluated through an evaluation workshop. In Figure 1, the process of the research is visualized. The main methods for gathering of empirical material was the interviews, the workshop and the evaluation of actions. The abductive, iterative method is visualized as a feedback loop where the theory is matched and redirected depending on findings in the empirical material.

Below the method will be presented and discussed more extensively in terms of the different elements of the study.

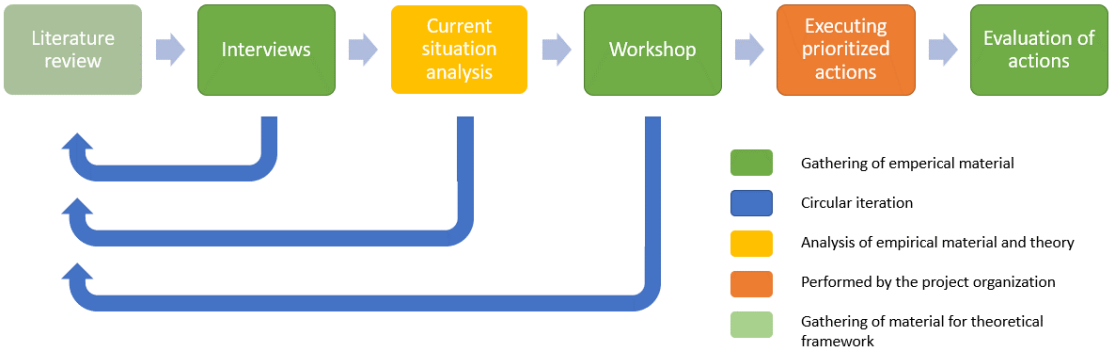

Figure 1: Visualization of the research process using an abductive research strategy (Authors own figure)

2.1 Research strategy

Research strategies can inherently be divided into two main categories, a quantitative research strategy and a qualitative research strategy. The basic distinction between them is the use of measurement. In quantitative research measurements are employed, in qualitative research they are not (Bryman and Bell, 2011). Another distinction is that a quantitative research strategy is often oriented towards the testing of theory, while the qualitative is oriented towards generation of theory. Quantitative researchers often view social reality as an objective reality while qualitative researchers view social reality as constantly changing and emerging from individuals. Qualitative research generally starts with quite general and wide research questions from which the theory emerges from collection and analysis of empirical data.

The purpose of this study is to generate theory rather than testing theory. To be able to initiate the study with wide analysis of the current situation to find possible improvements regarding theory and avoiding ruling out potential causes for defects or

potential improvement actions a qualitative research strategy has been chosen. Since the case study is conducted on a single project with a small project management group with the main purpose of finding improving actions fitting the specific project a qualitative study of the single project allows for a more in depth and investigative study than a quantitative one would.

Regarding the orientation towards theory Bryman and Bell (2011) mention two different orientations, deductive and inductive theory. The deductive theory is oriented towards forming a hypothesis based on previous knowledge on the subject which is then subjected to scrutiny of the empirical world. Using a deductive theory basically means forming a theory based on previous literature i.e., conducting a literature review and then using empirical material to confirm or reject the theory. Inductive theory on the other hand may be considered a reversed process of the deductive theory where the empiric material is collected and used to formulate theory. Both orientations are somewhat linear in their processes. There is however, a third theory orientation in which theory, empirical fieldwork and case analysis are developed simultaneously and iteratively called abductive theory (Dubois and Gadde, 2002). This iterative approach towards theory allows for and sometimes calls for redirection of theoretical framework when empirical observation generate unanticipated issues or knowledge. The abductive theory approach is non-linear in nature, meaning that the iterative development of theory is more about going back and forth between the empirical material, and theoretical framework with the purpose of matching them. A visualization of the abductive theory approach used in this study can be seen in Figure 2.

Figure 2: Visualization of abductive orientation towards theory, adapted from Dubois and Gadde (2004)

Because of the initially wide research questions and in-depth investigation of the studied case project to find causes and improving action without risking ruling out possibly important concepts an abductive orientation towards theory is used. This allows for a non-linear and iterative process where theory and empirical material are developed simultaneously while influencing each other.

2.2 Literature review

This study was initiated with a review of previous literature on the topic or related to it to be put into a wider perspective. The initial literature review was used as a basis for knowledge and theory when developing the interview guides. Subsequently, the process of the literature review was on-going throughout the entirety of the research process, gradually being narrowed down and complementing the empirical material using an abductive research strategy.

The literature search of the study was initiated using wide key words on the topic of defect, error, and quality management within the industry. Databases used for literature search include Scopus, Chalmers Library, Google Scholar and Taylor & Francis Online. From reviewing articles and reviewing sources cited in those articles a few key authors on the topic of the study were identified mainly from Sweden, Denmark, and Australia. Some of the key articles found was written a relatively long time ago but are still cited

frequently in newer articles on defect and quality management within the construction industry.

The literature review has been complemented with industry reports on the causes of defects within the Swedish construction industry written on behalf of Swedish industry organizations and institutes such as Boverket and Centre for Management of the Built Environment.

2.3 Case study

The empirical part of the study is a case study where the empirical material gathered comes from a review of internal quality management document from the studied organization and project, semi-structured interviews with five project team members, a workshop where causes for quality defects and actions to proactively deal with lacking quality has been discussed and an evaluation meeting where the prioritized actions from the quality workshop has been discussed in terms of barriers, possibilities and future changes.

When conducting a case study, the aim of the research is usually to investigate the nature or complexity of the specific case (Bryman and Bell, 2011). There are different types of cases, a case can be: a single organization, location, event or individual. In this study the case is a specific project where multi-residential buildings are produced and more specifically the project organization and their processes. Because of the complexity and particular nature of single cases the researcher should focus on the uniqueness and complexity of the case rather than trying to claim too much generalizability (Bryman and Bell, 2011). This research case is in nature a revelatory case, meaning that it provides an opportunity to analyse a previously inaccessible phenomenon. However, Bryman and Bell (2011) suggest a broader view of the revelatory case where it is not restricted to previously inaccessible situations. They also suggest that much of the qualitative case studies conducted that is not deductive in their approach could be considered revelatory cases.

The case project The reason for choosing this specific project as the case of the research is that it is a multi-residential housing project, where the project organization is interested in participating actively. Studying a multi-residential housing project rather than a commercial housing project provide a possibility for a slightly higher degree of generalizability. This is because there is an aspect of repeatability as well as similarities between projects connected to the process of producing residential buildings.

2.3.1 Document review

To gain a wider perspective on the quality routines of the organization in which the project and allow for a comparison between the guidelines of the organization and the actual processes of the project, internal documents and guides on quality processes has been reviewed. A guide for rounds, a guide for work preparations and a guide for quality management in construction processes has been reviewed.

2.3.2 Interviews

Interviewing in qualitative studies tend to be less structured than interviews in quantitative interviews (Bryman and Bell, 2011). When conducting qualitative interviews, the own perspectives and thoughts of the interviewee is usually of interest. For this reason, the researcher tends to encourage extensive answers and to ask

following up questions. The researcher is also allowed to depart from the planned interview guide if previously unidentified phenomenon or insight surfaces.
Qualitative interviews are divided in two main categories, semi-structured interviews, and unstructured interviews. Both these interview methods are flexible compared to structured interviews (Bryman and Bell, 2011). The unstructured interview method could almost be considered to resemble a conversation between the researcher and interviewee where one or few very open questions are asked and discussed. When using a semi-structured interview method, the researcher prepares an interview guide prior to the interview. The interview guide covers questions on certain topics predetermined by the researcher and after the interview most of these questions will be answered but might not be so in the pre-determined order. The researcher, when using this method has the freedom to ask follow up questions and depart from the interview guide if new perspectives or topics of interest is brought up by the interviewee.

In this study a semi-structured interview method is used to allow for follow up questions or departure from the interview guide. Some structure compared to an unstructured interview method is still considered necessary to allow for insights and perspective on the several topics regarding proactive quality management and defects found to be of interest in the study. Some degree of structure also facilitates a comparison of results between interviews and the coding of the interviews.

Five members of the project team has been interviewed on a variety of potential causes for defects in the production phase of residential construction. These potential causes were identified in the literature review prior to the development of the interview guide and include time management, resource management, motivation, knowledge management and information management. The interviewees were also interviewed about their current quality management processes. A list of project members interviewed can be found below in Table 2. One interview guide was prepared for the interviews with members of the site management team, this interview guide can be found in Appendix 1: Interview guide: Site management team. The site worker interview was conducted after the site management interviews. For this interview, a separate interview guide was prepared which can be found in Appendix 2: Interview guide: Site worker. The purpose of the site worker interview was to get a different perspective on topics of interest from the site management interviews.

The interviews were performed in a digital setting through video calls in Microsoft Teams. They were recorded to enable post-interview transcription.

Interviewees	Role	Years of experience from current or similar roles
Interviewee 1	Site manager	8 years
Interviewee 2	Assisting site manager	5 years
Interviewee 3	Site supervisor	3 years
Interviewee 4	Site supervisor	4 years
Interviewee 5	Site worker	34 years

Table 2: List of interview respondents

2.3.3 Workshop

A quality workshop was held with the interviewed site management team members, the regional quality manager and the regional operational manager. The purpose of the workshop was to discuss the findings from the literature and interviews regarding causes for defects and identify potential actions to take to manage these causes through proactive measures. Findings were presented to the workshop members which they could discuss freely regarding the potential impact and importance of different causes and potential actions to take in the project to improve their proactive quality management work. The workshop resulted in several suggested actions and five actions to prioritize in the project.

The researcher involvement during the workshop was limited to presenting the current situation analysis regarding error causes, taking notes, keeping the discussion on topic, and progressing the discussion to stay within the time set beforehand. The reason for low researcher discussion involvement was for the project members to find the solutions they themselves feel can make an impact to the proactivity in their quality management with the intention of this leading to a project member driven implementation process.

Present individuals during the workshop were:

- Carl Jansson (The thesis author)
- Site manager
- Assisting site manager
- Site supervisor
- Site supervisor
- Regional operational manager
- Regional quality manager

2.3.4 Evaluation

The prioritized actions identified during the quality workshop within the scope of the case study was evaluated in a late stage of the research period. The evaluation method was an evaluation meeting where the prioritized actions were evaluated through identifying which actions have been tested or executed, how the performance of actions could be changed in the future to generate more effect and if there were any actions not tested that may have been more beneficial to try rather than the prioritized actions decided.

2.4 Analysis of theory and empirical material

While performing qualitative research, large amounts of empirical material tend to be generated quickly (Bryman and Bell, 2011). When analysing quantitative empirical material there are strict rules and guidelines regarding the process. The case when it comes to qualitative empirical material analysis is not the same, leading to a less straightforward analysis process. Analysing the large amounts of qualitative, often unstructured empirical material therefore requires certain strategies.

The analysis of theory and empirical in this study was done through matching and categorizing (Dubois and Gadde, 2002). The empirical material was matched and

categorized towards the simultaneously evolving theoretical framework in a circular process where empirical findings could provide a source for redirection of the evolving framework.

2.5 Ethical considerations

Sections in the study based on internal material from the studied company has been read and approved by a company contact to avoid the spread of confidential information.

Before starting the interviews, the interviewees have been informed that their participation as well as which project they represent will be anonymized in the written report while the company name will not. They were asked for consent regarding the recording of the interviews and were informed that the purpose of recording was to enable transcription of the interviews and that the recorded material will be deleted when the study is finalized.

The participants of the study have been presented with the possibility to read a copy of the study before it is published to make sure that they feel comfortable with the result of their participation. Sending a copy of the study to participants could also help build trust between researcher and participants as well as a sense of mutual benefit from the research (Bryman and Bell, 2011).

2.6 Critical assessment of method

Historically single case studies have been considered inappropriate for generalization (Dubois and Gadde, 2002). The main argument for this standpoint is single case studies being too situation specific. The use of single case studies is increasing with the argument that it could be considered an opportunity to understand the interaction between a phenomenon and the context in where it is observed. In-depth case studies can facilitate the understanding of specific situations.

There is an on-going debate between qualitative and quantitative researchers (Bryman and Bell, 2011). Examples on critique aimed towards qualitative research by quantitative researchers include it being too subjective, difficult to replicate, problematic in relation to generalization and to lack transparency.

The subjectiveness critique stems from a belief that the findings in qualitative research are too reliant on the unsystematic view of the research regarding what is important (Bryman and Bell, 2011). Qualitative researchers also tend to develop personal relationships with the people studied which quantitative researchers mean could influence the findings of qualitative studies.

On the topic of replicability, the critics find difficulties because of the non-standardized procedures and unstructured research process as well as the findings and focus of the research being influenced by choices the researchers make through their belief of what is significant (Bryman and Bell, 2011).

Regarding generalization, the critique is about unstructured interviews with few individuals within an organization not being representable for the whole population (Bryman and Bell, 2011). Inherently the findings in one or two cases will not be

representable for all cases with their different variables. This type of generalization is not the main purpose of the qualitative few or single case studies though, the individuals interviewed are not supposed to represent a population. To generalize the results of this study the context of other projects would have to be researched and compared to the results of this study. The results of this study may provide groundwork and inspiration for action in both the studied project and similar projects though. This research approach may also provide more substantial and understandable actions for the specific project to take.

The critique on lack of transparency is based on a difficulty to understand the process and choices made by the researcher leading to the conclusion of the study (Bryman and Bell, 2011). There is also critique on the transparency of data analysis, it is often unclear how the data was analysed for the researcher to arrive at the conclusion.

3 Theory

There are no construction processes completely without errors or disturbances (Josephson, 2013). Projects have been observed where the site manager perceives the production phase as being free from errors and disturbances. This may be a result of the errors and disturbances having a small impact on the specific project leading to a perception of the project as disturbance and error free. It may also be a result of site managers being so used to managing errors and disturbances that the process is taking place subconsciously while their focus is oriented towards forward progression in the project rather than looking to and analysing the past.

Direct costs connected to defects and their correction in the Swedish construction industry is 59-73 billion Svenska Kronor yearly (Boverket, 2018). When indirect costs for construction defects are considered, the number rises to 83-111 billion Svenska Kronor yearly. It is possible to avoid or detect and correct errors and defects earlier in construction projects (Love and Josephson, 2004). Doing so may lead to lower construction costs connected to errors and defects as well as a more disturbance free construction process with a reduced construction time.

In this chapter literature on the topic of defect and error management is reviewed. This is done through exploration of how defects and error are defined, what causes defects and errors in the production phase of construction projects and the error management process of construction project. Further the concept of a proactive approach towards quality management in construction projects is explored through definitions of proactivity, positive aspects of a proactive approach towards quality management and aspects identified in the literature to help improve the proactivity towards quality management in construction projects.

3.1 Error management

3.1.1 Error, defect, rework, and quality costs definition

When defining a lack of quality there are some terms used frequently and to some extent interchangeably (Park *et al.*, 2013). Examples on such terms presented by Park et al. (2013) are rework, error, defect, and failure. They further differentiate the terms defect and rework by defining defects as being a physical phenomenon needing to be corrected and defining rework as either being field activities needing to be executed more than once or removing previous executed field work in the project. The defect is a physical phenomenon in need of correction and the correction of the defect can be considered rework. In the literature rework is generally considered as wasteful activities that are nonvalue adding to the project from a lean construction perspective (Love *et al.*, 2016). A need for rework might also be caused by a need to attend to scope changes in the project. Love et al. (2016) uses following definition of rework: “the unnecessary effort of re-doing a process or activity that was incorrectly completed the first time”. (Love and Josephson, 2004)

When describing defects as a fault in need of correction it is important to put it into relation to what would not be considered a fault in need of correction (Koch and Schultz, 2019). In this light Koch and Schultz (2019) reason that the concept of defects is unclear and relative. Deciding what is a defect and what is not is a result of negotiations between contractor and client. This is in line with Josephson and

Hammarlund (1999) defining a defect as "the non-fulfilment of intended usage requirements", while they further state that not all requirements can be specified. Details difficult to specify are referred to as "usage requirements" and may be wrong, leading to a need to rely on opinions from the client or user organization. Not fulfilling these opinions on user requirements may also be considered defects. Defects can be divided into three categories, technical, aesthetic and functional defects (Schultz *et al.*, 2015).

