Coordination in the Construction Process

Aalborg Universitet

IBM
SYNOPSIS:

From the general contractor’s point of view, the main challenges of the preconstruction phase are the project management team and the ability to handle changes in the project schedule. In the construction phase we have focused on the challenge of managing subcontractors. Based on findings in construction industry literature and empirical studies, it is argued that solving these three challenges is critical to the preconstruction and construction phase.

Each of the three challenges consists of causal mechanisms that in sum are what creates the basis for the challenge. These causal mechanisms have various dependencies identified through Crowston and Malone’s coordination theory. A dependency is explained as what creates the need for coordination, however these dependencies can be limited through coordination mechanisms.

In the theory study of the two phases we have found that there is theoretical grounds for limiting the dependencies of the causal mechanisms, through coordination mechanisms. As the coordination mechanisms presented by Crowston and Malone (1994) are only guidelines, we have elaborated from the basis given by the original authors by suggesting various ICT solutions in extension of the original coordination mechanisms. This has been done through our cooperation with IBM and based on the fact that we have seen clear indicators of these being valid suggestions in order to make the coordination mechanisms more powerful.

By applying coordination mechanisms we hope to have created better-coordinated causal mechanisms that in turn should ease up the challenges and make already critical phases of the construction project run smoother, with less chances of coordination related issues during the execution of the phases.

As the phases addressed in this thesis are critical to the success of the construction project as a whole, we hope that this will also contribute to a more successful construction project in total.

Ved at underskrive dette dokument bekræfter hvert enkelt gruppemedlem, at alle har deltaget lige i projektarbejdet og at alle således hæfter kollektivt for rapportens indhold.
Abstract

From the general contractor’s point of view, the main challenges of the preconstruction phase are the project management team and the ability to handle changes in the project schedule. In the construction phase we have focused on the challenge of managing subcontractors. Based on findings in construction industry literature and empirical studies, it is argued that solving these three challenges is critical to the preconstruction and construction phase.

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Acknowledgements

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5.5 EMPIRICAL ANALYSIS
1 Introduction

1.1 Problem Area

The problem area of this thesis is the construction industry. The reason why we have chosen to focus on the construction industry is based on our belief that there is room for improvement in making this industry more productive and efficient.

According to the U.S Census Bureau of the Department of Commerce, the value generated by the U.S construction industry in 2010 was roughly $800 billion (U.S. Census Bureau News, 2012). This makes up 6 percent of the entire GDP (gross domestic product) in the US. In the Scandinavian countries the percentage of the GDP by the construction industry varied between 5-10 percent (Statistisk Sentralbyrå, 2011) (Statistisk Sentralbyrå, 2012) (European Commission, 2012).

However, although the construction industry generally represents a considerable percentage of the GDP in most western countries, the productivity of this industry is lower than most other industries. The definition of productivity and the importance of this productivity, is described by Horner and Duff in the following:

“Output measures how much we produce. Productivity measures how much we produce per unit input. From a client’s perspective, higher productivity leads to lower costs, shorter construction programs, better value for money and a higher return on investment. From a contractor’s point of view, higher productivity leads to more competitive edge, more satisfied customers, higher turnover and increased profits. From the country’s point of view, higher productivity leads to more efficient use of scarce capital, greater incentives to invest, more jobs and economic prosperity. It take but a simple calculation to demonstrate that a 10 percent increase in UK construction labor productivity would represent a saving of some £1,5 billion to the industries clients; sufficient to produce perhaps an additional 30 hospitals or 30 000 houses a year” (Horner & Duff, 2001).
In addition, as described in a report made by Veiseth, Røstad, Andersen, Torp, and Austeng (2004) in cooperation with SINTEF (Stiftelsen for Industriell og Teknisk Forskning) and NTNU (Norges Tekniske-Naturvitenskapelige Universitet), the productivity in the Norwegian construction industry is significantly lower than in other industries (Veiseth, Røstad, Andersen, Torp, & Austeng, 2004).

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Table 1 - Development of productivity within industries in Norway 1996-2001 (Veiseth, Røstad, Andersen, Torp, & Austeng, 2004)

The table (Table 1) above shows the development of productivity within the Norwegian construction industry in the period 1996-2001 in comparison to other industries. It is evident that the construction industry has not been able to keep up with the development of industries. The gap in productivity in this period is estimated to account for a “loss” of NOK 95 billion. It is argued in the report that inadequate logistics and poor cooperation between parties and ineffective processes are to blame for the negative development. This shows how the nature of construction projects, where there are substantial amounts of actors involved, poses a challenge to the productivity in construction projects where all these actors need to be coordinated (Veiseth, Røstad, Andersen, Torp, & Austeng, 2004).

How coordination takes place in processes is what inspires this thesis. Considering how the construction industry is generally underperforming, while at the same time representing a substantial part of the GDP in most countries, we find it intriguing to investigate this further in our thesis. With the problem area being the construction industry, we seek to analyze the possibilities of creating a better-coordinated construction project management process.
1.2 Problem Statement

The problem statement for this thesis consists of a research question and an empirical question. These questions will enable us to conduct a proper study of coordination in relation to the problem area.

1.2.1 Research Question

What determines the coordination constraints in a construction project and how can they be limited?

In answering the research question we will gain a thorough understanding of where the coordination in a construction project takes place and what variables cause the need for coordination. Moreover, we will be able to establish how to obtain a better-coordinated construction project.

To answer the research question we will:

- Identify a theoretical framework that will enable us to analyze where and why the need for coordination arises.
- Identify theoretical propositions to limit the coordination constraints.

1.2.2 Empirical Question

What are the appropriate coordination mechanisms for a construction project, and what are the implications of using ICTs as a coordination tool?

The purpose of the empirical question is to create a platform where the findings of the theory study can be applied to the empirical study. The aim is to find out if the case company faces the same coordination constraints identified in the theory study. Next we will
analyze how the case company handles these coordination constraints and analyze whether the theory study can contribute to the findings of the theory study.

To answer the case study question we will have to:

- Determine if the case company faces the same coordination constraints as uncovered in the theory study.
- Establish how the case company handles coordination constraints.
- Conduct a comparative analysis of how the coordination constraints are handled theoretically versus how they are handled by the case company.
- Based on findings, analyze the feasibility of ICTs as a coordination tool.

In sum, the research question and the case study question should provide us with the means to argue for how coordination constraints in the construction industry can be limited and if ICTs can prove a useful tool in achieving this. By analyzing both theory and practice (empirical study) we hope to be able to suggest a reasonable approach to possibly increase productivity by limiting coordination constraints in the construction industry.
1.3 Project Scope

We have chosen to write this thesis from the general contractor’s point of view. This is because the general contractor will have most of the managerial responsibilities in a construction project and will therefore also have the most influence on coordination of the processes and ultimately the productivity of the construction project.

As a construction project includes numerous actors it would be impossible to address the coordination that takes place within all the involved actors. By focusing on the general contractor we can still address coordination constraints in a construction project in a relevant way as we employ the point of view of the actor that has the overall responsibility of the processes.

For the empirical study we have chosen a major Norwegian general contractor who represents the point of view that we have employed throughout the theory study.

The literature used in this thesis does mainly revolve around construction management and coordination theories. By studying construction management we are able to obtain a substantial understanding of the processes of a construction project and how these are theoretically managed. This will enable us to identify what phases of a construction project are most critical and what they entail.

The empirical study will compliment the theory study by adding a more realistic point of view in addition to what can be found in the literature. This is also where the feasibility of the findings in the theory study will be tested.

Finally, the idea of this thesis is not to create a revolutionary way of coordinating a construction project, but rather to examine the potential of limiting coordination constraints in the construction industry. Hopefully our combination of theoretical and empirical studies can also hypothetically somehow contribute to increasing the productivity of the industry.
1.4 Project Structure

1 INTRODUCTION

2 LIMITATIONS

3 SCIENTIFIC METHOD

4 THEORY STUDY

5 EMPIRICAL ANALYSIS

6 PRINCIPAL FINDINGS

7 DISCUSSION

8 CONCLUSION

9 FUTURE RESEARCH
2 Limitations

There are certain limitations to this thesis, which we find important to clarify as we acknowledge that several factors related to decisions made throughout the process of this thesis, can affect the quality of our interpretations and findings. Quality assessment in relation to reliability and validity is elaborated on in the methodology section.

The authors experience

We acknowledge that, although we both have experience with construction work, our experience is limited to student internships. We therefore recognize that our interpretations regarding a generic construction processes may be biased at certain points, however we strive to continuously confirm our interpretations with secondary data.

Limited accessibility of theory

There is a comprehensive amount of theory available regarding coordination. Literature regarding construction is also available on a large scale. However, the literature addressing coordination within construction is limited and we therefore had to make certain assumptions in the theory in order to study both subjects combined. We recognize that such assumptions can result in limitations of the findings.

Coordination theory as a still developing theory

Coordination theory is not a fully developed theory. We therefore had to make decisions in regards to what segments of the existing theory to employ. We acknowledge that selecting certain parts of an existing theory can result in a certain bias. Further explanation of our choice of theory can be found in section 4.1.

Literature

We recognize that different countries have different methods of conducting construction projects, thus the challenges through a construction process may be different depending on nationality. As the empirical study has been conducted in Norway we recognize that
there may be important differences between how the “international theory” evaluates construction processes compared to what has been uncovered in the empirical study.

Challenges and Causal Mechanisms

In the theory we identify certain challenges and subsequent causal mechanisms related to construction processes. We strive to continuously confirm theoretically what causal mechanisms are related to the specific challenges. However, in regards to this we had to make certain assumptions based on the theory and we recognize that such assumptions can be incorrect where related challenges and causal mechanisms may be inappropriate.

Dependencies

We further identify certain dependencies in relation to process challenges and the subsequent causal mechanisms. As the coordination theory within construction is limited, the coordination theory does not clarify which dependencies exist within each causal mechanism. Consequently we had to make decisions regarding the connection between dependencies and causal mechanisms, based on our theoretical understanding. We acknowledge that this can result in limitations, as there may be certain dependencies in the theory that should or should not be connected to the specific causal mechanisms.

Analyzing coordination mechanisms in the empirical study

We acknowledge that the grounds, on which we base the decisions regarding the appropriate coordination mechanisms under “comparative analysis” in the empirical analysis chapter, should have been founded on a firmer basis. The method applied has been presented in the introduction to the empirical analysis, however these decisions should have arguably been based on, for example, a “point/numeric system” so that the decision could have been further strengthened.
3 Scientific Method

The purpose of this chapter is to clarify the methodological approach of the study.

3.1 Research Strategy

The project’s research strategy is to identify the different methodologies, clarify the appropriate research method and thereby construct an adequate project design based on theoretical findings. We conduct a deductive study as we seek to achieve sufficient knowledge on the subject by investigating the existing coordination theory and theory on construction before we collect the empirical data (Yin, 2009).

Robert K. Yin (2009) has made a table (Table 2) that clarifies which method to apply depending on the three conditions:

a) The type of research question
b) The extent of control an investigator has over actual behavioral events
c) The degree of focus on contemporary as opposed to historical events

Yin (2009) further distinguishes between five different research methods: Experiment, Survey, Archival Analysis, History and Case Study. Table 2 illustrates the range of different research methods for each relevant condition.
It is essential to mention that the methods are not always mutually exclusive and it may often be beneficial to combine two or more methods. In some research contexts the boundaries are not always evident and they may overlap where some questions may be answerable with more than just one method. According to Table 2 the best research method for this project is a case study, archival analysis, or a survey due to the fact that the study does not require control of behavioral events and it takes place in a contemporary setting.

We believe that coordination within the construction industry is a complex subject relying on a comprehensive set of variables. Due to the fact that coordination within the construction industry is a relatively unexplored area, the accessibility of concrete archival data is moderate, and we therefore decided to use the case study method to handle the empirical part of the thesis. Further, we find it suitable to use a mixed methodology with a case study consisting of archival analysis and history, as we prefer to triangulate interviews with secondary data.

A case study allows us to maintain a holistic approach to the units of analysis and thereby obtain data that will enable us to sufficiently answer the problem statement. Coordination within the construction industry involves management issues, which makes the empirical
study even more relevant. We find it important to manage the variation of data through the project, which the empirical study allows us to do.

In this project we seek to make case study conclusions based on analytical generalization as opposed to statistical generalization. These two versions of generalization are widely discussed between researchers and have both have strengths and weaknesses (Yin, 2009). One major concern with analytical generalization is that the quality of such research may be low because data is collected and analyzed in an unsystematic and biased manner. We will therefore strive to counter this in all aspects of the thesis. Statistical generalization is considered unsuitable in this thesis because the complexity of the unit of analysis would require too many statistical variables.

3.1.1 Case Study Design

A case study can have different designs, namely single, multiple, holistic or embedded designs, which depends on if the study investigates one case or several individual cases in one study (Yin, 2009). It is therefore important to consider how to construct the case study prior to the collection of data. Figure 1 (Yin, 2009) visualizes the different designs.

If investigating several cases, comparing and triangulating data and observations from different studies, then a multiple-case is the appropriate design to employ. The logic underlying the use of multiple-case studies is that each case must be carefully selected so that it either predicts similar results or predicts contrasting results, but for anticipated reasons (Yin, 2009).

For single cases, Yin (2009) clarifies five different rational designs: critical case, unique case, representative case, revelatory case and longitudinal case. Yin describes the objective for a representative case as "to capture the circumstances and conditions of an everyday or commonplace situation." This coincides with the objective of this case study where we seek to investigate the case company's coordination methods, which we argue can represent the general common methods of coordination in the construction industry. Thus, the findings in this case can generally represent coordination in construction companies by being
informative about the experiences of the average construction company. We therefore find the representative single case design as appropriate for this study.

Figure 1 - Basic Types of Designs for Case Studies (Yin, 2009)

The matrix shows that single- and multiple-case reflect different design situations and that, within these two variants there can also be unitary or multiple units of analysis (Yin, 2009). The four types; single holistic case, single embedded case, multiple holistic cases and multiple embedded cases clarify that there is a dissimilarity depending on how many units of analysis one operates with. This is exemplified by Yin in the following quote: "The same single-case study may involve more than one unit of analysis. This occurs when, within a single case, attention is also given to a subunit or subunits. In contrast, if the case study examines only the global nature of an organization of a program, a holistic design would have been used" (Yin, 2009, p. 50).
This thesis has a holistic design as the unit of analysis is limited to the case company and we are only investigating one phenomenon within the organization.