When defining errors, a distinction between technical and human errors may be useful since these errors may arise from different causes. Technology may fail under certain circumstances, in certain environments or due to deterioration while human error may be caused by human mistakes (Love and Josephson, 2004). Love and Josephson (2004) further uses the following definition of error: "a deviation from what is intended and caused by human actions" in their paper, emphasising the human aspect of errors.

In this paper following definitions will be used:

- Defect: A physical phenomenon in need of correction. Does not necessarily have to be a result of human error.
- Error: Deviation from the intended result, caused by human action.
- Rework: The re-doing of a process or activity that was incorrectly performed the first time.

Quality costs:
Quality costs can be calculated in several different ways. One example is dividing them into the costs of conforming to quality and the cost of not conforming to quality, conformance costs and nonconformance costs (Figure 3) (Jafari and Love, 2013).

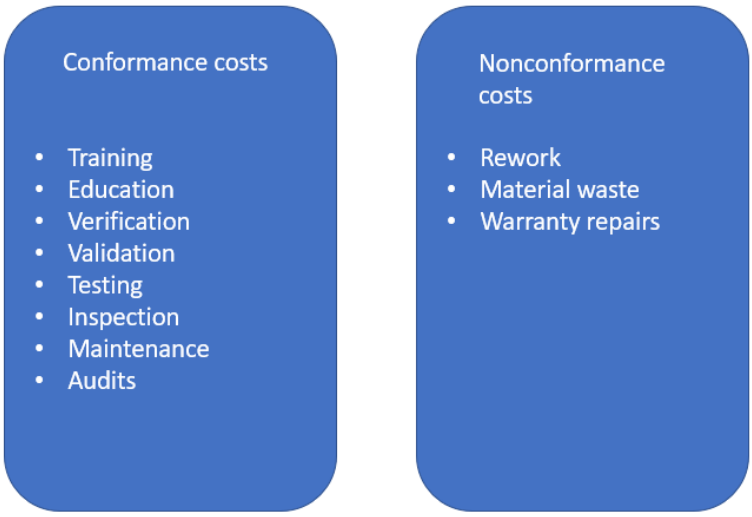

Figure 3: Division of conformance and nonconformance costs, adapted from (Jafari and Love, 2013).

Another example on how to calculate and classify quality costs is dividing them into the three categories: prevention, appraisal, and failure costs (Jafari and Love, 2013).

- Prevention costs: Costs of trying to prevent or reduce errors or defects by eliminating their causes.
- Appraisal costs: Costs of measures taken to detect errors and defects. This is done through measurement of quality conformity.

- Failure costs: Costs of correcting or rectifying errors or defects. They can be divided into internal and external costs.
    - Internal failure costs are the costs of correcting or rectifying errors or defects while the product is still under control of the responsible organization.
    - External failure costs are the costs of correcting or rectifying errors while the product is no longer under control of the responsible organization. For example, the rectification of errors during the warranty or aftermarket phase of the construction project.

3.1.2 Error management process

The error-recovery process in construction project can be divided into three steps (Love and Josephson, 2004). The first is detecting an error, then the person responsible for correction should be informed of the error, this step is called "indication of error", the last step of the process is the actual correction of the detected and identified error. In Figure 4 a visualization of the error-recovery process can be seen. According to Love and Josephson (2004) it is important to fulfil all the steps of the error-recovery process for costs to be decreased and learning to be enhanced.

Figure 4:Visualization of error recovery process, inspired by Love and Josephson (2004)

The relationship between error causes and their consequences can be explained using a "chain of events" model or "error chain" model (Love and Josephson, 2004). A visualization of the error chain model can be seen in Figure 5. The cause of an error may be human error, organizational or external forces. If the cause of the error is not acted upon or acted upon in a faulty way the error will be manifested as a defect or failure. The defect will have consequences on the product, process or both and will therefore need corrective measures for consequences to be mitigated.

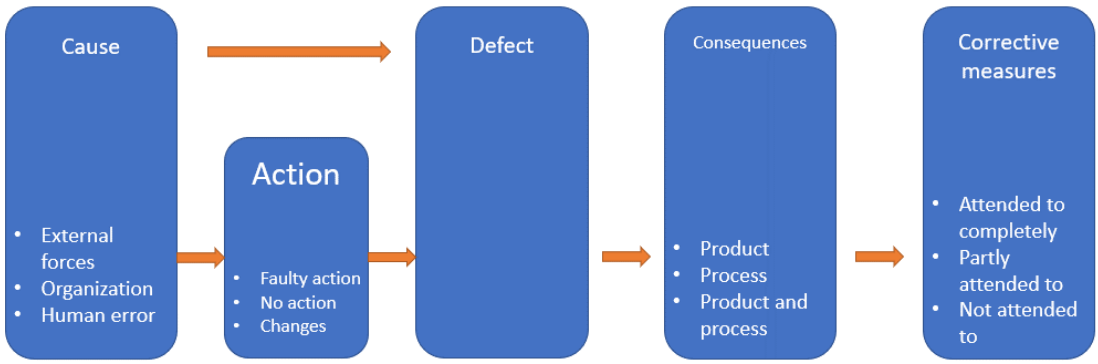

Figure 5: Error chain model, adapted from Love and Josephson (2004).

The error chain correlates to the impact and cost of an error (Love and Josephson, 2004). Early detection and correction of defects can contribute to lower error costs and less severe consequences. It is therefore of importance to have adequate routines and procedures in place to detect and manage defects, but also to learn in order to avoid similar defects and errors further on.

Learning:
Love and Josephson (2004) suggests a presence of single- and double-loop learning within the error chain model to avoid recurring errors and defects. A single-loop learning regarding construction errors is described as organizational members responding or reacting to changes in the form of detected errors by correcting them while organizational norms, original objective, policies and goals are maintained and unquestioned. Single-loop learning can lead to an increased generation of knowledge or competence as well as new routines which might mitigate the occurrence of similar errors in the future of the project and potentially in future projects. The fundamental nature of the organizational activities remains unchanged though in other words this may lead to the fundamental problem causing the error to remain unchanged, the symptom is treated rather than the disease. Double-loop learning on the other hand is described as the implicit norms and objectives of the organization being modified as a result of the detection and correction of errors. A result of double-loop learning can be a development of creativity regarding problem solving. This type of organizational learning is sometimes difficult since it requires the organization and its members to break away from sometimes deeply rooted organizational and construction industrial norms. The double-loop learning involves modifying organizational culture, strategies, structure, and objectives when needed. Learning from the error management process have been found to be more effective when the whole error-recovery process is performed (Figure 4). Performing the whole process on all errors and defects may be time-consuming and complicated though. In a time-pressured work environment, as is often the case regarding construction projects, the correction of errors and defects is often prioritized over learning from them. Due to a fragmentation regarding the performing of activities error chains may become very complex, while the knowledge of individuals generally is limited to the activities they are responsible for. Love and Josephson (2004) further suggests that managers should ensure that all project members understands that they must react, respond, and act upon occurring errors.

Root cause analysis:
To prevent errors from recurring Love and Josephson (2004) suggests performing a root cause analysis and then eliminating the identified root cause. A root cause is the primary, most basic cause leading to an error and may be difficult to identify since there may be several apparent causes identified for the manifested defect or error. In Figure 6, error causes are visualized, showing the difference between correcting, or acting upon an apparent cause or the symptom of a problem or unwanted event and acting upon and preventing the root cause to eliminate the recurring of errors.

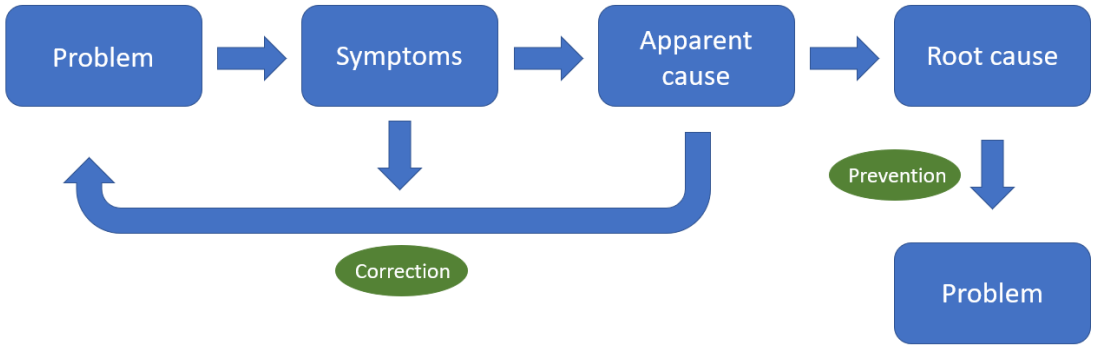

Figure 6: Visualization of error causes, adapted from Love and Josephson (2004).

3.2 Causes for defects and errors

Some studies have been produced to unravel the causes and origins of construction defects in the Swedish construction industry. In this section of the thesis findings from some of these reports and studies on defect causes will be presented.

The Swedish National Board of Housing, Building and Planning (Boverket) published a report in 2018 where defects, errors and deficiencies within the Swedish construction industry (more precisely regarding residential housing projects) were mapped (Boverket, 2018). The main causes for errors and defects in the production phase of construction projects were found to be (the presented order represents the frequency in the report):

- Lack of time, due to short project time-schedules.
- Lack of motivation.
- Lacking competence and resources within the producing organization.
- Using materials or construction solutions that are not tested before or unsuitable for the project.
- Organizational problems such as work preparations, coordination, subcontractors using subcontractors for example.
- Lack of weather protection actions.

Another problem appears to be connected to deficiencies in the currently used quality control system, this mainly regards the inefficiency of self-inspections (Boverket, 2018). A fragmentation of the industry leading to a need for close and efficient collaboration between actors is mentioned as well, with lacking knowledge, commitment, organization and motivation claimed to work as barriers for said collaboration and the construction process

Boverket (2018) further states in their report that a majority of problems and defects detetected in construction projects are related to moisture and water problems. Common causes for moisture and water related problems are further claimed to be leaks in the building envelope, lacking weather protection and displacing water from pipes. Problems related to water and moisture are also found to have a large impact on construction projects and often lead to severe correction costs. It is also stated that most problems in construction projects related to water and moisture problems are caused in the production phase and remain undetected until after the expiration of the building warranty time.

Josephson and Hammarlund (1999) found in their longitudinal study on seven Swedish construction projects that on average, 32% of defect costs originated in early project phases (the design phase and client related processes), 45% originated on site (in relation to site management workers and subcontractors) and 20% of defect costs were found to originate in materials or machines. The main defect cause found in their study was a lack of motivation, that even though the individual responsible for the occurrence of the defect had the right information and knowledge the work still resulted in a defect. In their study a lack of motivation was found to be the cause for an average of 50% of project defect costs in relation to site management, 69% in relation to workmanship and 47% in relation to subcontractors. The defects caused by a lack of motivation was found to often be a result of forgetfulness or carelessness rather than being intentional. The

second most frequent defect cause identified in the study was a lack of knowledge which could be attributed to approximately 29% of defect costs. Other but less frequent causes were found to be a lack of communication, time pressure and risk. In their study they define motivation as being a combination of motivation, expectations, and commitment. Motivation is defined as a desire to contribute through own actions to the resultant organizational action. Expectations as an individual believe that the own action will result in organizational action. Commitment as being able to rely on certain types of behaviour and attitudes from the rest of the team. Knowledge is defined as a combination of skill and experience with skill being the knowledge and ability to perform specific tasks very well and experience being knowledge or skill in a particular job acquired through working with that job for a long time. Knowledge is recognized in the study be generated through communication between project members. Motivation, knowledge and information are not independent causes for errors, there is an interdependency aspect to consider between them.

Jingmond and Ågren (2015) on the other hand in their study on causes of defects found that project organisational factors are the main cause of defects. They further suggest that to improve the quality or reduce the number of defects improvements should be made at a management and strategic level within projects rather than at an operational level. This should be done by making a reduction of defects a project management a daily priority. They also found inefficient knowledge transfer to be a main cause for construction defects. In their study a few other causes are recognized as well but as can be seen in Figure 7, other causes such as a lack of holistic approach, lack of knowledge for example are inherently caused by organisational problems or inefficient knowledge transfer.

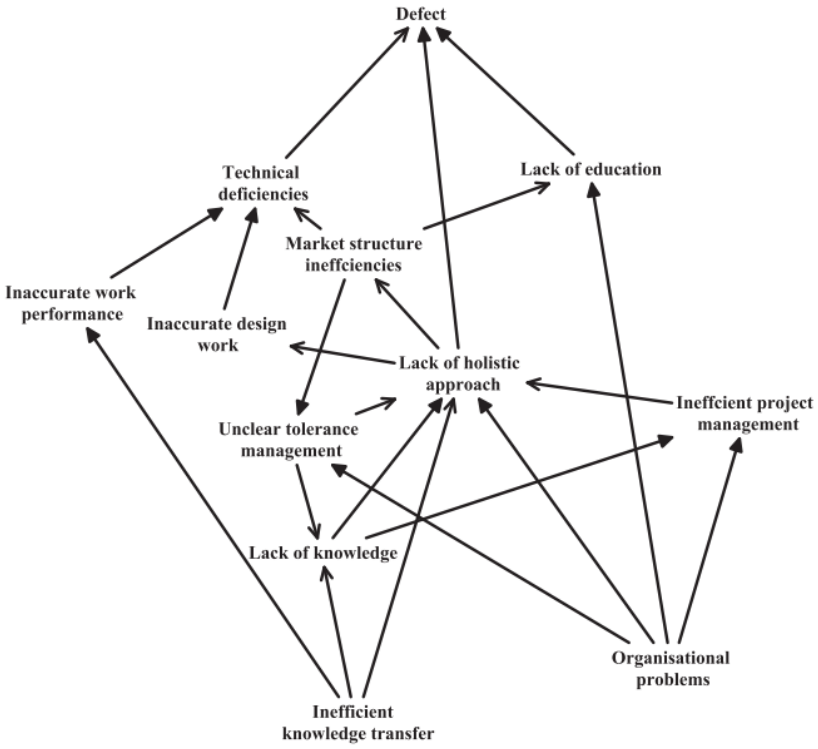

Figure 7: Map of defect causes (Jingmond and Ågren, 2015).

In the Swedish construction industry, there appears to be problems with laws and regulations limiting the possibility of repercussions for non-compliance regarding

quality (Buser and Koch, 2020). The limitation in repercussions leads to quality deviations often being handled in negotiations with pragmatic characteristics. Further on these limitations leads to a culture and approach to quality where good enough rather than excellent quality is accepted, lowering the incentives for contractors to deliver excellent quality when a product with a certain number of negotiated deviances is sufficient.

Executing projects with a continuously improving quality and a diminishing number of errors or defects requires some degree of experience and knowledge acquisition and more specifically the utilization of it. Individual team members have been found to learn from their experiences of specific solutions in construction projects (Koch and Schultz, 2019). This knowledge tends to become less applicable when the individuals, as often is in the construction industry, change jobs or start working in other business areas once the project is finished.