### 3.1.2 Level and Unit of Analysis

Linking the phenomenon of investigation to the research question is important, and failure to adequately do so can result in the empirical data collection giving incorrect responses to the qualitative study (Yin, 2009). We have narrowed the empirical analysis to a more specific topic to ensure reliability. Thus, the case company's methods of coordination are the level of analysis and the unit of analysis is the case company's construction management department.

### 3.2 Theoretical Basis

The existing coordination theories have different approaches to explaining coordination, however we solely employ coordination theory by Crowston and Malone. Their in-depth analysis of coordination gives us the opportunity to reach the desired level of analysis and thoroughly study the different mechanisms within a construction process.

Further, our choice of theory regarding construction has a general character, where we seek to achieve fundamental knowledge about construction projects. After conducting theoretical analyses within the scope of the thesis the next phase is to suggesting a theoretical framework, thereby using the framework to explain coordination mechanisms within the construction industry and to finally answer the project research question.

After conducting the empirical research, we will explore if the theoretical results are applicable to the empirical findings and appropriate to practice. Finally we will suggest a solution to the overall problem statement in relation to the case company and thereby discuss whether the use of ICTs can be a potential extension to overcome coordination constraints in construction projects.
3.3 Collection of Data

According to Yin (2009) a good case study has as many sources as possible and there are six sources of evidence used in case studies: documentation, archival records, interviews, direct observation, participant observation and physical artifacts. We have found the following sources applicable to this project (Yin, 2009):

- Documentation
- Archival records
- Interviews

3.3.1 Documentation

The documentation collected through this study is other formal studies revolving around the same subject and articles appearing in the mass media.

We have primarily used the Internet such as the university's online databases and Google Scholar, Proquest and others to collect relevant data. We have found both platforms useful as a source, especially the university's database as it is possible to evaluate the articles from academic ratings. In regards to theory on construction, we found it necessary to acquire an academic book to achieve fundamental knowledge about managing construction processes, and we therefore purchased the book "Managing Construction Projects" by Graham M. Winch (2010).

As Yin (2009) argues, documents can be used to support information from other sources and to spot new references by observing distribution lists. Yin explains this accordingly: "Because of their overall value, documents play an explicit role in any data collection when doing case studies. Systematic search for relevant documents are important in any data collection plan" (Yin, 2009, p. 103).

However, we acknowledge the different weaknesses of using documentation as a source of evidence, such as overreliance on documents and issues related to handling the
abundance of material available (Yin, 2009). We have strived to overcome the overreliance by being critical to the literature and making sure that statements and findings are supported in several studies. The literature on coordination and construction is comprehensive, however the literature on coordination within construction is somewhat limited. Thus the issue of material abundance is not compromising the validity. The academic databases of the university further allowed us to maintain a certain level of validity control for documentation collected through the project.

3.3.2 Archival Records

We have collected internal documents concerning the typical course of a construction process, which was important for us in order to achieve sufficient knowledge about the methods of managing construction projects employed by the case company. The archival records were not quantitative, but rather informative about the processes in a general manner.

An essential limitation identified in relation to archival records is the limited access of internal in-depth reports and analysis of the case company's previous construction projects. It was not common for the case company to make reports after construction projects, which could have been an essential archival source to this thesis. With further access to such records the arguments could be supported on a more comprehensive level and be more thoroughly analyzed in relation to theory. We acknowledge that the records are produced for a specific purpose and a specific audience other than the case study investigation, which can result in certain bias in terms of records accuracy (Yin, 2009).

3.3.3 Interviews

It is argued by Yin (2009) that interviews are one of the most essential sources of empirical information, and he defines two different types of interviews: in-depth interview and focused interview. In-depth interviews may take place over an extended period of time, while the focused interviews last for a short period and have several respondents.
In this project we have conducted focused interviews where each interview lasted for approximately one hour. We used the interviews to support or challenge certain arguments established in the theory and to identify variables of relevance.

When we designed the interview questions we noticed the following challenges: not asking leading questions and remaining neutral in the process to avoid bias, including how and why questions to get the in-depth responses we needed, maintaining a conversational process instead of asking direct questions. This is related to the difference between asking so called "Level 1" and "Level 2" questions. Level 1 questions are the specific questions asked in the field, while Level 2 are the investigators questions of inquiry (Yin, 2009).

When designing the interview questions we attempted to appear naive about the topic and allowed the respondents to provide a fresh and independent commentary. Most questions included how and why formulation to provoke explanatory and descriptive responses. We experienced throughout the process that the importance of rehearsing the interviews should not be underestimated.

To achieve a thorough understanding of the coordination methods of the case company we chose to interview respondents with different experiences and functions within the company. The thesis revolves around coordination both on a project management level and a field engineering level, and we therefore involved respondents with project management experience and field engineering experience.

The respondents are all employees within the case company and we find them relevant to the case as they are involved in the coordination of construction projects on a daily basis. We acknowledge that there might be bias occurring in the case interviews as the respondents may only wish to share certain information.

The table below (Table 3) shows the case company interviewees, their position in the company and where they are located during the construction project.
### 3.4 Empirical Quality

In this thesis we collect empirical data by using an empirical study, where it is important to ensure the scientific quality, both in the theory of the literature and the collection and analysis of empirical data. As an inadequate level of quality can have a negative effect on the conclusion we ensure the project quality by controlling the construct validity, internal validity, external validity and reliability (Yin, 2009). The methods are explained in the following.

#### 3.4.1 Construct Validity

To avoid a case study being based on subjective judgments and to reduce the risk of bias as such, Yin (2009) suggests three tactics to increase construct validity. The use of multiple sources of evidence, establishing a chain of evidence and having the draft case study report reviewed by key informants.

Multiple sources of evidence, in the context of data collection, is to use many different sources of evidence, such as archival data, literature in the form of articles and papers, and field research in the form of interviews. The use of multiple sources of evidence in empirical studies allows investigators to address a wider range of the subject and to create converging lines of inquiry. “Case study finding or conclusion is likely to be more convincing and accurate if it is based on several different sources of information” (Yin, 2009).
By documenting elements such as: sources, collection of data, interviews and observations, investigators is able to maintain a chain of evidence throughout the case study. This allows the readers to trace elements within the study and confirm the validity.

Another way of securing the validity is to have the draft reviewed by the participants and informants in the case. This may benefit the investigators as the comments can be exceptionally helpful and be used in the report. By reviewing the draft, evidence and facts may be further supported. New and important material, which may have been missed during the data collection period, can be added in this process (Yin, 2009).

To secure the project’s construct validity we have used multiple sources of evidence in the form of archival data, academic articles and interviews. The literature has been located through Aalborg University’s database, our semester-books, research web pages and case archives. To increase the reliability of the information in our case study we have tried to preserve a chain of evidence by documenting each step of the project, such as documenting data collection and reporting meetings.

3.4.2 Internal Validity

When an event cannot be directly observed an investigator has to make certain assumptions based on interviews and documentary evidence collected as part of the case study. Internal validity is a test that concerns achieving validity, and it explains how and why event x led to event y through a third factor. We do not find this logic applicable to this study, as this study does not explain but explore a given event.

3.4.3 External Validity

To secure external validity it should be possible to generalize the findings beyond the particular empirical study. As the research in this study is based on an existing theory and, it is possible to apply the final findings. We acknowledge that a so-called replication has not been applied for this project, which Yin (2009) recommends in relation to external validity. However, we strive to generalize our results to further develop the theory on coordination within the construction management process. A theoretical framework is prepared and tested in the case study, and by employing existing theory we build a foundation to
construct external validity. It is not given that a single case study proposes a good foundation for generalization, however since we rely on analytic generalization we believe that a single case study is sufficient.

3.4.4 Reliability

The reliability of a project is secured by making sure that the case study findings and conclusions can be confirmed again, if another investigator were to conduct the exact same study. “The goal of reliability is to minimize the errors and biases in a study” (Yin, 2009, p. 45). Yin describes two different ways of overcoming reliability issues: case study protocol and case study database. However because the reliability is so closely related to the chain of evidence, we have chosen to use the chain of evidence to secure the reliability by documenting important steps through the duration of the project and archiving important documents linked to collection of data and observations.
4 Theory Study

4.1 Argument for Choice of Theory

In section 4.1 we will explain the background for how the need for coordination started, further we will introduce the theory we have chosen for this thesis.

In 1776 Adam Smith published “An inquiry into the Nature and causes of the Wealth of Nations”, better known as “The Wealth of Nations”. As a response to the early stages of the industrial revolution, Smith wrote his book “The Wealth of Nations” to introduce his belief that free market economies are more beneficial to the shifting times than feudalism, which was the dominating system of economical governance at the time.

“The Wealth of Nations” soon gained enormous popularity and came to be a fundamental piece of work in classical economics. Smith’s work represented a clear shift in economics where, according to Smith, economic growth was rooted in an increased division of labor.

Smith’s division of labor was based on three core principles. First, capabilities of a worker can be increased by “reducing every man’s business to some simple operation, and by making this operation the sole of his live”. Secondly, there would be considerable savings in time if a worker did not have to switch from one type of work to another. Smith’s third principle was oriented towards innovation, where he stated “men are much more likely to discover easier and readier methods of attaining any object than when it is dissipated among a great variety of things” (Smith, 2005, p. 15).

As Smith’s theory gained momentum the world soon started to follow his teachings, which have led to how we structure our organizations today. Along with this change came a need for coordinating the growing number of differentiated skills, where a number of theorists have since contributed with various theories related to coordination. Several of these theorists and their findings in relation to coordination are presented in the appendix.
However, this section will continue with the introduction of the theory we have chosen.

Kevin Crowston and Thomas W. Malone

Crowston and Malone (1994) created their “coordination theory” with the purpose of creating a general framework that would make it possible to analyze various processes with the intent to improve how they are coordinated.

The theoretical basis created by Crowston and Malone has three elements that makes it possible to break a process into the pieces required to better understand why there is a need for coordination and how to coordinate in the best possible way. These three elements are process, dependencies and coordination (Crowston & Osborn, 1998). The process is the situation where the dependencies occur and, as a result, the coordination is needed as explained in this quote “...we analyze processes in terms of actors performing activities to achieve desired goals. According to coordination theory, these actors face coordination problems arising from dependencies that constrain how tasks can be performed. Coordination problems are managed by activities that implement coordination methods” (Crowston & Osborn, 1998, p. 7).

As mentioned an important claim of coordination theory is that the dependencies and mechanisms for managing them are general so that they can be found in a variety of organizational setups. This is especially relevant in a situation where a task require specialized skills, which according to Crowston and Osborn “…arises in some form in nearly every organization” (1998, p. 7).

Next, when managing a dependency there are often several coordination mechanisms that can be used. This means that “…organizations with similar goals achieved using more-or-less the same set of activities will have to manage the same dependencies, but may choose different coordination mechanisms, thus resulting in different processes” (Crowston & Osborn, 1998, p. 8).

In sum we argue that Crowston and Malone’s theory provides an excellent basis for making a process analysis and redesign.
4.2 Structure of Theory Study

Section 4.2 revolves around how the theory study will be conducted according to Crowston and Malone's coordination theory. We have created a model (Figure 2) where the three first parts (Critical Phases, Challenges, Causal Mechanisms) are developed in cooperation with the case company. The remainder of the model is based on the coordination theory of Crowston and Malone. This will enable us to analyze why and where the constraints of coordination derives from, and ultimately how these constraints can be limited.

![Figure 2 - Model for theoretical analysis](image)

The theory study is divided into two main sections, the preconstruction phase and the construction phase. The purpose of this is to highlight the two phases of a construction
project that are most critical in terms of coordination and a completing a successful construction project (as established by the case company).

The preconstruction phase and the construction phase will be briefly introduced in order to give a description of what each of the phases entails, and why they are important for the success of the construction project.

Later, the phases will be examined by analyzing the most substantial coordination challenges and factors that can be found in each of the phases. The challenges are defined as the factors that are especially important in order to obtain a well coordinated phase— and thereby a construction project with better chances of reaching a successful end result.

Next, the challenges will be analyzed through the causal mechanisms. The causal mechanisms are what cause the challenges that in turn make the preconstruction and the construction phases critical to the overall success of the construction project in regards to coordination in the perspective of the general contractor.

The causal mechanisms will be examined through the framework provided by the coordination theory of Crowston and Malone (1994). By applying Crowston and Malone’s theory we will be able to identify the various dependencies within each of the causal mechanisms, these are what causes the need for coordination.

In sum this means that we will conduct a theory study that involves five steps of analysis, these are what create our model of analysis (also shown in Figure 2):

1. Critical Phase (Preconstruction and construction phase)
2. Challenges (Reasons for why the phase is critical)
3. Causal Mechanisms (Causes for challenge)
4. Dependencies (Why the causal mechanisms need coordination)
5. Coordination Mechanisms (how to coordinate the given dependencies)

4.2.1 Purpose of the Model for Analysis

The model for the analysis consists of two parts, a part created by us (steps 1-3) and the part taken from the coordination theory by Crowston and Malone (steps 4-5). These
steps (except step 1) are also used in the structure of the empirical analysis (see Figure 8 - Structure of empirical analysis).

The purpose of the first three steps is twofold and serves a purpose both in the theory study and later in the empirical study where the structure for the empirical study is based around the same steps. This is explained below.

First, these steps will serve a purpose in the theory study by allowing us to reach the level where we can start applying the theory of Crowston and Malone. This level is the 4th level referred to as the "dependencies". The reason for why we need the prior steps to identify the dependencies is that the dependencies are a direct consequence of a relationship between a task and a resource (as will be presented later). In order to locate these tasks and resources we will have to perform the prior steps (steps 1-3) so that we can end up with a specific situation where these tasks and resources, and thereby the dependency, can be found.

Second, in the empirical study we are also reliant on these steps so that we can be sure that the case company is indeed struggling with the same dependencies. By being able to prove that the case company faces the same challenges and causal mechanisms, we can claim that they also face the same dependencies, as these are the direct consequence of the challenges and causal mechanisms.

To summarize, this model enables us to analyze our way down to where the coordination theory by Crowston and Malone is applicable, as well as providing a reliable basis for comparison between the theory study and the empirical analysis.

4.3 Introducing Coordination Theory

This section provides an introduction to Crowston and Malone’s (1994) coordination theory that will serve as the basis of our theory study and later the empirical analysis. The theory will first be implemented in the “preconstruction phase” and the “construction phase”.
Throughout the last several decades, the topic of coordination has been continuously brought up in organizational science and is relevant in most activities performed by organizations that require more than one actor in order to reach a set goal. The activities that have to function together/be coordinated in order to achieve this goal will lead to dependencies among the actors which causes coordination constraints.

According to Crowston, Rubleske and Howison (2004, p. 3)“... many studies describe dependencies and processes only in general terms, without characterizing in detail differences between dependencies, the problems dependencies create or how the proposed coordination processes address those problems”. Due to this incomplete approach to coordination, it has been difficult to effectively determine which alternative solutions or processes could be applied to better coordinate a given task by reducing or eliminating various dependencies.

In response to this, Crowston and Malone started developing their “Coordination Theory” in 1994. The core of the (1994) paper (The Interdisciplinary Study of Coordination) by Crowston and Malone was to identify coordination constraints that one could expect to encounter in a number of disciplines by synthesizing work done on coordination from a variety of fields. The emphasis in Crowston and Malone’s research was put on how dependencies arise between the tasks the actors are performing, as opposed to between actors - which had been the traditional approach by previous theorists. The reason for this angle of approach was to explain the effects of a dependency on what actors do instead of focusing on describing patterns of dependencies, which had been the common approach up until 1994. This would be the first step in generalizing common coordination dependencies in order to create a framework that could be used in a wide range of disciplines and types of organizational systems.

In our thesis we have chosen to utilize the coordination theory created by Crowston and Malone (1994) when analyzing the processes of the construction project in a coordination-perspective. Our decision to use this theory is confirmed by Crowston and Malone in how calls for coordination are evident in situations where:

A) Temporality is a factor, such that effects of delays or of future consequences of today’s decisions are not immediately apparent.
B) There are a large number of actors.

C) There are a large number of interactions between actors or tasks in the system.

D) Where combinations or occurrences in the system involve an aspect of probability (stochastic variability).

The coordination theory by Crowston and Malone belong under the theoretical body of operations management, which is defined by MIT Sloan School of Management as follows: “Operations Management deals with the design and management of products, processes, services and supply chains. It considers the acquisition, development, and utilization of resources that firms need to deliver the goods and services their clients want” (MIT Sloan School of Management, 2012).

Based on this definition coordination theory can be legitimized through how it encompasses the aspect of process redesign. Further, the role of operations management is “…planning coordinating, and controlling the resources needed to produce a company’s goods and services” (Reid & Sanders, 2007) where the intent is to transform organizational inputs into outputs.

When using coordination theory this means that the process redesign of coordination in the construction project will be based on how the resources, representing the input, needed to complete the project will be controlled in such a way that they can be coordinated to create a best possible output (the completed project).

The coordination theory only addresses the factors causing the need for coordination, and where in a process they occur, as well as proposed mechanisms to limit this need. These coordination mechanisms are only intended by Crowston and Malone (1994) to provide a basis for addressing the need for coordination, which again has to be adjusted to the particular situation. Crowston and Malone advocate the use of ICTs. This means that when using coordination theory we will only address coordination and not account for the possible implications our solutions or findings can have in regards to other theories.
Further, as “causal mechanisms” is a central element in the theory framework that we are using in this thesis (to be introduced) we find it necessary to state that the causal mechanisms are an attempt to link a situation to the context of the theory (more specifically, a dependency). This means that a causal mechanism is not something absolute that has a concrete precondition and outcome.

What we want to solve/address in this thesis by using coordination theory is to identify how and where in the organizational process of managing a construction project coordination constraints occur and how they can be limited.

We will now give an introduction to the coordination theory framework provided by Crowston and Malone, which will be the starting point for our theory study and also the framework for our theoretical analysis.

The approach used by Crowston and Malone is to analyze the actions performed by a group as actors performing interdependent tasks, where the need for coordination arises from how these tasks may create or require a variety of resources. Because of this, actors that are involved with creating the common goal of the group will face problems of coordination caused by dependencies that constrain how tasks can be performed.

The general dependencies used by Crowston and Malone are task-resource dependencies and dependencies among multiple tasks and resources. Dependencies among multiple tasks and resources include three types of dependencies. These are shared resource dependency, flow dependency and common output dependency. For each of the different dependencies alternative coordination mechanisms as presented by Crowston (1994) will be described.

The coordination theory by Crowston and Malone has been tested through various case studies performed by the theorists. One of these case studies was conducted in a software engineering company where Crowston conclude that "...coordination theory seems to provide a much-needed underpinning for the study and design of new organizational processes. The results of these efforts will be a coordination-theory based set of tools for organizational analysts and designers, which perhaps will help realize the potential of electronic media and new organizational forms" (Crowston, 1997, p. 174).
Further Crowston states "Coordination theory is a success if those attempting to understand or redesign a process find it useful to consider how various dependencies are managed and the implications of alternative mechanisms" (Crowston, 1997, p. 174). This statement supports our purpose for using this particular coordination theory in our thesis, where we seek to come up with a feasible general proposal to how coordination in the construction industry can be handled alternatively.

4.4 Theory Framework

This section will explain in detail what the theoretical contribution of Crowston and Malone entails.

According to Crowston and Malone, coordination is defined as “managing dependencies” (1994) where they analyze group action in terms of actors performing interdependent activities to achieve goals.

Practically, this means that when actors are members of an organization, they will at some point have to deal with coordination constraints that are caused by dependencies, as they usually do perform tasks that rely on other actors or tasks. When an actor faces a dependency, this will in many cases constrain how the actor can perform his or her task. For example, if a subcontractor in a construction project is planning to implement a change to his specific task, he will have to make sure that this change will not influence the tasks that are to be performed by other actors, subcontractors or other parties.

The dependencies employed by Crowston and Malone can be found in two levels, which helps us distinguish at which level the dependency is situated and consequently which level will be directly influenced by this dependency.

The first level is the “objects that make up the world” (Crowston 1994). These are the goals, processes, actors and resources that are needed in order for the set activity to be performed. The second level is the task that is to be performed by the actor.
The dependencies are made up of *tasks* and *resources*. We will now give a quick explanation of what Crowston and Malone mean by their tasks and resources, as these two elements are what the dependencies are founded on.

### 4.4.1 Defining Tasks

Tasks include both achieving goals and performing various tasks needed to achieve them. Practically goals, which are defined as “a desired state of the world” and tasks, defined as “actions performed to achieve a certain state of the world,” are very different (Crowston, 1994). However, when defining a task within the framework of Crowston and Malone’s coordination theory, it makes sense to analyze both goals and activities together despite their general differences, as goals can be broken down into sub goals that in turn can be broken down into tasks. This allows the researcher to analyze the tasks involved in whatever he is analyzing without necessarily having to go all the way down to tasks performed by the individual (Crowston, 1994). This is a clear advantage for us when studying the construction industry, and more specifically the nature of a construction project where it will not always make sense to analyze all the way down to the tasks of the individual worker. Further, by considering high-level goals as tasks, this allows us to examine the assignment of goals to sub-units in the same way as when assigning goals to individuals. This is also an advantage when looking at the construction project, as we do not have to distinguish how the assignment of goals should be done, whether we are talking about actors in the form of groups or individuals.

In short, this means that *both* goals and tasks are considered tasks to be undertaken by the actor, which can be either an individual or a group (Crowston, 1994)

### 4.4.2 Defining Resources

Resources include everything that is used or affected by the tasks that are being performed by the actors. One can argue that there may be resources that are difficult to encompass in a study revolving around coordination. For this reason, resources that are not involved in the tasks of an actor are not considered relevant for analyzing the behavior of an actor.
As an example based on Crowston’s (1994) illustration from the automobile industry, for typical resources used in a construction project the following could be considered relevant “...tools, materials, parts, partially completed assemblies, information such as designs or process instructions as well as the effort of the employees of the company”. The fact that the actors (employees) are included in this example is fully intentional as “…this means that actors are simply viewed as particularly important resources” (Crowston, 1994). The reason for why actors are categorized together with other various kinds of resources is due to how the steps required to assign a task to actors are the same as when assigning general resources to tasks. Because of this actors will mainly be referred to resources from this point on.

In a more abstract way, particular states of the world may also be considered a resource. This is exemplified by Crowston (1994, p. 11) by how a “…particular tool setup is necessary for a manufacturing task to be performed”. In the construction project this can be translated into how the construction site has to be rigged before the construction phase can start.

In the following section we will introduce the various dependencies presented in Crowston and Malone’s Coordination theory along with the corresponding coordination mechanisms.

4.4.3 Task-Resource Dependencies

The task-resource dependency is a particularly important dependency as it appears in most organizational setups and is often directly linked to obtaining the ultimate goal of the task involved. The preconditions, together with the effects, are what make up the resources that are required, created or consumed by a task (Crowston, 1994). This can be generally translated into the construction project as how the preconstruction phase provides a precondition that includes the knowledge of what needs to be done where the effect is the task performed in the construction phase that leads to the completion of a (sub) goal. This, in turn, becomes a precondition for the next step of the construction process. This leaves us with two different scenarios where a task either uses a resource or produces a resource, which creates the dependency between task and resources. This will be further explained,
starting with the figure below (Figure 3), followed by an explanation of what the two elements of this dependency entail.

![Diagram of task uses a resource and task produces a resource](image)

Figure 3 - Tasks use or produce resource (Crowston, 1994)

4.4.3.1 Task Uses a Resource

If a task uses a resource and there is only one appropriate resource that is applicable to the task in question, then this resource will be what is needed to perform the task. However, especially when managing a construction project, one can argue there will almost certainly be a number of appropriate resources that may be used in order to have a task performed in an acceptable manner. This situation is what creates the problem of resource assignment.

We will now continue by introducing the necessary steps in assigning a resource to a task when there are several appropriate resources available. According to Crowston’s setup in his 1994 paper, the focus will be on “...the problem of assigning a task to a particular actor to be performed, but most of the steps discussed are necessary to assign any kind of resource to a task” (Crowston, 1994, p. 12).

When assigning resources to a task, there are certain steps that must be followed, which will represent the sub-dependencies of the task uses resource dependency. According to Crowston (1994) these sub-dependencies are:

1) Identifying what resources are *required* by the task
2) Identifying what resources are *available*
3) *Choosing* a particular set of resources
4) *Assigning* the resource (in the case of an actor, getting the actor to work on the task)
According to the coordination theory by Crowston and Malone (1994) these steps can be performed in any order according to what may best fit the particular situation. For example, in a construction project where the actors will be following a predetermined schedule, it may be beneficial to set up the task according to available resources (2), or grouping them depending on a particular set of resources (3), as opposed to starting by identifying what resources are necessary for performing the task (1) when these resources may not be available at the same time.

We will continue by an in-depth look at the four steps.

**Identifying necessary resources**

The first step centers on identifying the appropriate resources needed for the task to be executed. This requires the assigner to figure out where the dependency occurs. This is essential in order to identify the resources that are necessary to limit the dependency at the level that it occurs. According to Crowston, Malone and Herman (2003), the assigner may need to know what types of resources are available so that he can characterize the task requirements according to the dimension of the available resources. This is due to the specialist-generalist complexity, which indicates that the assigner must fit the task requirements to match with the competences of the specialist. When the actors are generalists, the assigner can base the task requirements on other factors.

**Identifying available resources**

Second, when the assigner knows what the necessary required resources to solve the task may be, he has to identify available resources. Sometimes the dependency is located within a certain (specialized) group of resources, such as, the project management team in a construction project, where the available resource employed to the task should be a member of this group. Or, the dependency can occur on a more general level, such as in the execution of the construction schedule where the assigner will have to identify the available resources among a broader specter of resources. In any of these cases the assigner will have to rely on appropriate information in order to be able to evaluate a proper fit between a resource and a task. Such decisions can typically be based on factors such as speed, quality, availability and motivation (Crowston, Malone, & Herman, 2003). Arguably, ICTs can play an
important role in providing the assigner with the appropriate information when determining a good fit between resource and task.

Choosing a resource

For the third step the assigner will have to choose the specific resource that will perform the task. Most likely the assigner will base his decision on the factors mentioned above, however it is important that the consequences of these decision factors are carefully evaluated. For example, in a construction process, it may not be beneficial to assign a resource to a given task just because the resource is available, saving time and money, as this may have unforeseen consequences for the quality. The decision factors obviously depend on the nature of the task that is to be coordinated, but generally one may argue that saving time over ensuring quality is not the best prioritization in for example a construction project where the task may involve the creation of a physical structure.

Assigning resources

Finally, the resource has to be officially assigned to the task. Practically this means that the assigner must somehow communicate to the resource that he has defined this particular resource as appropriate to perform the given task. As some resources can be considered non-shareable, it is important that the assigner is able to mark this non-shareable resource as “in use” in order to avoid conflicting assignments. When the resource is an independent firm/contractor and the “personal” goal for this contractor differs (significantly) from the overall goal of the general contractor that has the end result of the construction project as a set goal, incentive schemes or the monitoring of performance could be introduced to ensure the subcontractor’s compliance. This is especially relevant if the subcontractor must perform a task “outside” the definition of their job/role in the project schedule.

In all these aspects of assigning resources, ICTs could improve the feasibility of successfully performing proper resource allocation for the “task uses a resource” –dependency.
4.4.3.1 Coordination Mechanisms - Task Uses a Resource

When assigning a resource to a task in a situation where the “task uses a resource” there are two different methods presented by Crowston (1994). These can be used to ensure the correct allocation of resources in a way that will limit the task uses resource dependency according to various organizational categories and desired outcomes.

Method 1
The different coordination mechanisms that can be applied to the four steps presented above can be constituted by the choices made when going through these steps (Crowston, 1994). For example, the assigner can assign a task to a resource by doing the following based on the four steps:

1) Determine what skills are necessary to perform the task.
2) Identify which resources are available.
3) Collect information about which resources have the necessary skills.
4) Decide which resource is the most appropriate, based on skills, workload etc.
5) Ask the resource to perform the task (Crowston, Malone, & Herman, 2003)

Method 2
However, in most complex organizational setups, like in a construction project, these coordination mechanisms for resource allocation are tied up to three different categories, which are related to the different setups under which the resource operates. These three categories are market, hierarchy and network. By organizing the resources into these three categories it will be easier for the assigner to allocate the resources according to the organizational setup they belong to. The three categories will now briefly be introduced according to Crowston (1994).

Market
In the market setup an available resource is competing with other available resources in the market place. Here, the assigner will have to advertise what type of resource is needed for
the task and will then receive bids from various resources. The assigner must then make a choice based on the bids submitted by the interested resources. In the construction project this could be done more efficiently through ICTs so that the assigner will gain a quicker indication on which resources are available if there, for example, is to occur a sudden need for change that has to be implemented quickly.