Construction organizations have been found to seldom have high learning capabilities (Love and Josephson, 2004). Low or medium learning capabilities can lead to a recurrence of errors previously experienced within the organization. One reason for this relatively low learning capability can be explained by how data is handled within construction organizations. Data collected about errors and deviations is not always transformed into usable information leading to a lack in lessons learned. Another reason potentially contributing to a lowering of learning capabilities and an increase in errors occurring is a time and monetary pressure regarding project delivery. This pressure can sometimes result in a subconscious disregard for the lessons of previous projects leading to a failure in providing the time and resources needed to improve the next project through the lessons of the former project. Other reasons leading to a lower learning capability may be the project members being involved in their next project while simultaneously finishing their project, leading to a disregard in lessons learned, knowledge transfer and analysis of the project in benefit of the new project. Often after a project is finished parts or the entirety of the project team is split up when they move to new projects leading to their shared knowledge and experiences within the team being split up as well (Josephson and Hammarlund, 1999).

3.3 Proactive quality management in construction projects

In the following section of the study the concept of proactivity regarding quality management in construction projects will be presented. First proactive quality is defined, then findings from the literature on the positive effects of proactive quality management is presented and the last part of the section literature findings on how to achieve a more proactive quality management and how to decrease the amount of error and defects in construction project through a more proactive quality management is presented.

3.3.1 Definition of proactive quality management

The difference between proactive and reactive management could be described as either acting before the occurrence of a situation or problem or acting afterwards (Elvnäs, 2017). In the context of construction defects or errors this can be translated into acting before or after the occurrence of said defect or error. In the studies conducted by Elvnäs (2017) it has been concluded that it is more common for leaders to act reactively rather than proactively. Proactive management is further described as being characterised by:

- Structures rather than specific events.
- Controlling events rather than being controlled by events.
- Planning beforehand rather than acting unplanned and impulsive.
- Calmness and stability rather than extinguishing fires and managing crises.
- Long-term and predictable rather than improvising.

The difference between proactive and reactive quality management in the construction industry could be described as (Dubas and Pasławski, 2018):

- Identification and checking of potential problems before proceeding to subsequent work rather than detecting and identifying problems when in collision with subsequent work.
- Preparing checklists for operational staff in order to detect errors at the source rather than finding and verifying errors in an unplanned manner.
- Monitoring quality continuously in the project rather than occasionally.
- Carrying out quality inspection directly after every stage of work is finished rather than doing it solely when finishing the final work stages.

3.3.2 Positive aspects of proactive quality approach

Working reactively rather than proactively can lead to more time and resources needed to be spent for the management of operations. The need to perform rework in construction projects has been shown to contribute to overruns in project time schedule and costs (Love *et al.*, 2016). Project rework have also been shown to reduce construction productivity and increase the probability of safety-related accidents taking place. A reactive quality approach to quality cost reduction is a common reason why construction organizations fail to reduce their quality costs (Josephson and Lindström, 2011). A reactive approach rather than a proactive approach with a focus on controlling or inspecting after executed work leads to errors being corrected rather than mitigated.

Love and Josephson, (2004) in their article on the error recovery process in construction projects state that 80% of production management errors in the production phase of the projects studied could have been detected earlier. Many of them could also have been detected before the erroneous activity was carried out since many of the errors were found to stem from lacks in planning and work preparation.

Early detection of errors is desirable for two main reasons, the first being the cost of correction, it is usually less costly correct an error that has been detected early, maybe even before carrying out the erroneous activity, rather than correcting it later when subsequent work might have been carried out as well (Love and Josephson, 2004). The second main reason for early detection of errors is the learning and analysis aspect of the error. It is generally more difficult to identify and analyse the cause of the error if time may pass before detection, subsequently inhibiting learning from the occurred error. The time between the occurrence of an error and its detection is critical for the severity of the impact caused by the error (Love *et al.*, 2016). According to Dubas and Pasławski (2018) the costs of error prevention are lower than the costs of error correction and error failure, as can be seen in Figure 8.

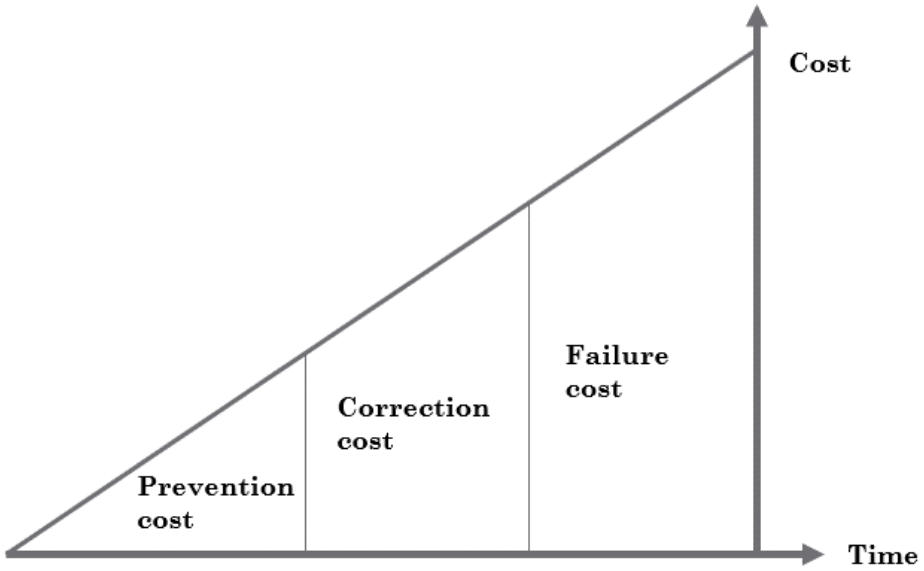

Figure 8: Differences in quality costs, based on Dubas and Pasławski (2018)

There is also a strategic aspect regarding a structured and proactive quality management to consider. Beyond the cost reduction aspect of quality management, a structured and transparent system with client access for registration and follow-up of errors may work as a strategic advantage when negotiating new projects (Josephson and Lindström, 2011).

The solution to project quality problems and high-quality costs does not appear to be solved solely by proactive investments in quality, prevention, and appraisal though. Taking it to the extreme and spending too much on prevention of errors might lead to the investment not paying off (Rosenfeld, 2009). On the other hand, spending less than optimal will lead to costs for non-quality that may exceed what could have been proactively invested. Therefore, there is a need to find a balance on proactive investments to reduce costs of lacking quality. It is also important to consider that quality failures are connected to hidden costs, such as damage to company reputation, loss of customers, and project delays for example.

3.3.3 Achieving a more proactive approach to quality management

In the following section of the thesis measures identified in the literature to help achieve a more proactive quality management and counteract the earlier identified defect and error causes in construction projects is presented.

One important aspect of a proactive quality management is detecting errors early. Love and Josephson (2004) categorizes measures for early detection into four categories: individual characteristics, activities, routines, and organization which are then divided into subcategories, see Figure 9.

Figure 9: Measures for early detection of construction errors, adapted from (Love and Josephson, 2004).

Developing individual characteristics is described as important since individuals have a significant role in detecting human errors (Love and Josephson, 2004). The individual characteristics to develop are knowledge/experience and motivation. Knowledge is gained by communication and reading. Experience is gained through doing a task many times over a period of time.

Activities to do more accurately to facilitate earlier detection include coordination and cooperation regarding drawings and documents, planning and preparing work, and inspections (Love and Josephson, 2004). Planning includes checking time of delivery and basic information. Preparing work includes checking requirements for a work activity and examining drawings prior to the start of new activities, as well as doing a consequence analysis, securing, testing, and investigating if necessary. Inspection includes inspecting the own work (self-inspections), inspecting material deliveries, and inspecting drawings, documents, laws, regulations, and specifications before the activity. In their study on error-recovery Love and Josephson (2004) found that this category could potentially have prevented 40% of all detected errors.

Establishing routines for early detection of errors include work instructions, where the extent of work to be executed is determined, routines, for contract review, inspections and document review, and routines for more detailed design drawings with clear explanations of solutions and details (Love and Josephson, 2004).

In the last category Love and Josephson (2004) suggests that providing resources in the form of time, cost, machines, equipment, and information could also facilitate earlier detection of errors. Information described as being information and instructions about the result of specific activities or the entire project.

3.3.3.1 Motivation

Defining motivation is difficult due to its complexity (Love and Josephson, 2004). Elvnäs (2017) uses the following definition in his book on effective leadership:

"The expected satisfaction of needs that emerges between the perceived current situation and a desired goal."

How strong the perceived correlation between the goal and the satisfaction of needs determines the amount of effort an individual is willing to put into the work. In other words, the effort an individual is willing to put in correlates to the perceived reward for the effort put into the work. In the study on error-recovery processes Love and Josephson (2004) shares suggestions they found through interviews. In their study motivation is described as "a will to contribute", other characteristics used to describe motivation in their study is: being energetic, careful and quality-minded. It is also described based on attention: being attentive, observant and through thoughtfulness: being, reflective questioning and critical thinking.

In Herzbergs dual-factor theory of motivation factors that can lead to increased individual motivation are (Forslund, 2013):

- Recognition for the work performed
- Satisfaction regarding problems solved
- Possibility to grow personally
- Career development
- Responsibility for the own work as well as the work of other employees
- Factors regarding the work itself: is it challenging, interesting and varying?

Feedback:
Five ways to give positive feedback to make individuals do more of what they have already done (Forslund, 2013):

- Be specific
- Be direct
- Achievable goal
- Attention
- Unpredictability

Measures to increase motivation

There are several ways of increasing individual and team motivation or commitment in construction projects. Construction projects in general are complex and they are often executed over several years. Instead of considering the project as a whole to be the goal for the project team to strive for, dividing the project into or re-formulating the end goal into short-term goals is one way to make the end goal of finishing the project more perceivable and achievable (Frödell, Josephson and Lindahl, 2008; Elvnäs, 2017). This could be done through weekly goals for example, it is important though, to not disregard the holistic project view, but instead combine the short-term and long-term goals and communicating how the short-term goals fit into the project (Frödell, Josephson and Lindahl, 2008). It is also important that the workforce feel that their managers show interest in the work executed without controlling them, but instead trying to make them feel like part of the project. In this including interaction with the workforce quality thinking should be encouraged. Improving the quality implies the workforce asking themselves why they are doing what they are doing and trying to see the consequences of actions taken.

Further on the topic of goal setting there are suggestions for the managers to set up individual goals together with employees alongside the earlier proposed short-term goals to increase motivation and a sense of purpose within the work setting (Elvnäs, 2017). To achieve the desired effect of increased individual motivation it is important

that the goals are developed in collaboration between the employee and their superior. The goals should be limited in time, preferably short-term and achievable. To achieve the desired effect the goals and their progress should also be followed up and revised if necessary, also in collaboration between employee and superior. Clear short-term goals (weekly or daily) help the employee visualize what to do and why. Unclear, long-term, solely holistic, and long-term goals on the other hand tend to decrease motivation and give the employees a sense of distance to the work they are to perform.

One aspect of increasing motivation among team members have also been found to be the opposite of dividing the project into smaller goals. Love and Josephson (2004) suggest that the holistic picture of the project should be accessible to all project members, for example by making 3D-models accessible. They recognized that a way to increase motivation is informing project members about how the work they do fit into the holistic picture, which may lead to them feeling a sense of importance in the work they do, rather than considering it to be isolated work. Team spirit of the project organization and actions to raise the team spirit has been found to be important to increase the motivation of individual project members in construction projects as well (Love and Josephson, 2004).

3.3.3.2 Learning in construction projects

There are several examples in the literature on how learning to reduce the number of defects and errors can be enhanced. The examples described below include production of pilot units, embracing an error management culture and the gathering and usage of defect data from projects.

Learning and productivity in construction projects characterized by a repetitive nature of activities may be enhanced (Jafari and Love, 2013). One example on how this enhancement may be achieved is the production of pilot units. The completed pilot units can be used to detect potential nonconformances which could then be prevented or detected early in the future repetition of production procedure.

To increase learning and reduce errors and rework in projects, attempting to steer the culture of the project towards a culture of error management could be an effective approach (Love *et al.*, 2016). An error management culture is characterized by a collective desire to learn from identified problems rather than finding an actor to blame while acknowledging that rework may not be completely prevented. The most important aspect of an error management culture is open communication where individuals are confident, they will not be blamed for errors they have caused, in a climate where focus is directed towards the positive consequences of errors, such as learning and innovation. New solutions to problems and sharing of knowledge within an error management culture can take place through lessons learned workshops. To manage a shift towards an error management culture an authentic leadership style has been found to be important, characterized by encouraging communication, positive behaviour, building trust, commitment, and shared values within the group.

Defect data collected in construction projects is considered a potentially powerful feedback source which could work as a driver for continuous improvement, and learning for future projects (Lundkvist, Meiling and Sandberg, 2014). The data gathered on construction errors and defects through third party inspections for example tend to

be used for a reactive correctional purpose within the boundaries of the single project rather than a proactive purpose, as a tool for continuous improvement and learning for future projects. When correcting the defects collected through defect data it is suggested that a proactive approach and focus on the defect root cause should be taken based on the collected defect data. They further suggest that consciously working towards minimizing detected root causes rather than just improving processes for detection could lead to lower quality costs, while only focusing on improved detection may lead to increased quality costs.

Companies within the construction industry have a history of to some extent failing when developing programs and processes for handling and evaluating information regarding quality costs (Josephson and Lindström, 2011). Two possible reasons why companies fail in doing this is firstly, attempts to develop from the organizations own experiences rather than trying to learn and use experience from other industries. The other reason presented is that there are processes and problems within the industry that are not considered to be problematic since they are considered to be natural within the construction organizational operations. Especially within larger construction organization a desire to create structured knowledge banks with examples of errors and their corrections has been detected. The gathering of information has been found to be relatively easy compared to the challenge of structuring it and developing systems to make it accessible and useful.

Lundkvist, Meiling and Sandberg (2014) suggest contractors within the construction industry could benefit from adopting a Plan-Do-Check-Act approach to their defect management processes and learning from their defect data. The PDCA-cycle (Figure 10) is a well-established model for continuous improvement and quality development within organizations (Elvnäs, 2017).

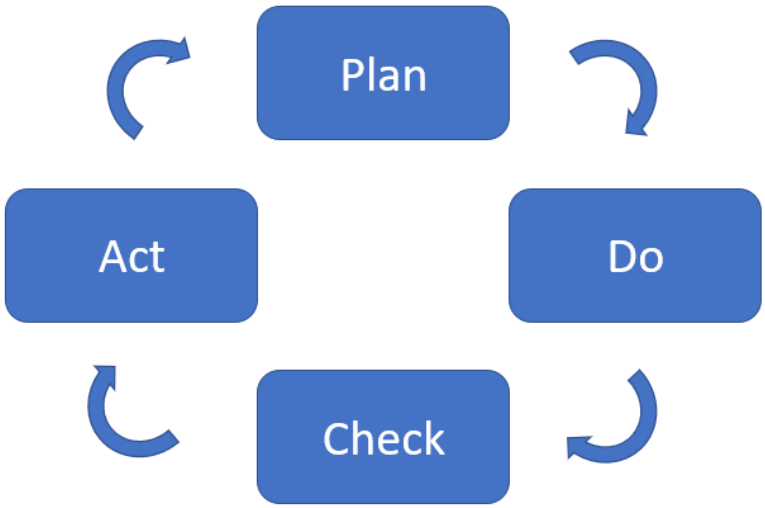

Figure 10: Visualization of PDCA-cycle, inspired by (Lundkvist, Meiling and Sandberg, 2014).