Hierarchy

In a hierarchy, the resources needed to perform the task will be owned by the organization. This setup could be especially relevant to the assigner when, for example, assigning a resource within a single group in the construction project. A group like this could typically be the project management team. If the resources are highly specialized, the assigner may only be left with one choice when it comes to which resource to assign to the given task. However, in situations where the resources are more generalized, the resource can be assigned according to other factors, such as workload, or be distributed among the group by dividing the task into sub-tasks.

Network

A network in this context is defined by different resources belonging to the same network. In the construction project these different resources would be represented by the various subcontractors, planners, designers and other functions related to the project. Each member of the network is defined by the type of specialty they contribute to the network of specialties. When assigning a resource based on a network setup, this is normally done according to reciprocal relations.

The three categories and their different mechanisms for resource allocation are summed up in the table below (Table 4).

<table>
<thead>
<tr>
<th>Step</th>
<th>Market</th>
<th>Hierarchy</th>
<th>Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify needs</td>
<td>Based on specializations in market</td>
<td>Based on specializations in firm</td>
<td>Based on specializations in network</td>
</tr>
<tr>
<td>Identify resources</td>
<td>Broadcast a RFP and wait for replies; check advertising</td>
<td>Use known set of resources in firm</td>
<td>Use known set of resources belonging to network</td>
</tr>
<tr>
<td>Choose resource</td>
<td>Evaluate bids</td>
<td>Specialization; workload</td>
<td>Specialization</td>
</tr>
<tr>
<td>Assign resource</td>
<td>Contract</td>
<td>Employment relation</td>
<td>Network membership</td>
</tr>
</tbody>
</table>

Table 4 - Decomposition of different mechanisms for resource allocation (Crowston, 1994)
4.4.3.2 Task Produces a Resource

When a task produces a resource, the assigner will be confronted with a whole other way of approaching the task-resource dependency. According to Crowston (1994), the assigner will have to do what he refers to as *choosing a task with a particular effect*. This is because the focus in this dependency gets shifted towards the resource created by the task, as opposed to the resource needed to perform the task. By choosing a task that has a particular effect it will be possible to create and maintain a goal-resource relationship between a resource and the tasks.

4.4.3.2.1 Coordination Mechanisms - Task Produces a Resource

To be able to maintain a goal-resource relationship between a resource and the tasks, the assigner must know the effect that is to be achieved and be able to create tasks that will correspond with the desired effect. When creating these tasks the assigner must know the preconditions, as well as the effects, and also have the proper amount of knowledge to be able to choose among different decompositions (into sub-tasks).

In a construction project it may seem too complicated to apply this method to the project as a whole, however it may be feasible to apply this method to parts of the project. By conducting this method through establishing sub-tasks, it could be feasible to follow this method as long as the sub-tasks represent independent sections/modules of the construction project.

4.4.4 Dependencies among Multiple Tasks and Resources

In general there will often be multiple tasks and resources that need to be considered, such as when a single task is dependent on several resources. This will generally happen in three different situations, *when a task is using multiple resources, when a task is producing multiple resources* and *when a task is using one resource while producing another*. However, according to Crowston, Malone and Herman (2003, p. 95) “only the first, a task using multiple resources, seems to pose unique coordination problems, namely constraints on the performance of the task and thus the need for a coordination mechanism”. 
This creates a need to synchronize the availability of the multiple resources, which theoretically can be done in two ways.

Method 1

As discussed, the task can be reduced so that it will only depend on a single resource, thus enabling the assigner to use the coordination mechanisms of “when a task uses a resource”. This will require the assigner to reassign each resource to a particular task (Crowston, Malone, & Herman, 2003). When facing a situation in a construction project where multiple tasks and resources do exist, it initially seems difficult to follow this method. Reducing tasks that originally require multiple resources to tasks that will only require a single resource may have unforeseen consequences.

Method 2

The dependency that occurs when a task requires multiple resources can (and arguably should) be dealt with according to the particular dependencies that arise in various cases. This method is the true approach to actually dealing with the coordination constraints created by the dependency of a task requiring multiple resources. The various cases in which the dependencies arise are defined by how “…a task may use several resources, consume one resource and create another or create multiple resources” (Crowston, 1994, p. 17). Therefore dependencies among multiple tasks and resources will manifest themselves as in Figure 4:

![Figure 4 - Dependencies between multiple tasks and resources (Crowston, 1994)](image-url)
When looking at the figure above there are three general dependencies that can be devised from this figure. These are “shared resource dependency” (shared resource and task consumes multiple resources), “flow dependency” (producer/consumer and task consumes one resource and produces another) and “common output dependency” (common object and task produces multiple resources). These three will be presented in the following.

4.4.4.1 Shared Resource Dependency

If two different tasks have the same resource as a precondition for them to be performed, then these two tasks are interdependent. This means that extra work will inevitably have to be performed so that these two tasks can share the same resource. The nature of the resource will define what additional work has to be performed. However, Crowston (1994) considers two ways in which resources can differ in regards to how they can be shared among more than one task. These two dimensions are share-ability and reusability, which is shown in the Table 5 below.

<table>
<thead>
<tr>
<th>Shareable</th>
<th>Non-shareable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reusable</td>
<td>Information: designs, problem reports, fixes</td>
</tr>
<tr>
<td>Consumable</td>
<td>Raw materials: components, assemblies</td>
</tr>
</tbody>
</table>

Table 5 - Examples of resources classified by shareability and reusability (Crowston, 1994)

**Share-ability**

Share-ability is dictated by how many tasks can use a given resource at the same time. In most cases, physical resources, such as raw material, tools or effort are non-shareable (Crowston, 1994). However, it is also important to keep in mind that a resource can be assigned to multiple activities, but can only work on one at a time. Crowston (1994, p. 18) further notes “information and other states of the world are important exceptions, since multiple tasks can use the same resource if it is not changed by the tasks”.

For the preconstruction phase in a construction project the most important resources, such as information, will often be shareable.
In the construction phase the manager/assigner is more likely to stumble upon resources that are not shareable, resulting in conflicts where two actors will not be able to perform their task if they are both dependent on the same non-shareable resource. This will require additional resources to be acquired, or if the resource is reusable, one task will have to be prioritized and performed before the other.

**Reusability**

Reusability is determined by whether a resource can be passed on to the next task once it has been used by the first. In construction (and in other fields), information and tools as well as actors are typical examples of reusable resources. However, raw materials will (usually) not be reusable, as they will be fully consumed by the first task.

**4.4.4.1.1 Coordination Mechanisms - Shared Resource Dependency**

In most situations a shared resource dependency will require additional work for this dependency to be limited (according to Crowston (1994), the coordination mechanisms for this dependency are similar to the solutions developed for the “mutual exclusion” problem in computer science).

The first thing the assigner must do is to identify and signal the conflicting interest of the two (or more) tasks in the same resource. This could be done by marking the resource as “in use”. For certain resources, such as important tools or machines, the simple fact that the resource is occupied by/being used by a resource may be enough. In a construction project, an example of a resource like this could be important machinery that appears in limited numbers on the construction site, such as cranes and other “heavy resources”.

For other resources, such as information and important actors, more elaborate systems may be beneficial. For resources involved in planning and design, such as various planners, architects and civil engineers, there should be a system in place that can notify other members that certain modifications are being done (or have been done) to a set of technical drawings so that other actors do not perform changes at the same time by accessing the same resources (database, drawings etc). An ICT system of this sort could also serve an
additional purpose of providing information on where important and unique resources, such as the project manager and superintendent, are located, as well as effectively transmitting changes made on tangible resources, such as technical specifications, to the various subcontractors performing the tasks on the construction site.

Resources can also be scheduled, which is an essential part of the construction management in a construction project, where the use of the resources by the different tasks are scheduled and performed according to a schedule. However, even though having a schedule in a construction project is a must, the assigner will almost always face several situations throughout the life span of the construction project where the schedule will have to be constantly modified or drastically changed.

4.4.4.2 Flow Dependency

The flow dependency most often occurs when a resource happens to be the effect of one task and the precondition of another. As this dependency between two tasks is so strong, it requires the tasks to be performed in a correct order where the flow of the resource between the two tasks has to be managed carefully in order not to jeopardize the preconditions of future tasks.

Typically this dependency arises in steps of a process, such as a construction process, and where there is a need for the sequential use of resources. The additional constraints implied on how the tasks are to be performed by this dependency are usability (similar to reusability above), prerequisite and accessibility. These sub-dependencies associated with the flow dependency will be explained below (Crowston, Malone, & Herman, 2003).

Usability

The usability aspect refers to the constraints that come with making sure that the resource is usable by the second task. Usability is similar to reusability for the shared resource dependency and can be explained in the same way, where information is reusable and raw materials are typically not reusable.
**Prerequisite**

The prerequisite aspect entails that the production of the resource must happen before its consumption. For this to occur, the producer must know that production is required and the consumer must know when production is complete.

The producer could work according to a pre-arranged plan that will enable the producer to produce continuously, or the production can be triggered by the consumer. This will require the rate of production to be matched to the rate of consumption.

The consumer may require ways of ensuring that the producing task is actually performed to the specific needs for the task to be performed by him. Only when the consumer is aware of the production of the resource is complete, will this resource be available to the consumer. For physical resources this may not be as relevant, as it will be practically impossible to attempt to perform the task without the resource. However, for information, and other states of the world, knowing that the resource is ready is essential to the consumer (Crowston, Malone, & Herman, 2003)

**Accessibility**

Additional work will have to be performed to ensure the accessibility to the resource by the consuming task. Essentially this entails moving the resource from where it is produced to where it is consumed (Crowston, Malone, & Herman, 2003). In a construction project this could be exemplified by how a structural module put together by one contractor somewhere on the construction site must be brought to the next contractor that is dependent on this structural module as a resource for his task. For information and generally, other states of the world, a resource can be made accessible to one task by another through the use of ICTs.

**4.4.4.2.1 Coordination Mechanisms - Flow Dependency**

Mechanisms to manage flow have been extensively studied in operations management, but do not address usability and accessibility (Crowston, Malone, & Herman, 2003)

Generally the flow dependency can be coordinated through an “inventory system” where the producer will be notified once the consumer reaches a certain lower limit of the resource they depend on.
However, in a construction project the supply of a resource required by one task that is produced by another is more likely to be handled through a “just in time” system. In this sort of system the consumer will not possess any sort of inventory and will be dependent on the needed resource arriving “just in time”. For this system to function properly it requires careful planning and communication of needs by the consumer. Again this is a point where adopting ICTs may be relevant. In order to ensure that the correct resource is received, quality control of the tasks can be implemented so that the output of one task is indeed the correct input for the next task (Crowston, 1994). Buffers can also be added between the processes of transferring the output of one task to the input of another to create a smoother flow of materials.

Crowston (1994) also brings up the aspect of “clobbering” which is commonly used in the planning literature to explain how a resource may be destroyed by another. This is exemplified by Crowston as follows “In construction, for example, installing one piece of equipment may block access needed to install another. Fixing the clobber can be done by reordering the steps to avoid this problem or possibly adding an additional task to recreate the resource or state of the world” (Crowston, 1994, p. 21).

![Figure 5 - Clobbering and Un-clobbering](image)

### 4.4.4.3 Common Output Dependency

A common output dependency occurs when the effect of two tasks are the same. This will typically have either positive or negative outcomes that in turn will require additional work in order to exploit potential positive outcomes, or avoid the negative ones. Crowston, Malone and Herman (2003) refer to three cases where this dependency is likely to occur.
This means that there are also three different ways of approaching these various forms of the common output dependency. Under the following coordination mechanisms for the common output dependency we will briefly introduce these three cases and the applicable coordination mechanisms.

### 4.4.3.1 Coordination Mechanisms - Common Output Dependency

First, if two tasks do the same thing, they are also likely to produce the same resource. In this case it may make sense to merge the two tasks in order to make them easier to manage whilst eliminating a situation in which two tasks result in the same resource. To be able to draw advantages from this synergy, the assigner must be aware of the possible duplication by the output of the identical/similar task and develop a plan to distribute the resource that is the common effect that will be the result of the tasks.

Second, when the two tasks specify different aspects of a common resource, the tasks will be constrained by the assigner’s ability to create a “fit” between the two outputs. In order to achieve this, the assigner will have to utilize the same (or similar) coordination mechanisms as for “usability” under the flow dependency.

Finally, if the effects or resources produced by the two tasks conflict, the assigner may choose to abandon one of the tasks or schedule them so that their output does not need to be used at the same time (Crowston, Malone, & Herman, 2003).

### 4.5 The Preconstruction Phase

The preconstruction phase is the first of the two critical phases as identified together with the case company. In the following, the phase will be introduced so that the challenges that make it critical can later be argued for.

In a situation where several parties are involved in the pursuit of a common goal, a plan is needed to bring all parties together and guide them in the right direction so that they can function together.
For the construction industry this is paramount due to the shared complexity of the undertakings that defines this industry. Compared to most other production activities, a construction project becomes a lot more complicated to manage due to the sheer size of what is to be built, the amount of time required from start-up to completion, the fact that a significant part of the process takes place in open air and that the production takes place where few or no facilities exists. All these aspects defining the construction industry make the project management of the construction process the most important function to ensure the successful undertaking of a construction project.

For a successful construction project it is important that every party involved has a general understanding of the process that is to take place. This is essentially the core of the project management team’s job, making it the most important resource for the success of the preconstruction phase.

In the beginning of the preconstruction phase, the project management team will have to go through a three-step process to acquire the subcontractors. This process is elaborated on in the appendix (Appendix 2).

The first important task of the general contractor that defines the start of the preconstruction phase is to establish a project plan, which will serve as a game plan for the entire set up and for the execution of each activity and function related to the construction project. A good way to picture the project plan is to view it as a puzzle where each piece has to be given an estimation of cost and time. Once all the pieces of the puzzle making up the project plan, and the project itself, have been assigned a time and cost estimate, the total time and cost of the project can be estimated. Once this game plan is in place, the client, architect, engineer and various subcontractors will develop the specifications for how the project is to be executed. Each of the construction activities determined through the specifications will then be divided among the general contractor and the subcontractors, where also the scope of each of the contractors will be determined.