The steps of the PDCA cycle could be desbribed as (Lundkvist, Meiling and Sandberg, 2014):

- Plan: Planning for change based on an analysis of the current situation.

- Do: The execution of a change or test.
- Check: Observation of effects and reporting of results.
- Act: Analysis of results and identification of measurements to take for process improvement and standardization.

Classification of defect data is important to learn from defect experience. For contractors to use defect data in a more proactive way, involvement of the collection is necessary, a way to become more involved is stating new requirements regarding the collection of data (Lundkvist, Meiling and Sandberg, 2014). These new requirements should be more extensive than just what data is needed for the correction of defects. The defects should be gathered in a "Centralized Quality Data Base" where they can be analysed and work as a foundation for actions to be developed in the *Plan* and *Act* steps of the PDCA-cycle.

Lundkvist, Meiling and Sandberg, (2014) propose that a central team within the organization should be responsible for defect-based improvement work. This team should focus on long-term goals through the *Plan* and *Act* steps of the PDCA-cycle. They would be responsible for selection and initiation of improvement work based on continual defect, root cause analysis and the identification of systematic problems. The defects should also be compared and valued based on their impacts. The individual projects should focus on the *Do* and *Check* steps of the cycle

3.3.3.3 Continuous controls and self-inspections

The self-inspection system has been found to frequently be used as a reactive tool rather than a proactive tool (Koch and Jonsson, 2015). The self-inspections have been found to work more as a tool to gather information and show results. They are often performed on finished activities, often with some time passing between activity completion and control. Another problem recognized is nonconformities while performing the control often being corrected before the control registration, leading to nonconformities not being documented. One project manager in their study describes that using the self-inspection as a proactive tool rather than a reactive one could lead errors being detected earlier and corrected earlier. They further suggest that continuous controls should be performed, rather than solely controlling when an activity is considered to be completed. They propose mile-stone controls being conducted when specific amounts of activity work have been completed. This could lead to a continuous quality focus during the execution of the activity rather than, as the authors claims it is today, a focus on the beginning and the end of the process. Early, continuous quality controls are identified as an influential difference in the construction process between projects with a low amount of quality defects and projects with a more severe amount of quality defects at project handover (Schultz *et al.*, 2015).

3.3.3.4 Improved information management:

Dubas and Pasławski (2018) suggests altering construction document structure in projects to make information easier to find and more accessible. Merging descriptive documents concerning the same element with the help of 3D-model and assigned parameters would make it easier to find and communicate all information regarding the element, material and requirements and would allow for easier comparison. It could also facilitate the process of sending material inquiries to suppliers.

3.3.3.5 Meeting forums

Debriefing meetings and lessons learned meetings is a common channel for feedback on construction defects (Lundkvist, Meiling and Sandberg, 2014). A problem with these kinds of meetings is that they tend to be discontinuous, leading to minor but chronic problems not being brought up in favour of more severe and critical issues. The wider apart these meetings are being held the more overlooked the minor problems tend to become. Josephson and Lindström (2011) suggest that to improve the quality in construction projects, improving quality and reducing quality issues should be made a top priority by the project management team. According to them improved quality and reduction of quality issues should be the first item on the meeting agenda.

3.3.3.6 Leadership

Elvnäs (2017) describes two different kinds of leadership styles, leadership based on structures and leadership based on the leader as an individual. The individually based leadership is about the leader making itself essential to the business or daily operations by not sharing knowledge and competence with others. This could lead to desirable perks for the specific leader or individual such as affirmation, higher salary and attention but is not optimal for good of the business. Elvnäs (2017) recommends a leadership style based on structures where ways of working are developed by the team and standardized. These standardized structures can facilitate learning for new employees, ensure quality of operations when team members are absent as well as an increased overall quality in operations.

On the topic of leadership, project management and knowledge, Elvnäs (2017) also suggests a shifted approach towards leadership where the leader rather than spending his or her time instructing, and informing should spend their time asking questions and providing feedback to performed work. The purpose of this approach is ensuring that the person performing the work knows how to perform it. The idea when using this approach is that it is more important for the performing worker to have knowledge on how to perform the work than the leader.

3.3.3.7 Weekly structure:

Elvnäs (2017) suggest working with weekly structures in projects to achieve a more proactive approach towards leadership and management. Weekly structures are described as the hours of the week being planned beforehand. Recurring meetings are scheduled beforehand and the same time every week. The time not spent in meetings is scheduled in division between time spent being accessible to employees and time spent doing individual undisturbed work. According to Elvnäs (2017) this approach to weekly schedule will lead to less time being spent on managing unpredicted events and lead to decreased levels of stress.

4 Case study

In this chapter the findings from the case study are presented. First a review of quality routines in the production phase of projects identified in the quality management systems are presented. Then the findings from the interview study is presented. Lastly the findings from the quality workshop are presented with prioritized actions in the project to achieve an improved proactive quality management along with other potential actions mentioned during the workshop that will not be prioritized initially.

4.1 Quality routines in the case company quality management system

Skanska has got a management system available for all employees in their intranet. It is called *Vårt sätt att arbeta (VSAA),* "Our way of working" in English. In this management system information and guides on how to conduct different operations and functions within the organization is available with filter functions, search functions or a drop-down tree where sections are sorted under project phases such as design, project preparations, production, final phase and warranty phase, as well as under different subsections such as planning, risks and opportunities, purchases, handling of demands (quality, environment and work environment), and economy.

In the section "performing quality management" a guide to quality management in production can be found. According to this guide the purpose of quality management is to produce a product fulfilling legal, client and Skanska demands and requirements.

4.1.1 Managing quality deviations

During the performing of work activities or after their completion employees are supposed to identify, report and document quality deviations. Skanska recommends doing this in the software Autodesk BIM 360 Field. The documentation should contain:

- A description of the quality deviation
- A cause analysis, where the objective is to identify the root cause of the deviation
- Identification of measures taken to correct the deviation or mitigate future occurrence

Data gathered on lasting quality deviations should be compiled to ease the follow up process in future controls and warranty discussion.

4.1.2 Work preparations

A work preparation is described as detailed plan of how to perform an activity in the production phase of a project. The purpose of work preparations is increased productivity, worker safety and quality as well as an increased control of time and cost regarding the activity. Work preparation documents should be developed, presented, and approved before starting an activity.

According to Skanska's quality management system a work preparation should be prepared for activities when the work preparation could contribute to:

- Increased productivity or a decrease in disturbances
- Elimination or reduction of safety, environmental or quality risks
- Increased commitment among the personnel executing the activity

When developing the work preparation, the personnel responsible for the execution of the activity should be involved. Before the meeting as much material as possible should be gathered, for example: contracts, drawings, time-schedule, and previous experience amongst the team members. The work preparation can be developed in different ways and should be done so in a manner that fits the ones responsible for carrying out the work. It could be done on a whiteboard, in a template document and be documented through drawn pictures, photos, videos and text.

4.1.3 Rounds

In the VSAA guide on doing rounds in the production phase doing rounds is about making the "daily rounds on site" or "management by walking around" more structured and including a clearer agenda. The site supervisor responsible for specific work moments should go for rounds with the purpose of preparing future work moments and eliminating obstacles that could act as future production disturbances. Another purpose is for the site supervisors to in a structured way gather knowledge on production quality, safety, and conformance with the project time plan.

Positive effects of rounds mentioned in the rounds guide are:

- Freeing up time for the site management through a more structured way of working where responsibilities are assigned and divided between team members, making clear what should be done at which time, when it should be finished and what should be controlled.
- Gathering a short-term knowledge about and getting control of the work moments the responsible site supervisor is responsible for.
- Improved communication between different team members where potential obstacles are identified.
- A way for newly employed site supervisors to learn their role and taking over responsibility of work moments from another site supervisor.
- Knowledge transfer and learning from other team members regarding how and what to control.

Preparation of the rounds is done by development of a checklist by the site supervisor with support from a site manager and other site management team members. This checklist should contain clarification of which activities is included, and what should be done before, during and after the execution of activities. It should also include the order in which activities should be executed and how the execution of these should be controlled and followed up.

When performing the round, the site supervisor follows the prepared checklist and checks the different activities accordingly. The importance of including and speaking to site workers as well as giving feedback on work done is mentioned as well.

After the round appropriate measures are decided and taken in accordance with the site manager.

4.1.4 Self-inspections

Self-inspections are controls conducted by the person responsible for executing the work to be controlled. At Skanska they should be done digitally in checklist form within

the Autodesk BIM 360 software. The purpose of self-inspections is to control and verify the fulfilling of project demands connected to the performed activity for the organization itself as well as the client.

4.1.5 Weekly structure

At Skanska, project organizations in the production phase are encouraged to work with weekly structures. In these structures, it is predetermined at what specific occasions or times during the week weekly meetings should take place, rounds should be performed and when team members have time for undisturbed office work. The purpose of using weekly structures is a more proactive project management where project disturbances are eliminated. Specific questions should have their specific forum within the structure. This is supposed to lead to the specific questions being managed more systematically and decreasing the need to work reactively with issues within the project.

4.2 Findings from interviews

Below findings from the interviews are presented. Findings have been thematically sorted. First, findings about the current error management process are presented, followed by findings about defect and error causes and potential areas of improvement identified during the interview regarding a proactive quality management.

4.2.1 Error management process

Routines for detecting errors in the project presented by the interviewees are:

- Inspection/verification of previous work conducted by representatives from the company responsible for the next activity. These are not always performed.
- Rounds, during and after work activity. It is stated in the interviews that it is difficult to inspect large areas of work, especially when under time-pressure leading to samples of work being inspected rather than everything. The rounding routines are not thoroughly implemented in the project yet.
- Observations when taking a walk on site.
- Digital self-inspections with pictures. Sometimes done with the purpose of producing the document rather than as a tool to improve quality.

Routines for avoiding errors in the project presented by the interviews are:

- Review of documents and drawings by the project management team before initiating work activities. These are performed when there is time and especially before more complex activities.
- Work preparations, to ensure sufficient knowledge from executing individuals and planning the work process, identifying potential quality or safety risks linked to the activity. Regarding these, more complex work activities are prioritized.

When errors have been detected, the main communication channel is the Autodesk BIM 360 software. Where communication takes place through a comment section, attaching pictures or changing the status of the entered issue. Communication through e-mails, text messages, phone calls or face to face regarding errors takes place as well.

When an error is corrected, it is sometimes specified how the error was corrected. According to the interviewees this appears to be an uncommon procedure though.

Regarding the correction of errors, it is stated by several interviewees that correction or rework connected to errors are not planned for proactively, meaning there is usually not time set aside for error correction in the time-schedule of the project. According to the interviews this leads to a cost being connected to correction and rework, this can be time taken from other activities, a delayed project finish or monetary.

A cause analysis of detected errors usually takes place to some degree when there is an economic aspect connected to them. The interviewees state that the analysis of the error cause is investigated to find out which party is economically responsible for the correction or impact of an error rather than trying to find the root cause for continuous learning. There is also a possibility to register the root cause of errors within the BIM 360 software with a drop-down list of prepared categories. This parameter is not frequently used in the project. Reasons for not doing a more thorough root cause analysis in the project that were mentioned during the interviews include:

- It is time demanding
- It is resource demanding
- To find the actual root cause often requires several steps of analysis, it is hard to know when the analysis is finished. The actual root cause may also be found outside of the production, in the design process for example. This requires a collaboration between actors.
- It may be hard to know how to act upon the information found through a root cause analysis, either because another actor is found responsible or because the problem is complex, which lowers the incentive to spend time and resources on doing them.

Regarding the learning process from detected errors, it is mentioned in the interviews to be lacking, mainly due to a focus on the future and moving forward in the project rather than looking to and analyzing the past.

4.2.2 Causes for defects and errors

During the interviews, a number of different causes that may lead to errors or defects in the production phase of the project were identified. The causes mentioned were:

- Carelessness
- Lack of planning
- Time pressure
- Lack of knowledge
- Design errors

Carelessness:
Carelessness as a cause is in the interviews described as “doing something while knowing it is wrong”, “Performing an activity while knowing that previous work done is wrong”, leading to the next stage maybe needing rework as well. One potential cause of site worker carelessness is mentioned in two of the interviews to be insufficient or counterproductive salary models for site workers. The solution mentioned is an individual setting of salaries based on results rather than time spent on particular sets of work.

Planning:
Poor or lacking planning in construction projects in general is mentioned as a cause for defects or errors. More specifically lack in planning and preparations before the execution of specific work moments is brought up. A specific problem mentioned is interdependent work moments being done in the wrong order, for example installations

being assembled in the wrong order. Two reasons for this happening are mentioned. It could be because the assembly order is decided in the design process but does not appear clear from reading and analysing the drawings available for the production team. This is described as a result of an information gap between the design team and the production team. The other reason mentioned is lacking work preparations before initiating work activities. Four problems with the process of developing work preparations are mentioned in the interviews:

- Sometimes they are not developed thorough enough
- Sometimes they are not developed in collaboration with the project members supposed to perform the activity or without experienced enough team members
- Often developing them for complex activities is prioritized over developing them for less complex activities, leading to problems or errors when executing the less complex activities
- Subcontractors sometimes use templates in several projects rather than developing them for the specific projects according to the interviewees. They are also sometimes considered a document that must be handed in rather than a tool to improve the performance of the activity, leading to the subcontractor site workers not being involved or having knowledge regarding the work preparation document.

Time pressure:

Time pressure is mentioned as an indirect cause for errors rather than a cause itself. According to the interviewees time pressure may lead to:

- Carelessness when executing a work activity
- A design process that is not thorough enough
- Preparation of complex activities being prioritized over the preparation of less complex activities
- Insufficient time to review drawings
- Insufficient time to detect errors
- Insufficient time to correct errors
- Insufficient time to learn from errors

Lack of knowledge and knowledge routines:

In the interviews it is stated that a cause for errors and defects may be a lack of knowledge and knowledge routines. A lack of knowledge was identified to include:

- To production personnel it is easier to identify errors on site than on drawings or in documents. Leading to errors being discovered after their physical occurrence rather than before.
- There is a demand for members of the project management team to have a deep knowledge on the works of a wide variety of different disciplines within the projects to understand what is an error and what is not.

A lack of knowledge routines was identified by the interviewees to include:

- Lacking knowledge transfer within the project and between projects.
- Lacking time and routines to learn from and reflect upon identified errors and defects.

According to the interviewees, information regarding common problems and their solutions in similar projects within the organization is difficult to find. Currently, the main way of acquiring this kind of information is asking someone you know has

produced a similar project or the regional after-market group about potential problems and solutions.

The sharing of knowledge and experience between members of the project is mainly shared through oral communication or as a part of some meetings. The interviews think that they are generally quite good at optimizing and taking advantage of the individual knowledge in the project when needed though.

Design errors:
Errors in the design process were frequently mentioned as a cause for errors in the production phase of the project by the interviewees. Causes for design errors identified by the interviewees include:

- A lack of practical knowledge from the designer, which could partly be solved through site visits potentially increasing the knowledge with designers on how drawn solutions and details appear on site and the problems they may lead to.
- Lacking review or clash control on drawings and the 3D-model in the design process.
- Production personnel is not sufficiently in the design process and therefore not able to put forward their inputs and experiences enough.
- The design process is often too short and not finished enough when the production phase starts since the design and production run in parallel to some extent. The problem as it appears to the interviewed production personnel is that late changes to the design may have a large impact on the production phase.