Once the project plan is in place, the development of a project schedule will take place. This schedule will define the initial scheduling for when all the work that is to take place in the actual construction phase. This makes the project schedule the most critical aspect of the construction management process. Besides further dividing tasks down to an even more
detailed level than what was done in the project plan, it lets other parties know what activities are to be performed and most importantly when. This requires the involvement of all parties, especially the subcontractors. The project schedule normally consists of various paths of tasks that will often take place at the same time once the tasks are being performed in the construction phase. However, there will always be a main path referred to as the critical path. The critical path is defined by those activities that will cause the entire construction project to falter or for example be delayed if one of them were to suffer unexpected changes (Barnard, 2011). This makes the project plan and the schedule the most important resources for the preconstruction phase in the general contractor’s point of view.

As the planning through the project management team of the general contractor constitutes the unifying thread binding all the tasks of the project together, it is essential to create a stable foundation for the planning team, as it will be the driver of all processes throughout the project life cycle. Next we will review the causes for changes to the project schedule, as this is a challenge that is likely to be first met in the preconstruction phase and later have repercussions or reemerge in the construction phase.

When the construction project starts to manifest itself and take physical shape as the project develops by critical decisions being made, designs and contracts being finalized, the power to influence or change the course of the project by the project manager gets increasingly limited in terms of applying more substantial changes. This means that the project managers will continuously have to be on top of what is going on so that changes and adaptations can be made before costly mistakes are done (Neale & Neale, 1989). This is exemplified in the figure below (Figure 6).
Because of the far-reaching consequences of inabilitys and mistakes made at this stage and level, the preconstruction phase proves to be a critical phase for the construction project to have a positive outcome. Determinants of the success of this critical stage will be the abilities of the general contractor’s project management team, and the capabilities of handling changes to the schedule (Neale & Neale, 1989). Because of the importance of the two elements, these will also represent the most substantial challenges to the general contractor in the preconstruction phase.

The most substantial threat to a construction project deriving from inadequate project management is cost overruns. When a situation involving cost overruns occur, it often originates from the failure of the project management team to bring the wishes of the client and the vision of the architect to life in a coinciding manner. Cost overruns can also have its base in poor constructability where the project manager has failed to make sure the right
materials are being used. It is also important that the project management team is successful in laying the most efficient path to project completion, as cost overruns are often linked to delays and changes in the schedule which again can increase the cost overruns, creating a “vicious circle” (Albion Scaccia Enterprises, LLC).

4.5.1 Challenges of the Preconstruction Phase

In the following we will address the challenges that are the most important factors for securing a well-coordinated and successful preconstruction phase from the general contractor’s point of view.

The challenges are:

- Designing the Project Management Team
- Handling Changes to the Project Schedule

4.5.1.1 Designing the Project Management Team

Once all contracts are signed and the client has given the “all clear” to proceed with the construction project, it will be time to expand the project management team from the estimators that have been involved in the contracting, to the fully established project management team under the general contractor.

The management team will now be appointed a project manager. Normally this will be the first time the project manager will lay his eyes on the documents that have been created previously in the process by the estimators. Because of this, it is important that these documents can equip the project management with everything he needs to know before taking the project further, without running the risk of him misunderstanding elements of the project. This is especially important in terms of cost control so that the project manager is able to set off respecting the preliminary agreements with the client.

The next step for the project manager after setting the course for the remainder the construction project is to appoint the rest of the team members. Depending on the size and the complexity of the construction project at hand a construction project will always need
the following team members: Project manager, contract administrator, general superintendent, maybe an additional superintendent and at least one field engineer. In larger construction projects, other personnel will often support these functions.

This will form the on-site project team, which again will be supported by an office management team. This supporting team will be in charge of further estimation as the work proceeds as well as helping out with contract administration, accounting, job costing and payroll.

The hierarchy of the project management team is elaborated on in the appendix (Appendix 3)

4.5.1.1.1 Causal Mechanisms of Designing Project Management Team

In this section the following causal mechanisms for the challenge of designing the project management team will be introduced. These causal mechanisms have been identified through preliminary conversations with the case company. The causal mechanisms are:

- Assigning resources to the project management team (putting together the team)
- Structure of the project management team

Each of the causal mechanisms will be analyzed through dependencies and corresponding coordination mechanisms created by Crowston and Malone.

4.5.1.1.1 Assigning Resources to the Project Management Team

As indicated, the reason why designing the project management team is a challenge in the preconstruction phase is due to the impact the project management team will have on all activities throughout the life cycle of the construction project.

However, in a more precise manner, the first causal mechanism is related to the creation of the team.

When the project management team is appointed by the project manager, the decisions made at this point will eventually determine how well the team will function based on the
resources (people) the project manager assigns to the team. This decision will have its balance in dependencies deriving from the project manager’s decision base.

4.5.1.1.1.1 Dependencies - Assigning Resources to Project Management Team

When assigning the project management team, the project manager will create a first level (“objects that make up the world”) resource that is a prerequisite for the construction project to enter its active life-cycle (Crowston, 1994). In order to get there he will have to face second level dependencies that are represented by the project manager performing a task, namely assigning resources to the team.

In this scenario the project manager will face a task-resource dependency where the preconditions, in the form of the information provided by the estimators, together with the effects of the decision made when assigning members to the team, will make up the resource that the project management team will represent.

Arguably the task-resource dependency that occurs when the project manager must assign resources to the various functions of the project management team can be regarded as both a “task uses a resource” dependency and a “task produces a resource” dependency.

Essentially, the task to be performed by the project manager will be the production of a resource. However, by applying this point of view we would not be able to analyze the actual dependencies revolving around the project manager ensuring the best quality possible of his team.

When taking this approach, where the task of the project manager is to assign the best possible resources to the team, he will in fact be in a situation where the task at hand uses a resource(s) instead of producing one (even though the team will represent a first level resource during the rest of the project once it enters the active life-cycle).

As the different functions of the project management team (as presented in Appendix 3) will have to be regarded as tasks to be performed by the appropriate resource, the project manager will have to go through certain steps to identify these resources.
The first thing the project manager will have to do is to determine what resources or competences are necessary for each of the functions. This will have to be done according to the characteristics of the specific construction project in question, which in turn is decided by the information presented to the project manager by the estimators. Essentially, the project manager will have to figure out if he needs to fill the functions of the project management team with generalists or specialists.

Secondly, the project manager will have to identify what resources are available to him. The most common criteria is availability, but factors such as quality are also equally important, especially if the construction project is deemed to be needing a project management team based on specialists.

To summarize, the dependencies that the project manager will be faced with when assigning resources to the functions of the project management team are to determine what resources are necessary and to identify what resources are available. These dependencies belong under task-resource dependencies as, more specifically, “task uses a resource” dependency.

4.5.1.1.1.1.2 Coordination Mechanisms - Assigning Resources to Project Management Team

Within the firm of the general contractor the resources will, in most cases, belong to a “hierarchy” category where they will be owned by the firm. This requires the project manager to determine the necessary resources according to the specializations within the firm, and identify these resources based on a known set of resources.

Arguably this may limit the project manager’s ability to utilize the necessary specialized resources, if these do not exist within the firm.

For construction projects with especially complex characteristics it may be advisable for the project manager to branch out and utilize the two other organizational categories of “market” or “network” where the resources determined to be necessary can be accessed on a wider scale. In a “market”, the necessary resources needed can also be advertised where the project manager can evaluate the received bids. In a “network” the identification of the available resources will be done in a similar way as in the “hierarchy” but on a wider scale.
Consulting companies would typically represent the “market”, whereas the network would be relevant in situations where the general contractor would work closely with other contractors of specialized competence in running the construction project. Resorting to third parties like these may be required, as determining necessary resources to be (highly) specialized will create a dependency between the resource and the task, where the only coordination mechanism will be to look outside the firm of the general contractor.

4.5.1.1.2 Structure of Project Management Team

Once the team is appointed, the ability of the team to deal with the tasks that it is responsible for will also depend on how the team is structured. In this theory study we will focus on the theoretical set-up of a generic project management team, in order to create a hypothetical inquiry as to how this set-up will generate certain dependencies in the team’s abilities to perform its tasks.

4.5.1.1.2.1 Dependencies - Structure of Project Management Team

The dependencies within the structure of the project management team occur in the information flow between the various functions and how functions rely on others to perform (a hierarchy for decision making) their tasks.

We will now briefly establish what constraints occur in the various functions and then argue for the dependencies in the structure of the project management team in respect to how these dependencies relate to the information flow.

Project Manager

When running the construction project, the project manager’s most important task is to create the schedule and make sure that all processes run according to this schedule. Because of this, the project manager will be an important resource to others as he has great authority in making major decisions. In turn, this makes the project manager reliant on accessing the information flow.
Contract Administrator

The contract administrator’s main task is to support the project manager and the superintendent. This task is performed by how the contract administrator continuously provides the project manager and the superintendent with contractual information throughout the life cycle of the construction project.

Superintendent

Outwardly, during the construction phase the superintendent is responsible for coordinating and running all activities taking place on the construction site. However, the superintendent’s most important task on the project management team to act as the point of contact with the client.

Field Engineer

The field engineer handles all information within the team is responsible for providing contractors with the information they need. This means that the field engineer’s role in the team structure is to relay information to the team from the outside and vice versa.

Implications for project management team structure dependencies

The main dependency that will have to be considered when looking at the way in which the project management team functions internally will be the shared resource dependency. This is because all functions in the project management team are dependent on the same resource in order to perform their tasks, namely the information flow. As stated before, information is categorized as a shareable resource.

Second, the structure of the project management team will also result in a flow dependency where the sub-dependency of accessibility is predominant.

4.5.1.1.2.2 Coordination Mechanisms - Structure of Project Management Team

To coordinate the shared resource dependency for a resource that is shareable, Crowston (1994) advises that a system notifying the members of the project management team that modifications have been made to the information (drawings, specifications, notes by
subcontractors and client related modifications etc.) will be implemented. This is essential in order to limit the shared resource dependency within the project management team, so that correct decisions can be made in order to secure a well-managed construction project, and that the correct information can be mediated between the client and subcontractors on-site.

This modified information must also be made accessible, which is where the flow dependency must be addressed. As the members of the various functions of the project management team will have to be able to utilize the shared information on their own terms, this information should be made accessible to all members through an ICT system.

This means that the bulk of information that makes up the resource that all members of the project management team are reliant on must exist in a form where it is the most recent version that is being used by all. This information must also be made accessible to all members on their own terms in order to create a smoother information flow. This ensures that the correct input (resource) is in fact accessible to the consumer.

4.5.1.2 Handling Changes to the Project Schedule

With the project schedule working as the main artery that links tasks and resources in the construction project together, it is important that the project management team is capable of maintaining a sound and healthy flow in the project. This importance is exemplified by Winch: “Once a project is running behind schedule, however, there is often little that can be done by adding additional resources because adding additional resources to a project that is running late will make it even later because of the disruptive effect of introducing those unplanned resources” (Winch, 2010, p. 291).

This means that in order for the project to run as efficiently as possible, the schedule needs to remain as intact as possible throughout the duration of the project. However, this is seldom the case. In every construction project situations will occur that will require changes in the project schedule. One issue is to apply these changes orders to the various subcontractors involved in the construction project. Another issue is to effectively handle these changes within the project management team before the change order is ready to be introduced to, for example, the subcontractors.
For the construction management team, changes in the schedule will almost certainly occur, and will thereby also have to be addressed in the preconstruction phase. Typically, the change orders in this phase are related to design issues and change proposals by the client, which needs to be implemented in the early stages of the scheduling. However, change orders can occur at any stage of the construction project, where the project management team will still be the actor that will be processing the change order and making sure the change it is put into effect.

When the need for a change in the schedule of a construction project occurs, this is referred to as rescheduling and is defined as “the process of updating an existing schedule in response to unexpected disruptions” (Herrmann, 2006, p. 137). This will require efficient communication within the team and mutual alignment in order to implement a change and reschedule without causing further delays in the execution of the preconstruction phase (and/or the construction phase).

### 4.5.1.2.1 Causal Mechanisms of Handling Changes to Project Schedule

In this section the following causal mechanisms for rescheduling will be introduced:

- Project management team’s ability to process change orders
- Change orders caused by other parties

Each of the causal mechanisms will be analyzed through dependencies and corresponding coordination mechanisms. This is because we deem the ability to process change orders as crucial to prevent further delay as well handling change orders caused by other parties.

#### 4.5.1.2.1.1 Project Management Process Change Orders

The traditional approaches to studying organizational design of coordination as a mechanism to control and manage interdependencies in decision making groups have been mostly founded in stable scenarios of relatively high predictability. However, in scenarios such as those of the construction industry that take place in high velocity environments, the unpredictability of the many possible events cause a high variety in type and criticality of interdependencies (De Snoo & Van Wezel, 2011).
Due to this high uncertainty of what changes and ultimately what rescheduling actions will need to be taken, it is important to construct the team with an organizational design that will be able to handle this as efficiently as possible.

When multiple members of the management team develop the schedules for the construction project, it is important to keep in mind that a change somewhere in the schedule will affect other parts of the schedule, or other interrelated sub-schedules. This requires a quick response by the management team.

For this we have found it necessary to extend on the coordination theory by Crowston and Malone through De Snoo and Van Wezel’s theory on interdependence and mutual alignment. This is based on the same basis as coordination theory presented by Thompson (1967) (see Appendix 2).

A high performance in the team’s ability to reschedule can only be achieved if all change order tasks are mutually aligned. According to interdependence theory, the commitment to mutual alignment activities depends on the perception of those involved in regards to task interdependence. For the task of rescheduling, this essentially means that the perception of their dependence on each other by those performing the rescheduling will be the main factor influencing their ability to achieve mutual alignment. This means that perceptions of interdependence, together with organizational structure, will influence the overall performance of rescheduling (De Snoo & Van Wezel, 2011).

4.5.1.2.1.1 Dependencies - Project Management Process Change Orders

When creating a schedule this task will be shared by all the people related to the functions of the construction management team (Project Manager, Contract Administrator, Superintendent and Field Engineer). This decomposition of the scheduling task results in interdependencies between those who are involved, as they together will perform the tasks of creating a revised schedule.

During the initial scheduling, interdependencies can normally be handled by approaching the task by performing a sequential scheduling, or by setting up rules for each of the project
management team functions to follow. As most activities that can have a direct impact on the course of the construction project have not yet started, there is usually enough time to communicate and perform the task under predictable and stable circumstances.

However, when the ball has started rolling and the construction project has entered its active life-cycle, where the schedule is being executed, the project management team will have to engage in rescheduling when change proposals are received. When such a situation presents itself, it is paramount that the management team can handle this challenge by finding solutions quickly so that the best possible solution can be passed on to those executing the schedule.