Collaboration culture in project:
From all the interviews conducted it was unanimously stated that the communication climate in the project appeared to be open and transparent regarding errors and their solutions both within the contractor's project organization and between actors in the project. The collaboration climate also appeared to be oriented towards solutions rather than blaming individuals or actors. The interviewees stated that they both give and receive feedback in general, but also positive feedback. The team spirit in the project appears high as well, especially between team members from the contractor organization but also between the contractor and the main subcontractors in the project. The main reasons generating a high team spirit is mentioned by several interviewees to be the open and collaborative work climate with a problem solution orientation, it is also mentioned that there is a will to listen to each other's problems which is mentioned as a central aspect of the team spirit as well. What is identified by the interviewed project members as difficult regarding project team spirit and involvement in the project culture is involving subcontractors that are not permanently stationed on site, doing smaller work at a few specific occasions.

Problematic activities:
During the interviews, some work activities or errors were frequently highlighted as problematic. Moisture related problems were highlighted as a focus area because they may lead to very extensive correction or rework in terms of cost, time, and resources, especially if they are discovered at a late stage of the project or after project completion. Problems related to prefabricated concrete elements and installations was highlighted as well. Errors in prefabricated concrete elements caused by design errors or incorrect production in factory appeared to be common in the project, leading to extensive rework and need for inspection on site. Problems related to installation assembly was highlighted as well, assembling installations in the wrong order may lead to extensive

corrective measures or rework. There also appeared to be a lack of knowledge regarding which assembly order is correct.

Another problem identified during the interviews was a lack of structure, routines, and standardization regarding error management processes within the digital software for quality management. This lack was mentioned as a problem within the project, but also between different project in the organization. It was not identified as an error cause, but rather a barrier towards the error management process of the project. The problems with the current digital routines of the project recognized by the interviewees include:

- Accessibility regarding organizational routines and guidelines.
- A lack of routines regarding the registration of information and what information is supposed to be included.
- A difference in routines identified between different projects.
- Problems on how to find and filter information on registered errors and self-inspection documents, since the information quickly accumulates.

4.2.3 Potential focus areas to improve the proactive approach towards quality management

Some potential focus areas to improve the proactive approach towards quality management was identified during the interviews, they are presented below.

Involving site workers earlier in work preparations:
Regarding planning and preparation of activities, it was found in the site worker interview that site workers want to be more involved more frequently and earlier. By being involved early they mean they could contribute with their experience and knowledge as well as receiving an opportunity to reflect upon upcoming activities. The site worker involvement in work preparations was also mentioned from a site management point of view where previous early site worker involvement was referred to as sometimes unsuccessful because of a lack of interest or will to contribute from site workers. It is mentioned though that the knowledge and experience of site workers is in general utilized to a great extent, though not as much as the knowledge and experience of the site management team. This is especially true regarding correction of errors and solutions to problems, individuals with experience of similar problems in the project is generally involved in developing a solution.

Individual goal setting:
The interviewees were asked about individual goal setting, developed with their closest superior. This does not appear to be a part of the daily work within the project. Goals are set to the extent that responsibility for different work activities is divided where the goal is to perform well and achieve a good work process. They are not structurally divided into weekly and daily short-term goals. Some interviewees expressed a desire to develop individual short-term goals to work towards and follow up with a superior to raise motivation.

Accessibility, holistic picture of project:
It is possible for all members of the project to acquire knowledge on the holistic picture of the project. The 3D-model is accessible on the computer, phone or tablet by using the BIM 360 software to which all project members can receive viewing rights. The

3D-model viewer in the software is described as somewhat lacking and difficult to navigate though. There is also a possibility if questions arise to ask the project management team to show specifics of the 3D-model. The 3D-model in the project is described as "bad" with lacking detail level and containing several errors. During the project introduction, which is mandatory for all new project members some information on the whole picture is given. Regarding the need for accessibility to knowledge on the whole picture the interviewees recognize that not all members want access to the whole picture since it may add another layer of complexity to the project, while some members want this access to feel motivated and understand how their work fits into the final product. Some of the interviewees feel that they do not get to take part of the whole picture to the extent desired and express that this could be solved by earlier involvement in decision making that will later affect their work for them to have a say and possibility to share their thoughts and knowledge in decision making. Another problem regarding the accessibility of information in the project is described as a difficulty to find all information and the right information regarding activities prior to their commencing. Information is separated into several documents and drawings which can be hard to locate within the current documentation system. A desire to reshape the documentation system by merging searchable documents to make information easy to locate and to ensure that all necessary information is found is expressed in the interviews.

Meetings:
There is in general no specific regular meeting in the project where quality is the main topic of the agenda. Instead, quality issues are raised as part of other meeting forums when needed. In the interviews several of the interviewees expressed a desire for quality issues to be discussed more, although there does not appear to be a desire to create yet another meeting forum in an already packed meeting structure. Occasionally, quality issues, knowledge or experiences gained is brought up during morning meetings including most production personnel, both internal and external project members with the purpose of spreading knowledge. Minor issues and improvements are brought up and managed on internal production meetings where the site management team and site workers are present, they are also brought up on meetings with the worker foremen.

Weekly structure:
The interviewees when asked state that the site management team have implemented weekly structure routines to some extent. Some of the weekly meeting forums are scheduled the same time every week, they have also predetermined which hours during the week should be spent on site and which hours should be spent in the office doing individual work. During the interviews, the predetermined schedule of meetings is mentioned as a positive feature in the project, reducing stress and allowing a more proactive approach to their work. Several of the interviewees mention that they have not fully implemented the division between time on site and time for undisturbed individual work. One reason they have not managed to fully implement the division part of the weekly structures is that it is difficult to communicate the meaning of closed doors to other project members, leading to that time often being spent as usual with managing questions and problems as they arise rather than working proactively.

4.3 Workshop findings

During the quality workshop where identified causes from the current case analysis was presented different potential actions to improve the proactivity regarding quality

management were discussed and developed. The workshop resulted in five prioritized actions for the project to implement and a few actions that could potentially improve the proactive quality management but will not be prioritized in the project within the time frame of this research. In the first section the prioritized actions are presented. In the subsequent section, other potential actions or measures of improvement discussed will be presented.

4.3.1 Prioritized actions

The workshop resulted in a decision to take five measures to potentially achieve a more proactive quality management in the project.

4.3.1.1 Initial quality meeting

This is a meeting routine which has been decided should take place in an early stage of all housing projects within the Gothenburg region. It was recognized during the workshop that this action should have taken place earlier in the production phase.

The purpose of the initial quality meeting is the identification of potential quality risks in an early stage leading to an increased possibility to mitigate or monitor these potential quality risks. The meeting is held between the project management team and the regional quality manager. Beforehand, the regional quality manager reviews documents and drawings to find potential quality issues and what action could be taken to mitigate risks. These issues and actions are compiled into a protocol which is discussed during the initial quality meeting.

4.3.1.2 Adjusted work preparations

In the interview material as well as during the workshop discussions regarding a lack in the execution of work preparations was recognized. This lack was found to be primarily connected to the execution of work preparations for the work activities considered to be uncomplicated in nature. This situation was also found to lead to quality issues or errors occurring during the execution of the less complicated work activities, it was also found to potentially lead to recurring errors.

The main reason found causing the lack in developing work preparations for less complicated work activities was time-pressure combined with the extensiveness of the work preparation routine. In a time-pressured environment developing work preparations for the more complicated work activities where the general knowledge among the team members is lower and the risk of errors occurring that could lead to a need for extensive correction or rework is prioritized while the less complicated activities is somewhat neglected.

To manage this problem and facilitate the development of work preparations for the activities that are currently more neglected it was decided in the project to try to adjust the work preparations to the activity prepared. Instead of applying extensive preparation routines and documentation to the less complicated activities these work preparation would be less extensive and time-consuming. They could for example be done in a One-note template or directly on drawings. It was decided that this work preparation routine would be tried on the activity of carrying material into the buildings.

4.3.1.3 Part completion control

In general, the current situation of the project is that activity quality controls are done retroactively through the self-inspection routines. To apply a more proactive aspect to these routines and a potential to identify errors earlier it was decided to try conducting activity controls before the completion of the activity. These controls could take place once or during several occasions during the execution of the activity. How frequently, when to conduct them (in terms of completion rate) and what to control during the activity is decided and stated in the work preparation. In the project this measure is decided to be combined with the adjusted work preparations.

4.3.1.4 Quality rounds

It was decided that quality round should be introduced in the projects. The quality rounds will be held in collaboration between the service technician responsible for the project during the warranty phase and the site management. These rounds were decided to take place shortly after or during the execution of certain critical activities of the project, examples on critical activities include:

- Sealing layers
- Garage flooring structure
- Roof structure
- Façade connections (windows and glass doors)
- The assembly of interior fixtures, parquet floors and hall doors

The purpose of these rounds is to involve responsible parties from the warranty-phase and taking advantage of their knowledge in identifying what could lead to errors needing extensive correction during the warranty phase of the project. In preparation of these rounds a checklist should be developed based on the protocol from the initial quality meeting.

Quality rounds are recognized to potentially decrease moisture and water related issues that according to the participants often lead to extensive and costly correction.

Within the timeframe of this study one of these quality rounds was held and evaluated. The checklist was prepared by the regional quality manager in the digital environment used to manage quality within the project.

4.3.1.5 Structure and standardization regarding digital quality management tools

Problems were identified during the interviews and the workshop regarding structure, standardization and routines within the digital quality management tools used by the organization. There is a possibility for individual projects to find and implement their own routines regarding data entry and work processes. A desire to find common routines between projects were therefore identified along with a desire for these routines to be accessible for all members of the project organization, both internal and external. This lack of clear and accessible routines was recognized as a potential cause for a lack of knowledge regarding how to use the digital tools as well as causing the data gathered to become unstructured and complicated to use in the project to find the desired data or information.

The measure decided to be taken to deal with the lacking accessibility and knowledge regarding structure, routines and standardization was to develop guides on how to

perform certain digital processes and how to enter information digitally. These will then be made accessible in the digital environment of the project and evaluated. During the timeframe of the study a pilot guide will be developed for a few digital work routines.

4.3.2 Discussed measures of improvement

Other measures than the prioritized actions discussed during the quality workshop include:

- An accessible and searchable database with filters where frequent errors and their solutions in similar construction projects can be found.
- An improved and more precise 3D-model.
- Accurate information on penetrations in walls and floor structure included in the 3D-model.
- Control of installations from the installation coordinator of the project in a manner similar to the quality rounds before the installations are built in.
- Earlier document, drawing and 3D-model review from installations subcontractor.
- Identification and correction of errors on prefabricated concrete elements in the factory rather than on site.
- Implementation of routines to control the work preparations from subcontractors and ensuring that the subcontractor workers have knowledge on the work preparation. This routine would also include ensuring that the work preparation document is specifically developed for the project and not just a template used in all projects.

4.4 Evaluation

During the timeframe of the case study research implementation regarding two of the five prioritized actions been initiated. As seen in Table 3 the prioritized actions initiated during the research period is “initial quality meeting” and “structure, standardization, and routines within digital software for quality management”.

Action:	Inititated	Reaction	Future
Initial quality meeting	Yes	Positive	Continuous follow up meetings, maybe in connection to quality rounds
Adjusted work preparations	Partly	N/A	-
Part-completion control	No	N/A	-
Quality rounds	Yes	Positive	Continuous quality rounds Reviewing work preparations
Structure, standardization and routines, digital software for quality management	Yes	Positive	Making pilot guides more succinct, develop guides for more routines

Table 3: Evaluation of prioritized actions

The actions were evaluated in an evaluation meeting towards the end of the research period. Where it was found that:

Initial quality meetings:
The meeting was held to late in the production phase. It would have been beneficial to conduct the meeting in an earlier phase where it would be easier to affect choices of solutions, details, and materials.

A need to develop a clear plan on how to control and monitor the issues brought up during the evaluation meeting as well.

A desire for the quality meeting to not be a one-time happening was identified. Suggestions were made to have short, continuous quality meetings in connection to quality rounds to follow up quality issues identified and communicated during the initial quality meeting.

The initial quality meeting was also found to increase knowledge and information gathering facilitating the planning of future work activities.

Adjusted work preparations:
Templates for developing adjusted and less extensive work preparations have been prepared. They have not yet been used to develop work preparations though.

The reason found during the evaluation meeting to why the templates have not been used yet was identified as time pressure due to a temporary decrease in project management team members being present on site.

Part-completion controls:
The implementation of part-completion controls as a follow up tool connected to the adjusted work preparations was not implemented during the research period for the same reason as the adjusted work preparations.

Quality rounds:
One quality round was conducted during the timeframe of the research. During the quality round garage flooring structure, windows, glass doors, and sealing layers were inspected.

The quality round was not performed digitally, a protocol was produced afterwards though for the information to be provided in written form to the site management team.

Potential measures of improvement regarding the quality rounds recognized by the participants include:

- Choosing a few activities or elements on site to inspect, rather than trying to through the whole project.
- Preparing a checklist of what is to be inspected that is made accessible to participants beforehand.
- In connection to the quality rounds, work preparations on the activities inspected could be reviewed as well.

- In connection to the quality rounds, work preparations on near-future activities could be reviewed as well.

Structure, standardization, and routines within digital software for quality management:
This action was implemented to some extent as a pilot project. Clarification on how to conduct certain activities and which information to enter when registering errors and self-inspections was developed and made accessible in the project.

The guides developed during the research period was:

- How to register and enter quality issues.
- How to create templates and fill in checklists regarding self-inspections.
- Which project members should have which authority role in the project to be able to work within the digital tool.

From evaluating the guides during the evaluation meeting they were found to need to be simplified even more. There were also found to be a need to develop guides for more activities.

The next step of this action is to develop guides for:

- How to conduct inspections digitally.
- How to invite new members to the software.
- How to add new companies to the software.
- How to receive needed notifications.
- How to upload new drawings to the document management software.
- How the document structure within the document management software works, and how to navigate the drawings and model.
- How to generate pdf-reports of quality issues and self-inspections.

5 Analysis and discussion

5.1 Error management

It is apparent from both the theory and the case study that producing buildings with zero errors or defects is difficult. It is also recognized in the theory that they if handled in the right way can provide valuable resources and feedback for continuous improvement and organizational learning. To decrease error costs and enhance learning from errors Love and Josephson (2004) emphasizes completion of the error management process (3.1.2 Error management process) must be completed. An analysis of the case project conformance to the error management process can be found in Table 4. The interviews indicate that some routines for error detection, indication and correction are present in the project but that there is room for improvement in terms of quality and consistency in the performing of the routines while a true root cause analysis do not take place within the project.

Step in error management process:	Performed in project?	Performed how?
Error detection	Yes	• Inspection/verification of previous work by the next discipline • Rounds • Observations • Self-inspections • Review and control of documents and drawings • Work preparations
Error indication	Yes	• Communication through registered issues in Autodesk BIM 360 • Oral communication • E-mails
Error correction	Yes	• Confirmation of corrected error in Autodesk BIM 360 • Irregular register of how error was corrected
Root cause analysis	No	• Financially responsible actor is identified • Root cause in general not registered in Autodesk BIM 360

Table 4: Analysis of project conformation to error management process.

Room for improvement is identified in all error detection processes in terms of both quality and consistency.