If the change order requires rescheduling of the project schedule, the project management team will be in a unique situation where it will have to face both aspects of the task-resource dependency.

First there will be a task uses a resource dependency. This dependency will manifest itself by the team having to identify the appropriate resources needed to conduct the rescheduling. There will be four elements that have to be considered:

1) First the resources in the project management team that are required to perform the task will have to be identified. This means that it has to be established whether it is a contractual matter, a technical matter or related to some other specialty found within the project management team.

2) As the change usually has to be implemented as soon as possible, the available resources have to be identified.

3) Based on number 1 and 2 above, a particular set of resources must be chosen.

4) The resource(s) must be assigned so that the task can be performed.

Second, there will be a task produces a resource dependency where the resource produced will have to have a particular effect.
4.5.1.2.1.1.2 Coordination Mechanisms - Project Management Process Change Orders

Task uses a resource

When looking at Crowston’s (1994) three categories for allocation of resources (Table 4) it is clear that the project management team will fall under hierarchy category. This means that the four elements that makes up the task uses a resource dependency will be addressed accordingly:

1) The resources needed to solve the task will be based on the specialization in the team.
2) The needed resources will be identified according to the known set of resources in the team.
3) The set of resources will be chosen based on their specialization and also workload. Workload is an important criterion so that the change can be implemented as quickly as possible.
4) The assignment of the task will be performed based on employment relation.

Task produces a resource

To solve this dependency the assigner must make sure that the outcome of the task to be performed will have the desired effect. According to Crowston (1994), the assigner of resources to the task should divide the task into sub-goals or smaller tasks that will be performed according to specialization. Provided that the assigner is able to make a sound division of the task into smaller tasks, the change can be introduced more quickly if the resources/actors can perform one small task each corresponding to their specialization.

However, we believe this brings about another dependency that is founded in the ability of the resources to create a proper fit between their smaller tasks. Crowston and Malone have not addressed this, and as mentioned we have found it necessary to introduce the works of Snoo and Wezel (2011) to provide a complete coordination mechanism to this dependency.
In the following we will introduce “performance based on task interdependence” – as an extension to the original coordination mechanism for task produces a resource dependency for rescheduling by the project management team.

We will now use the findings of Snoo and Wezel, published in the article “Coordination and Task Interdependence during Schedule Adaption” (2011), that explains the aspect of perceived task interdependence and how it can influence the project management team’s rescheduling performance when the task of rescheduling is divided into smaller tasks.

“Interdependence theory deals with the relationship between work units, describing the extent that one’s actions are dependent on actions of others and/or influence actions of others” (De Snoo & Van Wezel, 2011, p. 4). The organizational setup that the actors are related through, and the technological aspects of the “work unit” will determine these interdependencies.

Put into the context of the construction management team when performing rescheduling, the members of the team are interdependent because they are all dependent on each of the “smaller tasks” resulting in the desired effect of the main task.

In Thompson’s “Organizations in Action” from 1967, he proposes a categorization of interdependence, which is referred to as the different types of interdependencies. According to Thompson (1967) the different types of interdependence are:

- **Pooled interdependence**: Activities that belong to the same system, but are not directly interdependent.

- **Sequential interdependence**: A direct, non-systematical relation between activities. This means that action A has to be carried out before action B can start or proceed.

- **Reciprocal interdependence**: A direct and ongoing relation between two activities, where there is a mutual dependency between action A and B.

Thompson then explains these types of interdependence further by explaining how they should be coordinated and when they are applicable.
Pooled interdependence should be coordinated through standardization. This will require standardized routines, which will limit each action to fall into a path consistent with the path of other actions that are a part of the same interdependent process. A requirement for this to work is that the actions performed are internally consistent, which will require a situation that is relatively stable, of a certain repetition and where the tasks performed are few enough to permit matching of actions under the same standard.

Sequential interdependence should be coordinated through schedules for the interdependent units, whereby their actions can be governed. Coordination through schedules will not require the same degree of stability such as in pooled interdependence (coordination by standardization). This makes this mode better suited for dynamic situations where the organization needs to be able to respond more quickly to the changes in the environment.

Reciprocal interdependence is suggested to be coordinated through feedback—or mutual adjustment. Coordination through feedback entails transmitting information during the process of performing an action. As observed through the works of March and Simon, Thompson argues that the reliance on coordination through mutual adjustment will be higher the more unpredictable the situation.

To summarize Thompson’s theory on interdependencies (Thomassen, 2003) has made a table (Table 6) illustrating the relationship between interdependencies, coordination modes.

<table>
<thead>
<tr>
<th>Type of interdependence</th>
<th>Mode of coordination</th>
<th>Information and decisions costs / difficulties of coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled</td>
<td>Standardisation</td>
<td>Low</td>
</tr>
<tr>
<td>Sequential</td>
<td>Plans (+ standardisation)</td>
<td>Medium</td>
</tr>
<tr>
<td>Reciprocal</td>
<td>Mutual adjustment (+ plans) (+ standardisation)</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 6 - Coordination and interdependencies according to Thompson (Thomassen, 2003)
When studying Thompson’s (1967) three different types of interdependencies, it is generally clear that the project management team has to deal with both sequential interdependencies initially during the scheduling and later also reciprocal interdependencies for when the rescheduling becomes necessary.

The task performance when rescheduling in reaction to an unexpected event by those involved in the project management team depends very much on the characteristics of the situation and the time available to respond, and ultimately the possibilities for rescheduling. Thus, it is stated by Snoo and Wezel (2011, p. 110) that “determining the type and level of all these task interdependencies in such high velocity environments is almost impossible, and the traditional way of designing coordination modes based upon an analysis of these interdependencies does not fit”.

The alternative way of approaching coordination constraints in these types of environments is looking at how perceptions of task performance influence the performance in decision alignment. Perceived task interdependence is defined as “the extent to which employees perceive that their tasks depend on interaction with others' and on other’s tasks being completed” (Bishop & Scott, 2000).

What this means for the coordination of the rescheduling effort is that if the members of the team perceive such interdependence, they will be more motivated to cooperate and through that have a higher expected performance rate during rescheduling scenarios.

With a higher performance rate in a reschedule scenario, the perceived task interdependence will ensure more effort being put into coordination of the smaller tasks coinciding in the main task (rescheduling) that produces a resource (the revised schedule), and thereby an optimal alignment of the decisions made in regards to the tasks involved in the rescheduling can be achieved.

When testing the effects of perceived task interdependence in a case study, Snoo and Wezel (2011) introduce two coordination systems inspired by decision-making theories. These two coordination modes where distributed decision making (DDM) and group decision making (GDM). The distinction between the two are explained as follows “whereas in GDM the problem is to achieve consensus among members of a group who are all capable of
understanding the problem as a whole, in DDM the problem is to coordinate the efforts of humans that have limited models of the overall problem, and who may never achieve a global understanding of it. In GDM, all decisions are taken jointly: group consensus is a prerequisite for all decision making, whereas in DDM such consensus is not necessary, decisions are to be taken by individuals or (sub-) groups. Finally, in DDM, group members are dealing with only a sub-set of all problems, whereas in GDM, all group members are treating the full set of problems” (De Snoo & Van Wezel, 2011, p. 111).

Arguably the project management team will be best suited to embrace the GDM coordination system, as this system dictates that the members are supposed to undertake the rescheduling process in a manner where they will be sharing all the available information.

For the case study by Snoo and Wezel (2011), the level of perceived task interdependencies was expected to be higher in the GDM coordination system because the team members would then be forced to coordinate decisions and thereby have higher perceived task interdependence (As mentioned before, this perceived task interdependencies is claimed to result in higher task performance).

In the case study by Snoo and Wezel (2011), the two coordination systems (GDM, DDM) were tested to verify which coordination system would yield the best results in a rescheduling scenario.

Through the case study, Snoo and Wezel (2011) could prove that the perceived task interdependence indeed was higher in the GDM coordination system. In terms of rescheduling this means that ensuring an increased mutual alignment in important decision-making, which is the basis of rescheduling.

The research done by Snoo and Wezel (2011) suggests that the appropriate coordination mode for the project management team is enforced decision making (GDM) in order to be able to handle rescheduling in the best possible way by ensuring a certain level of perceived task interdependence. In sum, this means that to limit the task produces a resource dependency for this scenario, the assigner should divide the task of rescheduling into smaller tasks based on specialization, while simultaneously enforcing group decision making so that
the interdependency of these smaller tasks can in turn be limited by the perceived task interdependence.

4.5.1.2.1 Change Orders by Other Parties

As managing the schedule is one of the main tasks of the general contractor, it also makes sense to address where the reason to reschedule may derive from.

In the preconstruction phase liability in scheduling derives from the many actors involved in contributing to specifications and desired outcome of the construction project. These actors that are involved in the basis for the project schedule are typically planners, design consultants and the client, or even subcontractors who are involved in the preconstruction meetings and may come with change proposals to the project plan.

Typically such changes to the project schedule during the preconstruction phase relate to design documents lacking clarity or even failing to incorporate the specialties of the various subcontractors who are supposed to perform the tasks in question. This is a common problem as “other parties”, such as design consultants, fail to acknowledge their responsibilities and consequently expect the general contractor to uncover mistakes or weaknesses” (AGC, ASA & ASC, 2008, p. 9).

4.5.1.2.1.1 Dependencies - Change Orders by Other Parties

In these types of situations the general contractor through the project management team will be directly dependent on the resources provided by the planners, design consultants and client in order to perform the task of creating a well functioning project schedule.

This causes a flow dependency between the design consultants and the general contractor where the sub-dependencies of usability and prerequisite play an essential role as it will be difficult for the general contractor to perform his task of scheduling if these dependencies cannot be limited.
The sub-dependency of usability will imply that the documents prepared by the planners and design consultants must be usable by the general contractor. This means that the documents should not contain errors to the point where this is possible to ensure.

Next, the prerequisite sub-dependency will manifest itself in how the design documents and other specifications are required by the general contractor and the project management team to conduct the scheduling. The prerequisite sub-dependency can also arguably be related to how the general contractor must make the design consultants and planners aware of special concerns/needs raised by the subcontractors in regards to the performance of the future tasks.

4.5.1.2.1.2.2 Coordination Mechanisms - Change Orders By Other Parties

In the framework provided by Crowston and Malone, the coordination mechanisms for a flow dependency can generally be related to an “inventory system”. As the situation described above typically will be a one off situation (because the bulk of the documents required for the scheduling will be handed off once) it may not be necessary to set up an inventory system.

However, there should be a system in place, which can facilitate a mutual information exchange between the design consultants, general contractor and subcontractors. This will enable the consumers (general contractor and subcontractor) to communicate their needs to the producer (design consultants), and also be able to do quality control of the design documents and specifications before they are handed over and can cause a need for change orders.

4.6 The Construction Phase

The construction phase is the second of the two critical phases as identified together with the case company. In the following, the phase will be introduced so that the challenges that make it critical can later be argued for.
Once the design and specifications are complete and the schedule has been prepared in the preconstruction phase, it is time to move on to the construction phase.

The construction phase is where the construction project will take physical shape. It is at this point that the full potential of the designs, planning and scheduling conducted earlier in the process will be realized.

When looking at the construction phase in large construction projects through the overall perspective required by the general contractor, the process appears complex and, to some extent bewildering due to its many activities and parties involved.

Throughout the construction phase the general contractor will have to coordinate the various processes taking place so that all these processes will successfully coincide in the common goal of completing a new structure. The amount of parties involved in the construction phase depends on the nature of the project, however major construction projects will usually involve a substantial amount of parties. Therefore after the preconstruction phase has been carried out, the construction phase will be the most critical phase in terms of the sheer amount of parties that will need to be coordinated and the challenge this represents to the general contractor.

The project management team within the general contractor will coordinate the construction phase, observe and control the tasks and resources on the construction site. In effect this means that the project management team’s “...ability will strongly influence the success or failure of the project for the contractor, the professional team, the client and ultimately the general public” (Mustapha & Naoum, 1998, p. 1). Good organizational skills and an ability to anticipate problems, ensured in the assignment of the project management team in the preconstruction phase, are essential for the outcome of the project as there is limited margin for errors on the construction site (Mincks & Johnston, 2004).

The construction phase will consist of two major parts, where the first one is the rigging/creation of the job site in order to prepare it for the actual construction that will take place. The second part is the construction itself. Both parts will be performed by subcontractors.
4.6.1 Challenge of the Construction Phase

From the general contractor’s point of view, which is the basis for the thesis, managing the subcontractors will represent the most substantial challenge in this phase when seen through a coordination perspective.

"When multiple subcontractors are involved in the construction, the risks for delays can increase exponentially and can have serious detrimental effects on the overall success of a project. It becomes the responsibility of the construction manager to coordinate and organize the skills of these subcontractors in the most efficient manner" (Flynn, 2009, p. 1).

4.6.1.1 Managing Subcontractors

Managing subcontractors is the main coordination challenge, as these will be the actors performing the task of constructing whatever the goal of the project is. Next, the success of the project is directly dependent on the ability by the project management team, under the general contractor, to be able to effectively manage and coordinate tasks performed by subcontractors.

The subcontractor’s role in the construction project will be to conduct a set of tasks that the general contractor appoints through the process of awarding contracts once the relevant subcontractors have delivered their bids. A supplier is the actor who produces and delivers parts and materials that are necessary for the subcontractor to perform the task/work.

Despite this essential difference in the outset of the functions between the subcontractor and the supplier, we choose to regard their roles in a construction project jointly, as we seek to analyze parties in terms of coordination where they are understood as resources in a cluster of different parties performing a set of tasks. Thus, we do not consider the differences between the two as important in this context and we will use the term subcontractor to describe both.

The superintendent (supported by the field engineer) will play a vital role when it comes to coordinating the construction phase, as he works as an intermediary between the essential parties involved. Namely by conveying the wishes and expectations of the client, through his
own function as a member of the general contractor, and out to the subcontractors who are responsible for creating the physical structure in question.

The challenge of managing subcontractors is grounded in both the fact of it being many subcontractors that need to be managed in a way so that they together can contribute to important task being performed, and the reality that the various subcontractors are of different natures in terms of specialty and function in the construction process.

4.6.1.1.1 Causal Mechanisms of Managing Subcontractors

In this section we will address the causal mechanisms that are the reason why the management of subcontractors is a challenge based on a coordination view.

The following causal mechanisms will be introduced:

- Tasks that require specialized knowledge
- Several knowledge bases required to obtain a common goal
- The general contractor as a resource to subcontractors
- Spatial limitations
- Ensuring quality of subcontractor’s work

According to the theoretical framework, each of the causal mechanisms will be analyzed through dependencies and corresponding coordination mechanisms.

4.6.1.1.1.1 Tasks that Require Specialized Knowledge

In larger construction projects there is often a need for services that do not typically come as a part of the skill set of the more common subcontractors present on the construction site.

When managing the subcontractors at a construction site, these tasks that require specialized knowledge may often be of general importance to the proceeding works of the other common subcontractors. This generates substantial constraints when ensuring that these tasks will be performed so that they can lay the foundations for other work.
Typical tasks at a construction site that require specialized subcontractors are often related to environmental remediation services, landfill services, water resources services, ground engineering and mining services as well as initial rigging on the site (GAIA Inc., 2007).

4.6.1.1.1 Dependencies - Tasks that Require Specialized Knowledge

When considering a scenario where a specialized subcontractor has to be contracted to perform, for example ground engineering or mining services, this will essentially create a resource that will be the precondition for another task (the continued work by the common subcontractor).

This will result in a flow dependency that the project management team will have to be aware of in order to obtain the best possible coordination between the task of the specialized subcontractor and those who are to continue work on the construction work after.

The argument for the relevance of the flow dependency in this example is founded in how this situation requires a sequential use of resources, where the resource needed by the specialized subcontractor will be the space/construction site that he (according to the example) will need to perform his task.

Further, this flow dependency leads to a sub-dependency under the flow dependency for when a task requires specialized knowledge. This sub-dependency will be “prerequisite” which is based on how the specialized subcontractor (the producer) must know exactly what is required by the common subcontractor (the consumer). If these requirements are not met, the common subcontractor may not be able to perform his task that is dependent on the resource produced by the specialized subcontractor.

To summarize, the dependency of this causal mechanism is a flow dependency with the prerequisite sub-dependency.
4.6.1.1.1.2 Coordination Mechanisms - Tasks that Require Specialized Knowledge

According to Crowston (1994), the key to managing this dependency is quality control. This means that the project management team, and in particular the superintendent, should implement a system of quality control with where regular checkups on the task performed by the specialized subcontractor in order to ensure that the output of the task will indeed be the correct input for the next task. The project management team should strive to involve the common contractor(s) that will depend on the resource created by the specialized subcontractor when performing this quality control.

To avoid “clobbering” (note: clobbering is mentioned in the coordination theory framework and is explained by how too many tasks involved in obtaining a common goal can lead to complications, where dividing the goal into sub-goals that later will make up the main goal can be more beneficial) the task of the specialized subcontractor can be divided into several tasks so that (if possible).

When using the example of the specialized subcontractor doing the groundwork on the construction site, he can perform his task in sections of the construction site and thereby allow the common subcontractor to start his work on the sections as they become ready.

By making sure that the required quality of the resource is achieved and by allowing the common subcontractor to start his work on the sections as they become available, the flow dependency should be reduced.

4.6.1.1.2 Several Competences Required to Obtain a Goal

As there are often several specialized subcontractors in a construction project, it makes sense to address how these specialties can result in coordination constraints when trying to create a synergy between them.

According to Kazi (2005, p. 7) the knowledge in a construction project exists on three levels, these are:
• “The organization (company/subcontractor) knowledge base, which contains the data and information specific to the organization and wider environment in which the project is being executed”
• “The project management knowledge base, containing knowledge of the theory and application of knowledge management”
• The project-specific knowledge base, which contains the project-specific knowledge acquired over the project life cycle”

When looking at these three levels through the general contractor’s point of view and thereby the project management team, this underpins the relevance of this causal mechanism as an important part in dealing with the challenge of managing subcontractors that in the outset can be very different from one another.

This is due to how the project management team will be responsible for making these competences work together in order to reach the common goal of the construction project. At the same time the project management team will have to be able to perform their own level (2nd) well, in addition to acquiring substantial knowledge of the knowledge base of the various subcontractors (1st) and of the knowledge that derives from what is going on at the construction site (3rd).

This causal mechanism is based on how “...the construction industry is organized around projects delivered by multidisciplinary organizations working together in a “virtual” organization” (Anumba, Egbu, & Carrillo, 2005, p. 105), where the project management team of the general contractor will be in charge of the organizations involved working together as this “one virtual organization”.

In sum, this causal mechanism requires the project management team to obtain a sufficient overview of the knowledge bases involved in the project, and to make sure that the competences that these knowledge bases represent can be transferred effectively into tasks that can be unified and function together in the various activities in the construction project.

Further, we believe in the case of a change order, that the project management team must also demonstrate absolute control over this causal mechanism in order to be able to immediately reassign tasks and resources.
4.6.1.1.2.1 Dependencies - Several Competences Required to Obtain a Goal

When analyzing the causal mechanism of “several knowledge bases required when obtaining a common goal” based on the presentation above, there are two different dependencies that appear. These two dependencies are:

• Task uses a resource dependency
• Dependencies among multiple resources resulting in one task

Task uses a resource dependency

In this situation this dependency is based on how the assigner must obtain an overview of all the competences in order to be able to appoint the correct resource to the task. The four steps that make up the sub-dependencies represent this constraint in resource assignment. These four sub-dependencies will now be addressed according to this particular example.

1) Identify necessary resources. This sub-dependency represents the problem the assigner encounters when he has to obtain an overview of all the possible specialized competences involved in the construction project that could be used as a resource for the task to be performed. Next the assigner must ensure that the closest possible fit between the task and the competences found among the specialized knowledge bases (resources) is in place.

2) Identifying available resources. Once the assigner has made sure that there is as close as possible fit between the task and the available specialized competences (in other words, having established what resources may be relevant to performing the task), he will be facing the sub-dependency of identifying which resources are actually available to perform the task.

3) Based on the nature of the task and the available, necessary resources, the assigner must now choose which resource (specialized knowledge base/actor) to perform the task.

4) Last, the assigner must communicate the order to perform the task to the resource.
Dependencies among multiple resources resulting in one task

When a task (typically representing a “goal”) requires multiple resources (knowledge bases) this will put constraints on the performance of the task, namely due to the dependency on multiple resources (Crowston, Malone, & Herman, 2003). There will also be a need to synchronize the availability of those multiple resources so that they can be utilized when they are needed by the task. To achieve a “goal” (a substantial task), such as a section of a building or, for example an elevator shaft, this “goal” will most likely have to be divided into “sub-goals” consisting of smaller tasks that are interdependent.

This results in a flow dependency where the sub-dependencies of *usability*, *prerequisite* and *accessibility* will all be encountered.

We will continue by arguing for why these three sub-dependencies will be present when one task requires multiple resources.

1) **Usability** refers to how the tasks (“sub-goals”) will have to be usable by the next task. This means that once the “goal” has been divided into “sub-goals” the project management team must make sure that these “sub-goals” will eventually fit together and make up the main “goal”.

2) **Prerequisite** is manifested in how each of the “sub-goals” will represent a resource needed to perform the task of creating the next “sub-goal”. This creates a producer – consumer scenario where the consumer must know when the producer has made the resource ready.

3) **Accessibility** is the dependency that occurs when the produced resource must be made available to the consumer. According to Crowston, Malone and Herman (2003) this can entail physically moving a resource from where it has been produced to where it will be consumed. On a construction site this could be exemplified by moving a built module so that the next subcontractor can take over.
Task uses a resource dependency

To make a clear presentation of the appropriate coordination mechanisms for this particular dependency, we will present the coordination mechanisms according to the four sub-dependencies/steps.

As presented previously in the framework of the coordination theory, it is step 2 and 3 that form the basis of this dependency. Because of this, these two steps are where the main focus of the coordination mechanisms will be.

Sub-dependency 1 should be coordinated through an ICT-based database where the assigner will be able to access information about the specialties of the different knowledge bases. By having such a database the assigner can then ensure the best fit between the task and the potential resources that can perform the task.

For identifying available resources and choosing a resource (2 and 3), the assigner will have essentially two approaches to choose from in terms of coordination mechanisms. This choice depends on whether there are limited or multiple resources that are necessary for performing the task.

In the case where there are only a limited amount of relevant resources to perform the task, the assigner should apply a “network” strategy, which is organized according to specialties. This strategy is the most relevant for scheduled work that takes place under stable circumstances.

In a situation where there is a sudden need for specialized knowledge or where there are multiple relevant specialists that can perform the task, the assigner should employ a “market” strategy. The assigner will then advertise the need for a certain specialized knowledge base and receive bids from those resources that will be available to perform the task.

Sub-dependency 3 will then be addressed in direct response to the coordination mechanism of sub-dependency 2.
Sub-dependency 4 should be addressed through an effective system of communicating the signal for the task to be performed by the resource.

Dependencies among multiple resources resulting in one task

We will now address the flow dependency of the particular causal mechanism I question through its corresponding coordination mechanism.

In the situation as described above under the argumentations for this flow dependency, the consumer will be relying on a “just in time” system as he is directly dependent on the particular output/resource created by the producer (actor of the previous task) to perform his task.

Because of the consumer relying on that particular resource, the needs of the consumer must be carefully planned and communicated to the producer. In order to ensure this, Crowston (1994) suggests that the project management team should involve the consumer to make sure that the resource produced will be the correct input for the task of the consumer that yet is to be performed.

4.6.1.1.3 General Contractor as a Resource to Subcontractors

After considering the dependencies among subcontractors, the dependencies between the general contractor and the subcontractors should also be addressed.

In a construction project the most important resource to the subcontractor during the construction phase is, arguably, the general contractor. This is because the general contractor, through the project management team, sets the “state of the world” in which the subcontractors operate.

Because of this hierarchy, the subcontractor will face certain dependencies in the form of how their work relies on how it is organized by the general contractor in, for example, the schedule.

As this relationship affects the challenge of managing the subcontractor, this is something the general contractor will have to consider, and thereby this will be a causal mechanism to the challenge of managing subcontractors.
In a practical situation this causal mechanism is manifested by how the subcontractors will rely on the general contractor for information as a resource to perform tasks, and how for example incomplete specifications provided by the general contractor, through design consultants, will represent a malfunctioning resource to the subcontractor.

4.6.1.1.3.1 Dependencies - General Contractor as a Resource to Subcontractors

Given how the general contractor is the main source for information to the subcontractor, the general contractor should perceive itself as a distributor of information, which, from a purely managerial point of view, is exactly how the general contractor represents a vital resource to the subcontractor (note: the general contractor can, and often will, also be responsible for providing materials and supplies as well as machinery that the subcontractor relies on).

This creates a flow dependency between the information obtained and generated by the general contractor and the distribution of this information out to the subcontractors (note: the general contractor is also responsible for the reversed information from the subcontractors to the design consultants and client. However, as this reversed information flow does not go in under the management of subcontractors, it will not be further elaborated on) who rely on this information as a resource to perform their tasks.

The flow dependency in this case will involve all three sub-dependencies (usability, prerequisite and accessibility) as explained below.

**Usability** in this context relates to how the general contractor must make sure that the information transferred to the subcontractor can in fact be used. This means that this dependency will be enforced if the general contractor cannot provide guarantees to the subcontractor that, for example, information in the form of technical specifications is correct or not.

**Prerequisite** revolves around how the information as a resource to one subcontractor may result in this subcontractor performing a task that produces a resource that cannot be used by the next subcontractor. In the example above, this relates to how this second subcontractor may be unable to perform his task if the general contractor has provided the first subcontractor (the producer of the resource needed to perform the next task) with
incorrect information/technical specifications by not being able to handle the usability sub-dependency.

For Accessibility in the terms of information, it is important that this information is made available by the general contractor to the subcontractors so that the construction process does not falter due to subcontractor awaiting information needed as a resources to perform a task.

4.6.1.1.3.2 Coordination Mechanisms - General Contractor as a Resource to Subcontractors

In the following we will present the theoretical coordination mechanisms for the flow dependency in the “general contractor as a resource to subcontractors” causal mechanism.

First, the general contractor must make sure to limit the usability sub-dependency. It is vital that the general contractor is aware of the needs of the subcontractor. When using the example above, the general contractor must communicate the needs of the subcontractor to the design consultants to the extent where the subcontractor cannot do this himself.

Once the general contractor receives technical specifications from the design consultants during the course of the construction phase, he should confirm that these specifications are indeed correct according to the quality the subcontractor requires.

Practically this can be achieved by implementing an ICT system where the subcontractor can have early access (at least as early as possible) to the specifications and can provide change proposals before the point at which the task is to be performed. This will also give the general contractor a basis for better insight, so that he can help ensure the quality of technical specifications in a better way.

Second, if the general contractor fails to coordinate the usability sub-dependency, the prerequisite sub-dependency will remain intact and possibly also be enforced as it could make the next interdependent task impossible to perform.

This means that the coordination of this sub-dependency in this particular example is directly dependent on the success of the general contractor in addressing the first sub-dependency. Further, as these two sub-dependencies are so closely linked in this example, we suggest that the coordination mechanisms should also be equally linked.
When implementing an ICT system like suggested above and obtaining success with it, the next sub-contractor will be able to monitor what the first sub-contractor plans to do, and possibly what he indeed is doing. By utilizing a system like this, the general contractor will have a better chance at ensuring a fit between the “flows of tasks” by implementing a certain quality to the resource he is providing/distributing, namely the information required as a resource by the sub-contractors when performing their tasks.

Third, if the information flow does not work to the momentum that is required, this can impede the construction process. It is therefore important that the general contractor is able to maintain an information system (proposed as an ICT system) that ensures that the required information needed between the general contractor and the subcontractors is always readily accessible.

Arguably, this type of system can also limit how the subcontractors depend on the general contractor if the subcontractors all have access to a system that enables them to exchange trivial information without going through the general contractor.

4.6.1.1.4 Spatial Limitations

The importance of space as a resource in the construction project is exemplified in this quote “for example, it has been reported that studies conducted by Mobil suggest that 19 m\(^2\) per person is required and that 50% more man-hours are required when this declines to 10,4 m\(^2\) which is an absolute minimum. For well-planned emergency labor-intensive short-term tasks, it is possible to manage with 9,4 m\(^2\). Maximum productivity occurs at 30,2 m\(^2\) " (Winch, 2010, p. 297). Besides showing how space is an important resource in itself, it also underpins how important space is when managing subcontractors during the construction phase, as a poorly managed workspace will inhibit the productivity of the subcontractors.