- Inspection of previous work takes place on an irregular basis where samplings of work is inspected.
- The routines regarding rounds are currently not thoroughly implemented in the project.
- Observations when taking a walk on site are inconsistent in their nature since they are very dependent on the current focus of the individual.
- Self-inspections in the project were found to sometimes be conducted with the purpose of producing the document rather than working as a tool for learning and improvement.
- Review and control of documents conducted by the project management team prior to the start of activities was found to not always take place due to time-pressure. The review and control of documents concerning more complex activities and elements was found to prioritized over the review and control of documents concerning less complex activities. The review and control of documents also demands deep knowledge within a wide spectrum of construction disciplines from the site management team to find potential problems.
- Work preparations was found to not always be done for work activities not considered to be complex. The lack of work preparations was identified as a cause for errors in the project. Another finding regarding the work preparations was an occasional lack in involving the workers who are to perform the activity in the development of the preparation document.

The indication step of the error management process appears to work well in the case project. The main communication channel regarding errors is the error management function within the Autodesk BIM 360 software where there is a possibility to add photos, comments, a location pin on drawings and a description of the error. Not all errors in the project are registered in the software though, some are communicated orally or through e-mails.

The error correction step in the case project appears to work well in general. The possibility to change status on issues within the systems allows for communicating when an error is corrected. There is also a possibility to add pictures and comments describing how the error was corrected, this is not frequently done in the project though.

Regarding root cause analysis the case project was found to analyse the cause mainly to find out which actor is financially responsible for the correction or consequence. Analysing the cause to identify the basic root cause may very well go beyond identifying the financially responsible actor meaning that there is a probable lack in the case projects root cause analysis routine. The case project was also found to not register root causes in the Autodesk BIM 360 software where there is a possibility to do so. They are aware of their shortcomings in root cause analysis though and believe the reason to be the process being time and resource demanding while not knowing what actions or results identifying the information will lead to.

Learning from performing the error management process appears lacking in the case project according to the interviewees. This may partly be a result of the error management not consistently being performed in full. The lack of consistency in the identification, indication and correction steps combined with the root cause analysis not being performed may work as a barrier towards learning from errors. As emphasized by Love and Josephson (2004) it is of importance to fully complete the error

management process for optimal learning possibilities to take place. As the process in the case project is somewhat fragmented the result of that fragmentation may very well be limited learning possibilities. The learning that takes place in the project appears to be characterized by a single-loop learning rather than a combination of single- and double loop learning where errors are corrected but organizational norms, original objectives and goals remain unchanged. According to Love et al (2016) the optimal learning capabilities are found in an environment characterized by a combination of single- and double-loop learning. Apart from the fragmentation of the error management process one barrier towards increasing the double-loop learning in the project may be time-pressure and the knowledge of individual being limited to activities they are responsible for (Love *et al.*, 2016).

From the empirical material it is indicated that a need to perform rework or correct errors is rarely proactively accounted for financially and especially time-schedule wise when planning and bidding on projects. “There is always a cost connected to the correction of errors, either time or money”. This may be considered an industry problem, in a climate where projects are often won through bidding lower than competitors and finishing the projects earlier than the competitors it could prove fatal for winning projects to start declaring the time and money spent on rework and correction before the project while the competitors do not. Not planning for errors to occur and needing to be corrected may lead to problems not only with stressful correction processes but may also inhibit learning and continuous improvement. The problem found in the empirical material regarding a low degree of learning and reflection upon the error causes could be directly connected to a lack of time to reflect upon errors.

To some extent time for error correction is planned after the final inspections, but from a proactive point of view this should mainly include the correction of minor errors, since more significant errors would be beneficial to detect and correct earlier and are often not possible to detect at such a late stage of production since they are often built into the product. The proactive aspects of inspections should mainly include the process of data gathering and learning for future projects. The final inspections of the production phase may also enhance the negotiation aspect of errors and defects, contributing to a “good enough”-mindset. Because of the late stage of production extensive correction or rework may lead to a delayed project completion which might put the clients in a situation where they are more inclined to accept a certain number of errors or defects for the project to be delivered within the set time frame.

Problems with structure, routines, and standardization regarding digital software as well as accessibility of such routines and standardization was found to work as a barrier when considering the project error management process. This was also identified to be a problem residing outside of the project organization responsibility. Clear and accessible routines and standards should according to the empirical material be provided by the organization to facilitate similar routines between projects.

5.1.1 Case project conformance to quality routines in the organizational quality management system

In 4.1 Quality routines in the case company quality management system, a few quality routines to achieve a more proactive quality management were identified in the

company quality system. The quality routines of the case project have been compared to the writings of the quality management system to identify conformance or non-conformance to the identified routines in the project Table 5.

Quality routine in organizational quality management system	Conformance to quality routine in case project	Comment
Managing quality deviations	Partly	No proper root cause analysis.
Work preparations	Partly	Not done frequently enough for activities considered to be uncomplex.
Rounds	No	Currently being implemented.
Self-inspections	Yes	Sometimes with the perceived purpose of producing a document though.
Weekly structure	Partly	Currently being implemented, partly implemented.

Table 5: Case project conformance to quality routines in the organizational quality management system.

As seen in Table 5 there are room for development regarding quality routines conformance.

Regarding the management of quality deviations, the case project conforms to the routine with the reservation of conducting a proper root cause analysis.

Work preparations are developed in the case project, but they are occasionally not developed for work activities considered to be uncomplex. Not developing work preparations for work activities considered uncomplex is identified by the interviewees as a potential cause of error and defects. In the quality guide of the company, it is stated that work preparations should be developed for all work activities that could benefit from them being developed.

Rounding routines are currently being implemented in the project but is currently not widely implemented, hence the non-conformance. It should be noted that this routine is relatively new and not widely implemented in similar projects either.

Self-inspections are performed in the project and they are mainly performed digitally as recommended in the quality system. According to the interviewees the purpose of self-inspections in the project is occasionally to produce a document rather than learning from identified defects and errors.

The weekly structure routine of the quality system is described as “a recommended tool” in the quality system rather than being compulsory. This routine is currently under implementation in the project. Regular, weekly meetings are pre-scheduled. The division of undisturbed work time and time spent on site or performing interactive work

is not currently thoroughly implemented. It should be noted that this routine is relatively new and not widely implemented in similar projects.

5.2 Causes for defects and errors

There are several potential causes of defects and errors identified in the literature. Most of the causes identified are not independent causes, but to some degree interdependent relative to each other. Some of the causes identified are also recognized to be similar to a degree that they are inherently the same causes or almost the same causes but with different terms used to name and categorize them. Therefore, a categorization of identified error and defect causes have been made (Figure 11). In the bullet points under some of the categorized causes, other phenomena identified to be almost the same or significantly linked to the causes are mentioned. The design error box is of a different colour to visualize that design errors per se is not a category of defect causes since the individual design errors could probably be categorized into the other categories. Since the study is focused on production phase errors and improving the proactivity approach to quality management in the production phase, design errors are considered a semi-category for the purpose of errors in the design phase having an influence on errors occurring in the production phase. Design errors could also, if the right actions are taken probably be detected and mitigated in the production phase of the project but not avoided all together.

Figure 11: Categorization of error and defect causes (Authors own illustration)

As seen in Figure 11, the cause "motivation" includes the concepts of carelessness and forgetfulness while the cause "communication" includes coordination. Coordination is partly recognized as residing within the frame of "planning" as well. Knowledge is recognized as including the concepts of knowledge transfer, learning, experience, competence, and information. This may be perceived as a very broad categorization of knowledge. Knowledge though, is through this considered to be a result of knowledge generating processes and a lacking knowledge considered to entail a lack in certain knowledge generation processes rather than pointing towards individuals of the project organization lacking knowledge.

The categorization (Figure 11) of causes used in this study is a bit more broken down into causes in their own right than the main causes Jingmond and Ågren (2015) identify,

organizational problems and knowledge transfer. An interdependency of causes is recognized in the study though. The main argument for not using wider categories or main categories based on the interdependencies is to allow for a deeper understanding of problems identified in the case project as well as a possibility to specify how to manage the different causes which would be more difficult if more general and generic categories were to be used. The interdependencies between the categories identified through the case study and literature review can be seen in Figure 12.

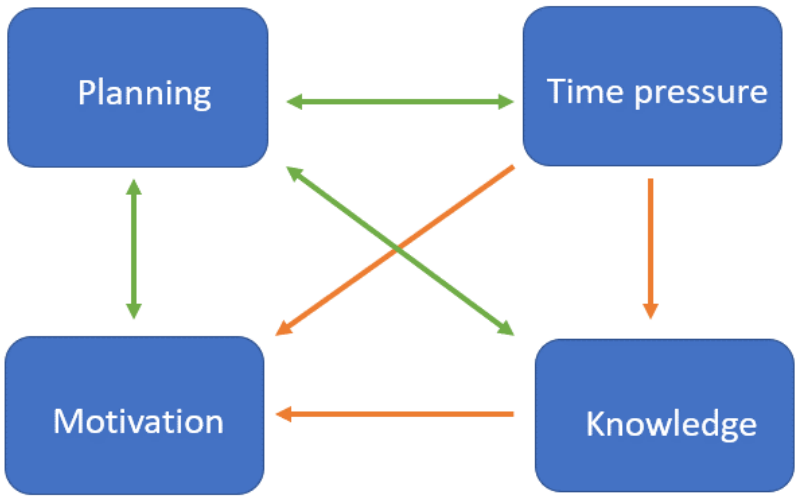

Figure 12: Visualization of identified cause interdependencies (Authors own illustration).

From analysing the interdependencies in Figure 12 some observations can be made. Time pressure within the project may lead to several other causes for defects and errors. A lack of time may decrease motivation among project members, leading to careless actions and forgetfulness (Josephson and Hammarlund, 1999). It may also inhibit knowledge acquisition and learning since learning from errors have been found to require time for reflection (Love and Josephson, 2004). A lack of time may also work as a barrier for learning since it may lead to an environment of prioritization, where future activities are prioritized over dwelling on the past.

Another observation to be made is time pressure and lack of planning affecting each other, meaning that a lack of planning will generate time pressure in the project while a lack of planning is frequently a result of time pressure and prioritization. It was found in the case study that being involved in planning and preparatory work before executing activities could increase the individual motivation towards the work activities.

Problems related to knowledge, knowledge transfer and learning is identified in the study to be enhanced due to time pressure, a lack of communication and a lack of planning. A problem similar to the time pressure – planning problem is identified regarding planning and knowledge as well. Planning the project and specific activities require individuals and the group to have specific knowledge on the activities to be planned and the involvement of individuals that possess the specific knowledge needed. Simultaneously planning can be considered a learning process where information needed regarding the activity to be performed is gathered and analysed and knowledge about the activity is acquired. A lack of knowledge has also been found to decrease the motivation of individual project members, especially a lack of knowledge regarding the

holistic picture of the project (Josephson and Hammarlund, 1999). Knowledge is in part acquired through communication between project members (Love and Josephson, 2004). In the case project oral communication and meetings were found to be the main method to transfer knowledge between individuals.

From this analysis of causes, one could easily be made to believe that responsibility and possibility of improving the quality management lies mainly with of specific project organizations. This is not necessarily the case though. The project organizations have appeared to have a possibility to improve their quality routines and manage their potential lacking quality and quality risks to some extent, but they should not be seen to act isolated from the organisational structure of which they are a part. As can be recognized from the prioritized actions decided they are similar to or adapted from current organizational routines within the organization. Therefore, it is important to recognize the organization's responsibility in providing routines and standards for the specific projects to use and adapt to fit the project in order for them to improve their quality management. Routines to improve or conduct planning activities as well as routines to improve knowledge transfer both within specific projects and between different projects should be developed at an organizational level rather than the project level. The specific projects on the other hand could be considered responsible for adapting the organizational routines to fit the specific project and facilitate the execution of said routines. On the topic of time-pressure it is also important to acknowledge that the overall timeframe and estimation of time needed for specific activities are usually decided in an early stage the project. Both time-schedules and budgets are often pressured to improve the chances of winning bids leading to a potential a pressured time-schedule and budgets already when initiating the project. Therefore, it could to some extent be recognized that specific projects are initiated in a bit of an uphill in terms of reducing time-pressure and budgetary pressure to allow for the mitigation of other error and defect causes. Pressured budgets and time-schedules during bidding processes may also to some extent be traced back to the tradition of

5.2.1 Causes identified in the theory and case study

In Table 6 a comparison regarding identified error and defect causes in the literature and the case study can be seen. There are to some extent consensus between the literature and the case study findings. The error and defect cause not identified in the project that is identified in the literature include "Use of untested or unsuitable material", "a lack of weather protection actions" and "a lack of communication".

Causes	Literature	Case study	Comment
Lack of motivation	**Yes**	**Yes**	The word carelessness is used in the interviews
Lack of planning	**Yes**	**Yes**	
Lack of knowledge or knowledge generating processes	**Yes**	**Yes**	

Lack of communication	**Yes**	No	
Time pressure	**Yes**	**Yes**	
Untested or unsuitable materials	**Yes**	No	
Lack of weather protection actions	**Yes**	No	
Design errors	No	**Yes**	Design errors are not mentioned in the literature as a basic cause, but are rather broken down into other categories of causes

Table 6: Comparison of identified defect causes in the literature and the case study

From the literature, a lack of motivation and knowledge has been found to highly impact the number of defects and errors. According to Josephson and Hammarlund (1999) a lack of motivation accounted for 50% of the defect causes, while a lack of knowledge accounted for 29% while these causes were identified as influential in the case project as well are considered important causes to manage as well. A lack of communication has been identified in the literature to be influential regarding the number of errors and defects in construction projects. In the case project, communication was not identified as a problem area though but was rather identified as a strength.

When considering the cause interdependency chart (Figure 12) it may be forthcoming to identify time pressure as the main cause of errors and defects. As observed in the case study though, time pressure is considered more of a catalyst for other causes than the main cause. Although, considering time pressure a catalyst could insinuate that coming to terms with the time pressure problematic would lead to a decreasing frequency of the causes mutually dependent with the lacking time and prioritization problematic. For this to be possible though the "Catch 22" problematic regarding planning and time pressure would need to be addressed first. This may be done through effort to structure and perform planning and preparations which would increase the time pressure short-term but may relieve some of the time pressure long-term allowing for more time in the future being spent on planning and preparing. With this reasoning in mind, it could be argued that planning and preparation is the main cause to manage. Improving planning and preparation of work activities could potentially long-term directly reduce time pressure in the project and enhance learning and knowledge acquisition as well as indirectly through a reduced time pressure mitigating a decrease of motivation and allow for time for reflection upon errors and learning from them.

The causes "untested or unsuitable materials" and "lack of weather protection actions" was not identified as influential in the case study.

A tendency for the interviewees to mention design errors as a cause for the defects they encounter, or produce was apparent despite it being made clear that the focus of the interview and the research was to find causes and improvements directly related to and possible to influence in the isolated production phase of the project. This tendency to mention problems in the design phase as a cause should not be disregarded though, as

recognized in the literature design errors play a substantial role in the number of errors recognized in construction projects. In the study by Josephson and Hammarlund (1999) design errors in combination with early client processes accounted for 32% of the identified errors. The design phase is also significant for the production prerequisites. Considering the scope of this study, improved proactivity regarding quality management, as well as the positive aspects recognized in this study of detecting and correcting errors and defects early. A proactive approach to quality management, detecting, mitigating, and correcting errors in the design phase rather than the production phase would be beneficial regarding costs, time spent and error consequence. This is true to a certain degree, but there comes a point when spending time and money on finding errors and improving the design is less profitable than starting the production. The interviewee orientation towards finding problems in the design phase may also to some extent be a result of it being easier to find errors in others work than the own work, to shift the responsibility towards someone else.

With all this in mind four primary causes applicable to the case project also found as influential in the literature has been identified. These are:

- A lack of motivation
- A lack of planning
- A lack of knowledge or knowledge generating processes
- Time pressure

5.3 Measures to improve proactivity towards quality management

In the literature and the interviews of the case study measures to improve the proactivity towards quality management and manage the primary causes of defects and errors mentioned in 5.2.1 have been identified. The measures identified along with if they have been identified during the interviews of the case study or in the literature review as well as which of the identified primary causes for errors and defects, they may potentially help manage can be found in Table 7.

Measures of improvement identified:	In literature:	Interviews:	Comment	Primary causes dealt with
Planning work activities and developing work preparations	**Yes**	**Yes**	Identified in case study as: • Involving site workers earlier • Developing work preparations for less complex work activities	• Planning • Knowledge • Time pressure • Motivation

Review and control of drawings prior to activity execution	**Yes**	**Yes**	Currently to some extent done in case project	• Planning • Knowledge
Individual goal setting	**Yes**	**Yes**	Currently not being done in case project	• Motivation
Dividing the holistic goal into short-term goals	**Yes**	No		• Motivation • Planning
Holistic picture accessibility	**Yes**	**Yes**	Done to some extent in case project	• Motivation • Knowledge
Shifting culture towards an error management culture	**Yes**	No		• Motivation • Knowledge
Continuous controls and self-inspections	**Yes**	No		• Knowledge • Time pressure
Merging descriptive documents and drawings	**Yes**	**Yes**		• Knowledge • Planning • Time pressure
Make improved quality a top priority in meetings	**Yes**	No		• Knowledge • Motivation
Continuous quality debriefing meetings	**Yes**	No	Quality has been found to feature in meeting forum. Quality is not the main purpose or only purpose of any meeting forum though.	• Knowledge • Motivation
Weekly structure	**Yes**	**Yes**	Currently under implementation in case project	• Planning • Time pressure
Database where information regarding frequent errors and their solutions in similar projects can be found	**Yes**	**Yes**		• Knowledge • Planning

Routines, structure, and standardization regarding how to use digital tools for quality	**No**	**Yes**		• Knowledge
Production of pilot units	**Yes**	No		• Knowledge • Planning
Rounds	No	Partly	Currently under implementation in the case project	• Time pressure • Knowledge
Root cause analysis	**Yes**	No		• Knowledge

Table 7: Measures of improvement identified in literature and case study.

Planning work activities and developing work preparations:
An importance of planning work activities and developing work preparations while involving the team members who are to perform the work activity has been recognized in the literature. The same importance was identified during the interview study. Potential development regarding work preparations in the project was earlier involvement of site workers or even involving site workers in general when developing the work preparations. Another potential area of development was identified during the interviews to be the developing of work preparations prior to less complex work activities since less complex work activities disregarded as problem free were found to generate errors and defects anyway with a risk of the risk and defects recurring several times during the execution of the work activity before being detected. Developing work preparations is identified in both literature and during interviews as a measure to motivation, knowledge and proactive planning while also decreasing the time pressure in the project long-term.

Review and control of drawings prior to activity execution:
In both the literature review and during the interviews an importance to control and review drawings before executing work activities has been identified. According to the interviewees more extensive controls should be performed during the design phase of the project. The site management recognizes a responsibility for them to perform controls and review as well which they attempt to do. Occasionally due to time pressure this is not done though, they also find it difficult to find potential errors and defects when reviewing drawings and documents since it requires deep knowledge regarding the work of a wide variety of disciplines while also being an extensive amount of information to control and review. Reviewing and controlling drawings is identified in literature and during interviews as a measure to detect errors earlier, increase knowledge regarding the project and to help the planning of future work activities.

Individual goal setting:
Developing individual short- and long-term goals for team members together with superior is identified in the literature as a measure to improve motivation among individual team members. A desire to develop these types of goals was found to be a desired method to increase motivation among some of the interviewees as well as providing groundwork for individual feedback on performance.

Dividing the holistic goal into short term goals:
A division of the holistic project goals into monthly, weekly, or daily goals is identified in the literature as a measure to increase the motivation of individual team members and facilitate the planning of near future activities. This was not described during the interviews to be consciously and strategically done, but to some extent unconsciously to make the holistic picture of the project more accessible.

Accessibility of holistic project picture:
Having access to the holistic picture of the project through a commonly accessible 3D-model, information or documents for example is considered in the literature to be a way of increasing motivation. This is because it may lead to individual project members achieving an understanding of how their work fit into the holistic picture while also helping to increase the project team spirit and will to collaborate between actors and individuals.

In the case project the accessibility regarding the holistic picture of the project is limited. There is common access to the 3D-model through asking the site management team or using the BIM 360 software (in which the there is limited functionality and a knowledge threshold). There is also no consensus between the interviewees regarding the benefit of an accessible holistic picture. According to a couple of interviewees it could potentially make the project feel unnecessary complex to some employees, while a benefit and desire from a couple of interviewees regarding to be able to influence the decisions made in the case project earlier is identified while also receiving holistic information earlier.

Shifting culture towards an error management culture:
A culture of error management within construction projects is identified to facilitate learning, problem solving, motivation and early detection of defects and errors in the specific project. During the interviews, the culture was not specifically described as an error management culture, some tendencies were detected though, including a transparency towards communicating errors, the purpose of finding errors being to find a solution to the problem rather than putting the blame on specific actors, and a will to listen to and help each other with faced problem, both within the contractor organization, but also between actors in the project.

Continuous controls and self-inspections:
Performing continuous controls and self-inspections regarding work activities is found in the literature to facilitate an earlier detection of errors and defects than possible when only performing controls and inspections after finishing the activity. Finding errors and defects earlier may relieve some time-pressure because there is a possibility to correct errors before the consequences become too severe and extensive subsequent work have been performed leading to a need for more complicated corrective actions.

Merging descriptive documents and drawings:
Merging documents and drawings while ensuring the documents and documents are searchable has been identified as a measure to facilitate information gathering regarding specific work activities and therefore knowledge regarding said specific work activities. Easier gathering of information needed will also make the process of planning work activities easier. It is also identified as a measure to ensure all information regarding a

work activity is found which may be more difficult if the information is fragmented and spread in different locations. The need to structure information in a more aggregated manner while being searchable was identified in the interviews as well, difficulties with finding specific information and ensuring all needed information is found was mentioned by several interviewees.

Make improved quality a top priority in meetings:
Making improved quality a top priority within meeting forums is identified in the literature as a measure to improve knowledge through increased experience and learning as well as motivation regarding quality, and the reduction of errors and defects. This may be done through having improved quality or reduction of defects and errors as the first item on the meeting agenda. Quality is not identified as currently being the top priority of meetings in the case project nor is it mentioned as a feasible way of improving the quality.

The reason making quality a priority within meetings may be difficult might be that there are a lot of issues in projects regarded as important, for example, safety, time-schedule, and the work activities to be executed and planned in the future. The prioritization of looking forward to advance in the project rather than dwelling on the past recognized during the interviews may also be an explanation.

Continuous quality debriefing meetings:
In the literature study, continuous quality debriefing meetings has been found to increase knowledge through enhanced learning and experience acquisition.

In the case project, there are currently no regular meeting forums solely dedicated to quality issues nor does there appear to be a will to add new meetings to an already crowded structure of meetings. If anything, a will to reduce the number of meetings held appears more desirable. Although a need for quality to be more prioritized within the meeting structure is identified by some interviewees it does not appear to be doable.

Weekly structure:
Working with weekly structures regarding the scheduling of weekly meetings and which hours to spend doing individual administrative work and which hours to spend on site or performing leadership activities with employees is identified in both literature and during the interviews to help reduce time pressure and facilitate project planning, leading to issues and problems in the project being managed more proactively.

Working with weekly structures is currently being implemented in the case project, so far mainly by working with the scheduling of meetings. Room for improvement is identified regarding the division of individual undisturbed work and on-site work.

Database where information regarding frequent errors and their solutions in similar projects can be found:
To increase knowledge through learning and information accessibility developing a database where error and defect registrations are gathered is suggested as well as proper actions within the organization is taken and evaluated to improve quality and reduce the amount errors and defects within the organization.

From the case study an apparent desire for such a database to be accessible and searchable for the site management team. This could allow for identification of potential problems or errors and how to mitigate or correct them from reviewing frequent problems and their solutions in similar problems in the database.

This measure of improvement is considered to be a bit outside of the research scope since it requires a large amount of organizational work to be undertaken rather than being an action the case project can perform on their own.

Routines, structure, and standardization regarding how to use digital tools for quality:
To improve the error management process and increase the knowledge on how to use digital tools for quality management suggestions during several interviews to find routines, structure and standardize the way of working digitally has been made. This included deciding on routines and structures not only within the case project but also between projects within the organization. This could allow for standardization regarding the gathering of error and defect information that could be used in the previously mentioned error and defect database. Standardized information registry is also identified by the interviewees to make information within the specific project easier to find through search and filtering functions.

Production of pilot units:
Producing pilot units of a work activity to be mass produced in construction projects and then evaluating and controlling the produced pilot unit have been found to potentially enhance learning. It could also allow for earlier detection of errors, more specifically help detecting errors before they become recurring.

A production of pilot units is not mentioned during the interviews. From a wider discussive point of view it could potentially be an applicable process when producing apartments, as in the case project. Finishing a single apartment early and inspecting that apartment could potentially help identifying potential problems and errors that could occur in the future production of apartments, while also working as a benchmark for the quality to strive for in future apartment production within the project.

Rounds:
Rounds are identified in the organizational quality management system (4.1.3) as a measure to free up time, therefore reducing time pressure through a more structured way of working, spending time on site and division of responsibility. It could also enhance knowledge acquisition through learning and gathering information of work activities to be performed.

In the case project the potential with rounds is recognized, but the routine is not thoroughly implemented. A potential degree of improved proactivity towards the project quality management could be found in a more thoroughly and structured implementation of the individual characteristics of weekly structures, scheduling the time to be spent on individual work and the time to be spent on site and performing leadership activities.

Root cause analysis:

When considering the error management process and how to reduce, mitigate and learn from errors, a thorough root cause analysis is considered a powerful tool to enhance learning and mitigating the recurrence of errors and defects.

Room for improvement regarding root cause analysis is identified in the case project. The aim of analysing error causes in the case project is currently identifying the financially accountable actor rather than finding the basic error cause and mitigating it. The main reason for not doing a proper root cause analysis is considered to be time-pressure, focus on the future, the complexity of error causes and a feeling among the project members of not wanting to analyse the root cause when it might be outside of their influence to mitigate it. A feeling among the team members is also connected to the organizational learning of a root cause analysis, where there is a feeling of vagueness regarding if and how the contractor organization (central or regional) will act upon the identified causes, if it will just lead to more information gathered or if it will actually be acted upon by the organization.

This approach towards root cause analysis may be considered a bit problematic though since there is no possibility to develop routines for acting upon root causes identified if they are not identified and registered. The focus on the future of the project rather than dwelling on the past is a bit problematic as well since it may work as a clear barrier towards learning and lead to errors recurring for the same reasons as earlier. Regarding the time pressure aspect, construction projects could potentially benefit long-term by scheduling time for the reflection and learning from errors and in that process freeing up time to do a root cause analysis on detected errors and defects.

5.4 Prioritized actions

The five prioritized actions to improve the quality in the case project (Table 8) will be further analysed and discussed in the following sections of the study.

Prioritized action:	**Approach towards quality management:**	**Comment:**	**Primary causes dealt with**
Quality rounds	Reactive & Proactive	Allows for earlier detection of errors and defects	• Knowledge
Structure/routines/standardization within digital quality management tools	Proactive		• Knowledge • Time pressure
Adapted work preparations	Proactive		• Time pressure • Knowledge • Motivation • Planning

Part-completion controls	Reactive & Proactive	Allows for earlier detection of errors and defects	• Knowledge • Time pressure
Initial quality meeting	Proactive		• Knowledge • Planning

Table 8: Prioritized actions approach towards quality management

Quality rounds

As seen in Table 8, quality rounds could be considered a reactive measure to improve quality. This is because the purpose of the quality rounds is primarily an early detection of errors. It could be considered proactive as well though, since it could allow for detection of errors before they recur, allowing mitigation of future errors. Quality rounds in the project may increase the knowledge acquired among the project team and induvial members. Quality rounds is also a measure of involving the right competence within the organization since service technicians from the after-market division are present with their knowledge on common errors and defects leading to extensive and costly rework during the warranty phase.

Conducting quality rounds may prove a high effort, high reward action since they may require some preparation and involving several individuals needing to coordinate prepare and act upon what is detected. Potentially, the checklists used for quality rounds could be standardized to a certain extent though, at least for projects that are similar to each other. They could prove effective in terms of cost reduction though as conducting them in connection to critical moments regarding potential moisture and water problems could help reduce these problems identified in both the literature and the empirical study to generate a need for costly and extensive correction and rework.

A potential way of developing the rounds could be the installation coordinator responsible for the project conducting similar rounds to control installation before they are built in and not accessible anymore. As there is a high demand on the project management team to have deep knowledge on a variety of disciplines work it these types of rounds could maybe support and relieve the project management team to some extent. Other potential development measures regarding quality rounds recognized from the evaluation include:

- Choosing a few activities or elements on site to inspect, rather than trying to through the whole project. Perhaps leading to a more focused in-depth inspection.
- Preparing a checklist of what is to be inspected that is made accessible to participants beforehand. Should be uploaded within the digital environment used in the project to be accessible in terms of preparation, results and subsequent registration of actions taken.
- In connection to the quality rounds, work preparations on the activities inspected could be reviewed as well.
- In connection to the quality rounds, work preparations on near-future activities could be reviewed as well.

Structure/routines/standardization within digital quality management tools:

The work with structuring and standardizing routines regarding how to work with digital quality management tools has been initiated during the course of the research. It has been found to potentially improve the error management process of the project and the organization through finding common routines between projects. Common routines could improve the error management process since specific projects would not need to develop and communicate new routines in every project, making it easier to move between projects and starting new projects. Standardized data gathering could also potentially facilitate learning from data on an organizational level while also benefit the data quality of the specific project through making data more searchable and easier to filter. The organizational learning is outside of the scope of this case study though, the actions taken in the case project could probably help set the right prerequisites for organizational learning in the future though.

This action could be argued to be characterized as proactive since it long-term allows for learning from errors and defects, while also providing improved prerequisites for an improved error management process in the future.

One important aspect regarding this action to bear in mind is the importance of not only developing routines and structure but the importance and strength in the action lies within the accessibility of information. Guides and guidelines must be made accessible for individual members of project teams so they, themselves can find and acquire the information, this includes both internal and external team members. The idea is doing this through uploading guides directly into the Autodesk BIM 360 software directly when a new project is created. Making the information accessible could perhaps also free up some time the project management team currently uses to explain and help internal and external team members to use the digital tools.

Adapted work preparations:
Adapted, less extensive work preparations may not deal with the most extensive errors but could prove an effective way to proactively mitigate smaller recurring errors that generate disturbances within the project.

Developing these work preparations could also prove effective since they have been identified to manage several of the main error and defect causes identified in the study. Planning and preparing these activities may lead to them being more disturbance free, further leading to time being freed up during and after the activity execution. It may also lead to increased knowledge through learning and information gathering prior to the activity being executed.

One important aspect to mind regarding the adapted work preparations is the site worker involvement, involving them will both lead to a wider perspective and knowledge regarding the activity, but also lead to the individuals performing the work getting the chance to gather knowledge and reflect upon the task to be performed. Involving the site workers and letting them influence the preparation of the work may also lead to increased site worker motivation regarding the activity and therefore fewer errors and defects.

Another aspect to take in mind is that this is not a new routine developed within the organization, as identified in the organizational quality management system, work preparations should be developed for all work activities that may benefit from them

being developed. The importance of this action lies within the execution as a strategy to facilitate their development. Through adapting them, making them less extensive they may be less time consuming to develop, leading to them not being as underprioritized.

Part-completion controls
Conducting continuous part-completion controls could be considered an inherently reactive approach to quality management. The main purpose of this action is earlier detection of errors and a possibility to detect errors before they recur, more specifically the detection of errors before they require extensive rework to be completed or before all occasion of the same work activity have been performed.

It could also be argued that more controls as an approach towards quality management and the reduction of errors may not be the most effective way to reduce errors and defects. If one could ensure a reduction of errors and defects to zero, there would be no need for controls or inspections at all. From this point of view more controls could be considered a way to treat the symptoms rather than the disease.

Initial quality meeting
The initial quality meeting is inherently a measure to transfer knowledge between projects and involving external competence. By having the documents and drawings reviewed by a member of the after-market division, potential errors or materials and solutions that may provide a risk could be identified early in the project where there is still a possibility to make influential choices. This action could be considered proactive in nature since the purpose is to identify errors before they occur. Since members of the after-market division is involved with their knowledge on common problems that are usually detected during the warranty phase of the project this action could potentially reduce the number of errors and defects detected in the warranty phase of the project where they are usually costly to correct and requiring extensive rework to be corrected.

One important aspect to mind is scheduling the meeting early in the project time-schedule, preferably during the design phase of the project when it is easier to influence choices made and make new ones to mitigate future problems. As it was conducted a bit late in this project the main purpose was gaining knowledge on potential risks and what to monitor and control during the production phase of the project. One potential improvement recognized in the study is also that it could be beneficial to conduct following up quality meetings in connection to the quality rounds where certain specific and topical problems and how they are monitored is discussed. This somewhat contradicts findings from the interviews where several interviewees stated scheduling more regular meetings into an already busy meeting structure is not an effective measure to improve the project quality.

Wider discussion regarding prioritized actions:
The impression of the prioritized actions in the project may be that they are neither very complex nor difficult to implement, especially since they are to some extent adaptions of already implemented routines within the organization. This may raise a question regarding why they have not been implemented earlier in the case project. One answer may be the time pressure frequently mentioned during the study. Time pressure may lead to an emphasis on managing the current problems of the project rather than considering long-term benefits that may initially be time-consuming. It may also be due

to quality not being the only issue to considered within the scope of a construction projects, there are other important issues to consider as well, worker safety for example. Implementing or changing routines may also to some extent call for a need to dissolve previous routines that may be deeply rooted within the project organization, especially in a project that has been on-going for over a year as the case project where routines have had the time to become cemented within the project. One reason may also be the desire to learn from the success stories and difficulties of others rather than being the lab rat. Knowing that how to implement actions and how effective they may be could incentivise project members towards implementing the same routines.

The prioritized actions identified are limited as to what can be achieved through implementing them. They will certainly not solve all quality related problems within the production phase of construction projects, nor are they intended to. The intention of the prioritized actions is to provide steps in a direction of improvement, while due to a recognition of difficulties to implement significant changes to the practices of construction projects, maintaining a relative closeness to current quality routines to potentially allow for easier implementation.

5.5 Limitations

Some limitations to the result of the thesis have been recognized during the research process. They are:

The Covid-19 pandemic:
The Covid-19 pandemic has been ongoing throughout the time of the research. This has led to a hindrance in site visits resulting in all information gathered in the case study being gathered through formal, digital meeting settings, mainly the interviews and the workshop. A possibility to conduct regular site meetings could have allowed the gathering of informal information as well, for example through observations on site.

Workshop format:
The workshop format as a method of deciding the prioritized actions may have had an impact on the prioritized actions chosen in the project. To find actions the project members believed to be effective as well as feeling an interest for and motivation to execute the researcher role during the workshop was a passive and neutral one towards choosing the prioritized actions. As a result of the project members present during the workshop having a high influence in choosing the actions, the prioritized actions chosen may differentiate somewhat from what is found in the literature regarding effective measures to increase the quality through a proactive approach.

Timeframe:
The relatively short research time in combination quite many prioritized actions decided in the project may be limiting to the result of the study, both in terms of implementation of prioritized actions and evaluation of prioritized actions. Implementing as many actions as attempted in this study simultaneously in a project that has been on-going for quite some time and therefore have had a possibility to cement their routines within the organization is difficult, especially in combination with the, as seen in the study, problematic time pressure identified in the case project. The timeframe of the study extensively limits the possible evaluation of the prioritized actions as well. Since the main purpose of implementing the prioritized actions is a reduction in defects, error and

the costs related to these phenomena, observing results regarding these parameters is difficult and true objective results may not be possible to observe until after project finish. To strengthen the results even further after project finish, perhaps comparisons with similar projects that has not implement the same actions would be beneficial.

Qualitative study on error and defect causes:
The research conducted to identify the causes of defects and errors in the case project is solely qualitative, potentially leading to the identified causes suffering from a certain degree of subjectiveness especially regarding which causes are most frequent and which causes have the highest impact on the number of errors and defects that are produced in the project.

Interviews:
The number of interviews conducted in the study may be considered relatively few, all the interviews also represent the contractor organization. To frame the results in a wider perspective and perhaps finding a more variegated picture of the project interviews with other actors, such as client representatives, subcontractors and inspectors could have benefitted the study.

Limitations regarding applicability
Another observation to consider regarding the prioritized actions recognized is that they are developed from a consideration of what is within the power of the specific project organization to influence. They may not be applicable to all project within and outside of Skanska as an organization. The prioritized actions are also developed from a standpoint that the project organization has both a certain amount of power and responsibility to reduce the numbers of quality errors and defects and improve their error management processes. From a wider perspective this study does not in-depth deal with underlying structures within the Swedish construction industry and the studied company that may either provide a root cause to the lacks in quality management identified or lead to the project organizations not having sufficient prerequisites to begin with. Potentially working towards removing barriers and identifying underlying structures with the purpose of improvement would generate greater overall results regarding a reduction in quality issues than finding measures of improvement in specific projects.

Single case study:
Using a single case study to investigate improved quality management provides possibilities to in-depth investigate and conceptualize the research within the context of the case project. Claiming generalizability and applicability to other projects within the studied organization and even more so outside of the studied organization is of a more limited nature though, without first analysing causes and problems within the specific project organizations and their contexts.

6 Conclusion

The purpose of this study is to through a literature review and an in-depth study of a single multi residential housing project identify causes for defects and errors in the project and how they can be managed and mitigated proactively in the project with the purpose of reducing the number of defects and errors during the production phase.

This has been done through answering four research questions:

What causes for errors and defects can be identified in theory and practice in the context of a multi residential housing project?
Through analysing findings from the literature review and the interview study of the case project four primary causes for potential errors have been identified:

- A lack of motivation
- A lack of planning
- Time pressure
- A lack of knowledge

A lack of motivation may lead to carelessness and forgetfulness. A lack of knowledge includes lacking learning processes, knowledge transfer and information accessibility. The identified primary causes are not isolated causes but mutually dependent in relation to each other.

How can the identified causes be managed in a more proactive way in theory and practice in the context of a multi residential project?
It was found in the study that a decrease in time pressure may lead to mitigation of the other primary causes identified and improved planning processes could lead to decreased time-pressure. Knowledge, accessible information was found to lead to increased individual motivation. While planning processes and knowledge being mutually dependent on each other.

What measures can be tried in the studied project to promote a more proactive quality management?
In the case project five prioritized actions to implement have been decided through a workshop based on the current analysis of the project. These actions include:

- **Quality rounds**, where a checklist is prepared by members of regional after-market group and the rounds are conducted in connection to critical moments of the production that could potentially lead to errors and defects frequently identified in the warranty phase of the project, often requiring extensive and costly corrections.
- **Development of structure/routines/standardization within digital quality management tools,** allowing for easier finding of information in the digital project environment and facilitating organizational learning from defect and error data. This action includes making guides and guidelines accessible to all project members.
- **Adapted work preparations for uncomplex work activities,** to facilitate the development of work preparations for often underprioritized work activities found to lead to errors and defects even though not being complex in nature, work preparations may be adapted towards being less extensive in their requirements to facilitate them being developed when not being as time-consuming.

- **Part-completion controls,** instead of controlling and inspecting the result of work activities after their completion, continuous controls during the execution of the activity may be conducted before the completion of work activities.
- **Initial quality meeting,** a meeting held in an early phase of the project by the regional quality manager where documents and drawings have been reviewed by the after-market division to identify potential risks that may cause errors or defects based on common problems usually detected during the warranty phase of housing projects.

How does the identified measures of improvement promote a more proactive way of working with quality?

- **Quality rounds,** may promote earlier detection of errors and defects potentially requiring extensive and costly corrections.
- **Development of structure/routines/standardization within digital quality management tools,** facilitates the error management process within the specific project while also providing prerequisites for organizational learning from error and defect data.
- **Adapted work preparations for uncomplex work activities,** facilitates the development of work preparations and planning of underprioritized work activities to mitigate causes potentially leading to errors and defects being caused during the execution of said activity.
- **Part-completion controls,** promotes earlier detection of errors, potentially before they recur. Also allows for earlier correction of errors and defects when correction is less costly and require less extensive measure to be taken.
- **Initial quality meeting,** facilitates knowledge transfer between projects and allows for earlier identification and mitigation of potential risks that could lead to errors and defects.

6.1 Recommendations

Some recommendations for the case project and the organization may be made based on this research. These recommendations include attempting to analyse and identify causes for errors and defects in similar construction projects to perhaps find a potential to apply the findings of this study to mitigate the identified causes. It is also recommended that the prioritized actions recognized in this study are fully implemented in the case project and that the effect of the actions are evaluated with the purpose of finding out if they have the effect hoped for or if they may need to be adjusted. If similar causes for errors and defects are identified in similar projects implementation of the recognized prioritized actions is recommended to allow for a comparative evaluation of results.

6.2 Further studies

Recommendations on further studies connected to this thesis include:

- An evaluative study of the results and effect of the prioritized actions recognized in the case project after project completion.
- Implementation of prioritized actions in similar construction projects with the purpose of conducting a comparative cross-case study.

- Deeper studies on the potential economic effect of implementing the recognized prioritized actions.
- Empirical research on the potential measures of improvements identified in this study but not being recognized as prioritized actions within this study.
- In-depth studies of underlying structures within the studied organization as well as the industry that could potentially work as a barrier towards improving the quality management in specific construction projects.
- Deeper studies on what benefits, and barriers or facilitators could be found regarding the implementation of a thorough root cause analysis in the context of a specific projects.

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Appendices

Appendix 1: Interview guide: Site management team

Background:

Role:
Years of experience in current or similar roles:

Error management process

- What do you think are the main causes of errors and defects in the production phase of a construction project?
- Are errors or defects more frequent in connection to specific work activities or building elements?
- What routines do you have in the project to detect errors and defects?
- What routines do you have in the project to prevent errors and defects?
- What routines do you have in the project to communicate errors and defects?
- What routines do you have in the project to ensure:
    - That an error or defect will be corrected?
    - That an error or defect has been corrected?
- What routines do you have in the project to reflect upon and learn from:
    - Causes of errors and defects?
    - Correction of errors and defects?
- When defects occur, how are they handled in general? Corrected or identification of root cause and managing the root cause?
- Are the tools and routines in the project to control, ensure sufficient quality and manage and prevent errors and defects in the project sufficient?

Causes

Time:

- Sufficient time for preparation before tasks?
- Sufficient time for execution of tasks?
- Sufficient time for correcting errors?
- Sufficient time for reflecting upon:
    - Error cause?
    - Error correction?

Resources:

- When/how is a lack of resources discovered?
    - In the own organization?
    - In subcontractor organizations?
- How is a lack of resources acted upon?
- How do the subcontractors handle a lack of resources?
- In which situations does a lack of resources occur?
- Measures of improvement on the topic of resources?

Knowledge:

- When/how is sufficient knowledge about tasks to be performed ensured?

- How is lack of knowledge, when discovered, acted upon?
- How is gathered information in the project acted upon to increase:
    - Knowledge in project
        - Individual
        - Collective
        - Organizational
    - Knowledge in organization (exchange/shared)
- How is the individual knowledge of project members utilized?
    - Is it utilized to its full potential?
- General measures of improvement on the topic of knowledge?

Digital tools

- Are the current digital tools used to ensure quality sufficient?
- Do you have sufficient knowledge about the digital tools used for quality management?
- Is the general knowledge on how to use digital tools for quality management in the project sufficient?
    - Supervisors?
    - Construction workers?
    - Subcontractors?
- General measures of improvement regarding the use of digital tools for quality management in the project?

Motivation:

- Do you provide feedback on performed work?
- Do you receive feedback on performed work?
- Do you have individual goals developed for you in collaboration with superior? Or have you set individual goals with you employees?
- Is the project team spirit good?
    - Are measures taken to improve the team spirit of the project between individuals and actors?
- Are there members in the project having a too high or too low amount of responsibility?
- General measures of improvement on the topic of motivation?

Information:

- Is there a way for participants in the project to in an easy and accessible way take part of information regarding the holistic picture of the project? (Access to 3D-model for example?)
- Do you think it would be beneficial for individual project members to have access to information regarding the holistic picture of the project?
- How is information regarding the project and tasks to be performed packaged and made accessible to project members?
    - Is it accessible/easy to find everything needed?

    - Is it ensured that everyone takes part of and understand the information needed?
- In which meetings/forums does quality issues and experiences come up?
    - Are there specifically dedicated meetings?
    - Is quality a brought up on the daily briefings?
    - Is there a standing forum for bringing up minor improvements?
- Is information about frequently occurring problems, their solutions, and preemptive actions in similar projects accessible?
- Is the information/knowledge/experience/error sharing between individuals and actors in the project transparent?
- Is there a common picture in the project regarding the purpose of sharing information on errors and defects?
- General measures of improvement on the topic of information?

Other:

- Is there anything else you feel you want to share?
- Do you have any suggestions on potential measures of improvement in the project that have not been mentioned during the interview?

Appendix 2: Interview guide: Site worker

Which is your current role in the project?

How many years of experience do you have in current or similar roles?

What do you believe to be the main causes leading to defects or errors in the production phase of construction projects?

Dou you feel heard or that you receive feedback when you detect errors or defects?

Do you feel that you receive feedback when you have performed or executed a work activity well?

In the current project do you perceive the communication climate as transparent? Are members willing to share information about things not working out as planned?

Is a sufficient amount of preparing or planning work performed to avoid the occurring of errors or defects?

Are you usually involved in the development of work preparations?

Dou you think that a sufficient action is taken to avoid errors or defects from recurring?

Do you usually feel that you have sufficient time to prepare and execute work activities?

Do you usually feel that you have sufficient time for the correction of errors or defects that have been identified?

Do you believe that the personnel resources of the project sufficient in general?

Is the team spirit within the project good?

Before the performing of a work activity is it ensured that the individuals who are to perform the activity have sufficient knowledge regarding the performing of the work activity?

If a lack of sufficient knowledge is identified prior to the performance of an activity, how is this managed?

Do you feel that you have the possibility to contribute with your knowledge and experience and that this is well received if you try to contribute with knowledge and experience?

Are you involved to a sufficient extent when performed activities are controlled or inspected?

Is the information needed to perform activities as a site worker easily accessible?

Is information regarding the holistic picture of the project easily accessible?

Do you feel that there is something you want to share within the interview that I did not ask you about? Regarding production quality management.

Do you have any suggestions on measures of improvement regarding a proactive quality management in the production?

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