According to Marx, Erlemann and König (2007) there are three types of spatial resources on a construction site. These three types are resource space, topology space and process space. To provide a better overview of what is meant by these three types of spaces, we will give a brief introduction of each of them.

- **Resource Space**: This is the space required by the resources (subcontractors) to perform their tasks.
• **Topology Space:** This space contains the building structure as well as the surrounding environment that form the boundaries of the construction site. A unique aspect of this type of space is that it will change over time as the building structure changes.

• **Process Space:** Entails process related spatial aspects, which will typically be hazard spaces, protected spaces and post processing spaces. This can be further elaborated on by how for example a tower crane requires a hazard space under the turning angle of the crane when moving an object. Protected spaces will be required when building components or parts of the built structure need to be protected from potential damage by adjacent construction work. Finally, some building elements may need to be post processed in areas that are especially set up for these kinds of tasks.

In sum, the spatial limitations represent a considerable percentage of the challenge the general contractor will have to deal with when managing the subcontractors involved in the construction phase.

4.6.1.1.4.1 Dependencies - Spatial Limitations

According to Heesom and Mahdjoubi (2002), the need for space by all actors combined with conflicting types of space, essentially results in a dependency between available space and required space.

Further, this can be put into context by the fact that there can be a conflict between types of space and share-ability. We will now elaborate on these two scenarios and identify which dependency occurs in each of them.

**Conflicting types of space**

As we have already mentioned the example of the tower crane, we will continue with this example when explaining the dependency between types of space. As mentioned, when operating a crane, a hazard area in/below the operation radius of the crane will have to be marked off. This will limit the general resource space at the construction site.
In this case, the dependency between the spaces being marked off as a hazard area and being utilized as a resource space, will be a flow dependency. The reason for this is that the area must be utilized as a hazard area before it can be transformed back into a resource area. Practically, this means that the tower crane will perform the task of moving a building element, in which period of time the area will be a hazard area, where once the building element is moved into place, the area will become a resource area where the subcontractors/workers will continue their tasks involving the building element.

This creates a flow dependency where a chain of activities are dependent on each other so that they all can be completed. The flow dependency in this particular example is manifested in how the construction schedule will let the operator of the tower crane know when he is to move the building element, for which period of time others will be sent elsewhere while the space is designated as a hazard area, and then when the shifted building element will become a direct or indirect resource to the subcontractors that will be able to continue their tasks in what has now again become a resource area to the other subcontractors.

**Shared Space**

As the construction site can only offer a limited amount of space to begin with, this creates a shared resource dependency where most tasks performed at the construction site by the subcontractors are dependent on the same resource —space.

The shared resource dependency of the spatial limitations that construction sites represent manifests itself in the sub-dependency of share-ability and reusability. This is because of how many tasks simultaneously will be dependent on a given resource, which can be used over again.

In the construction phase this can be argued for by how a subcontractor installing the plumbing may require the same spatial resource as another installing the electrical wiring.

The figure below (Figure 7), illustrates both conflicting space problems and the shared space problem in the context of operating two tower cranes.
4.6.1.1.4.2 Coordination Mechanisms - Spatial Limitations

We will now address the coordination mechanisms in the same order as the dependencies were presented above.

Conflicting types of space

In the example used in this context, the flow dependency is represented as a “softer” resource. What we mean by this is that space as a resource is not a specific product that has to be produced in order to be consumed, which means that in this context space is more “a state of the world”, hence no mentioning of the sub-dependencies.

However, it still presents the general contractor/the project management team with a significant managerial problem. In order to coordinate the use of conflicting types of space, the general contractor must plan carefully so that subcontractors waiting for the space to turn from a hazard area to a resource area do not lose time. This should be managed through a system where subcontractors can be warned about a certain space being turned into a hazard area, whilst at the same time ensuring that they will be able to perform other tasks as set for by the project schedule.

Figure 7 - Working spaces and conflict caused by crane operations (Marx, Erlemann, & König, 2007)
Shared Space

In order to coordinate a shared resource, the resource needs to be “marked as in use” when one or more actors are using the resource. The timing for when these tasks are to be performed is based on the schedule. As we have indicated in this thesis, the schedule will normally be changing as the construction project moves forward, which may directly influence the timing of the tasks that are dependent on the shared space resource.

As a result of this, the importance of all actors involved in the construction project being updated on the current version of the project schedule, directly translates into how the spatial resource may be “marked as in use”.

Whilst the project schedule will indicate when the task requiring the spatial resource may be performed, an ICT system could enable the subcontractor to mark the spatial resource as “in use”. This will let other subcontractors know the spatial resource is occupied, while at the same time provide the project management team a with good indication of the tasks being performed at the construction site.

4.6.1.1.5 Ensuring Quality of Subcontractors' Work

In the end, the quality of the work done is what matters to the client. As the general contractor is responsible for the outcome of the construction project, it is important to make sure that the subcontractors perform according to expectations.

According to Winch (2010), the typical causes for the quality of the construction project falling through are related to ambiguous drawings/technical specifications, inadequate workmanship, standards and regulations that may not be followed, details that are overlooked and accidents.

Further he states, “...within the firm, there are two main elements to the quality assurance system. Each firm has a quality policy, which is the general set of arrangements for managing quality in the firm. These policies are applied to individual projects through the quality plan for that project. An important challenge is adapting the quality plan to the needs of particular projects, while remaining within the procedures laid down in the firm’s quality policy” (Winch, 2010, p. 326).
In terms of the general contractor being responsible for the overall success of the construction project, this means that a substantial cause for the challenge of managing subcontractors will be ensuring conformity between the tasks performed by the subcontractors and the expectations of the client.

The medium in which this quality is ensured is through the quality policy by the general contractor that is adapted to fit the particular construction project at hand.

Arguably, this causal mechanism could also have been represented as a separate challenge in the preconstruction phase. However, since the cooperation with the subcontractors is manifested in the construction phase, we choose to address it here under the challenge of managing subcontractors.

4.6.1.1.5.1 Dependencies - Ensuring Quality of Subcontractors' Work

The dependencies in this causal mechanism, when put in a scenario where the general contractor is managing and striving to control the quality of the subcontractor’s work in the construction phase, are located in how the general contractor depends on the subcontractor following the quality plan for the project.

This puts the general contractor in the position where he is to perform a task and where the resource that is needed to perform/achieve this task is the subcontractor.

This is a dependency that the general contractor should be aware of as early on as in the preconstruction phase (please read argument for why it is addressed under the construction phase, above). Arguably, this dependency could also have been analyzed “in the opposite direction,” where the quality plan could have been viewed as a resource to the subcontractor. However, as we practice a top down perspective from the general contractor’s point of view, this would not make sense in this thesis. Hence we will perceive the subcontractor as a resource to the general contractor when performing the task of fulfilling the requirements of the quality plan.

When employing this point of view, the general contractor will be faced with the task uses a resource dependency, and more specifically the sub-dependency of identifying necessary
resources (note: as presented in the coordination theory framework there are also other sub-dependencies to this dependency, but these are not deemed relevant in this particular case). These resources are identified as the subcontractors that have the required competences and own resources to fulfill the specifications of the quality plan.

In order for the general contractor to be able to identify the necessary resource, he will have to know the abilities and competences of the subcontractors to fulfill the requirements in the quality plan (Crowston, 1994).

4.6.1.1.5.2 Coordination Mechanisms - Ensuring Quality of Subcontractors' Work

As presented in the coordination theory framework, there are three categories through which this dependency and/or sub-dependency can be coordinated. These categories are market, hierarchy and network.

When contracting the subcontractors, the general contractor will use the market approach where he will state the requirements of the construction project and therefore also the quality plan, and receive bids based on this.

However, during the construction phase it is likely that change orders will be introduced. This creates a situation where additional tasks may have to be performed. In order to ensure the quality of the construction project when these types of situations occur, the general contractor will (typically) be faced with the dependency/sub-dependency of identifying necessary resources among the subcontractors that are already contracted.

This changes the category of coordination mechanisms to “network”. This is because all subcontractors will now belong to the same network, consisting of the members of the construction project. According to Crowston (1994, p. 9) this choice when in a network category should be based on a “...known set of resources belonging to network”.

There should be a database in place for the general contractor to be able to base the choice of a known set of resources that will fulfill the requirements of the quality plan.
5 Empirical Analysis

5.1 Case Study Introduction

In this chapter we seek to do an empirical analysis based on the theoretical findings. This is done by using the model for the theoretical analysis in order to ensure that the case company experiences the same challenges and causal mechanisms. If the case company does experience these same challenges and causal mechanisms, the theory study and the empirical analysis are comparative.

Further, this means that we can address the dependencies and coordination mechanisms of the case company through the findings in the theory study, as these will be applicable.

The empirical evidence is collected through interviews with employees in the case company. We will first introduce the case company, and because the case company (from this point on referred to as “CC”) preferred to be anonymous the characteristics of the company will be moderately introduced, mainly describing the nature of the company.

The interviewees involve department directors, project managers and on-site, construction engineers and project management team members. Thus, we have engaged interviewees from varied positions in the construction company to ensure a diversified perception of the issue.

Based on our case results, we will first analyze how the case company deals with the causal mechanisms identified in the theory, and thereby analyze the coordination mechanisms they employ to manage the dependencies.

Next, we seek to clarify whether the CC's coordination mechanisms address the dependencies established in the theory.

Last, we will study how the CC manages the causal mechanisms compared to the theoretical suggestions. This will enable us to determine if the theory has alternative methods to cope
with the challenges. We will establish whether we can suggest changes to the CC's coordination mechanisms based on the theory findings, or if the empirical findings can contribute to solutions for managing coordination constraints in construction projects by suggesting improvements to the theoretical findings. This is exemplified by Crowston (1997) in how the theory does not seek to clarify what must happen, however, the theoretical analysis suggests possibilities that a manager can consider and modify to fit the particulars of the organization.

5.1.1 Grounds for choosing between theoretical and empirical coordination mechanisms

When conducting the comparative analysis of coordination mechanisms (see Figure 8 below), the question of how this choice is made will have to be addressed.

In this thesis we have made this choice based on an evaluation of how well the case company addresses the given dependencies of the causal mechanism through their own coordination mechanisms.

It is important for us to incorporate the case company’s own coordination mechanisms as these are proven to be feasible for the case company to execute. However, when we see that the coordination mechanisms by the case company do not suffice in properly addressing the dependencies identified through the theory study, it is important to also apply the theoretical coordination mechanisms.

This will result in a set of coordination mechanisms that will be based on both empirical, as well as theoretical coordination mechanisms. By combining these two we can ensure an increased feasibility of the coordination mechanisms as well as making sure the dependencies are properly addressed.
5.2 Structure of Empirical Analysis

In this section we seek to clarify the structure of the empirical analysis, so that it is easier for the reader to follow the logic of the analysis.

Further, we have made a figure to describe the structure of the empirical analysis (Figure 8).

- Introduce the *challenges* in relation to the case company
- Analyze what *causal mechanisms* exist in the case
  - Analyze how the *causal mechanisms* manifest themselves in the case company
- Analyze how the case company deals with the *causal mechanisms*
  - Analyze what *coordination mechanisms* they employ
- Analyze what *theoretical dependencies* exist in the case's causal mechanisms
  - Analyze how the case company addresses the *dependencies*
- Analyze differences and similarities between theoretical and empirical *coordination mechanisms*. The most appropriate coordination mechanisms will be identified

Figure 8 - Structure of empirical analysis

Based on these steps and findings in the empirical analysis, with findings in the theory study, we will be able to answer the problem statement.
5.3 Case Company Profile

Some of the information we have received is confidential, and we therefore decided together with the CC that conducting an anonymous case would be the appropriate strategy.

The CC is a major construction company in Norway with over 2000 employees and they do construction work on both a national and international level.

The company has comprehensive experience regarding all elements of a construction project, where the company is involved in most market segments regarding construction work and has rapidly grown in the Norwegian market during the last decade.

5.4 Empirical Analysis of Coordination Challenges

We will, in the following sections, analyze the different coordination challenges, causal mechanisms and dependencies in relation to the case. The analysis also includes a comparative analysis for each causal mechanism, where we study the coordination mechanisms employed by the case in relation to theory. The reason for this approach is to obtain a comparative analysis deriving from the same basis, where we can establish a best possible approach to coordinating the dependencies/limit the coordination constraints.

5.4.1 Designing the Project Management Team

The project management teams in the CC consist of various professionals that are put together by the project manager in the initial stages of each project. There are certain methods in place that the project manager utilizes when designing the teams, these will be further elaborated on in the following. A well functioning project management team is
important to the CC, as the outcome of the project will define the reputation of the CC in the market.

5.4.1.1 Assigning Resources to the Project Management Team

In relation to this causal mechanism the interviewees stressed that managing team members' knowledge and capabilities, and handling general limitations to resource capacity complicates the process of creating project teams. This is because there is a continuous strive in the CC to assign the best possible resources to the team, while at the same time battling with the constraint of there (always) being limited resources available.

We will now go through the case interviewees’ reasoning on the subject, first by clarifying how these issues affect the creation of project teams and secondly by studying which coordination mechanisms the case uses compared to our theoretical findings.

According to the interviewees, capacity is an issue; meaning that ensuring the project team has enough people involved to manage the construction project can be difficult. An individual's personal capabilities (e.g. managerial) are vital resources, which are often limited to the presence of that particular individual. Interviewee 1 (Department Director, CC) exemplified this by explaining how projects in the past may not have reached the potential outcome due to members of the team not cooperating to the full extent where the combined resource of their capabilities could have been utilized to its full potential. This represents a mismatch between the available resources and desired capabilities for the specific project. Consequently, due to lack of available resources within the project team, the CC often has to prioritize certain projects, which the interviewees stated is a method they use to overcome the lack of resources available. However, they argued that prioritizing certain projects affects the implementation of others, where the projects that are not prioritized would have to be postponed until additional resources were available.

The interviewees argued that project management teams are knowledge intensive and that it is challenging to ensure that all necessary knowledge bases are covered in the team. One of the interviewees stated: "A sufficient project team requires members with social skills, members that are 'doers', members with analytical capabilities and members with people skills" (Project Manager, CC). As a way to ensure that vital functions are acquired to the
team, the CC's project manager prioritizes the functions that he finds most important and acquires those resources first.

Further, it was argued by the interviewees that it is challenging to design a team where the members complement each other's functions. Thus it is essential that members have both specific knowledge (e.g. technical, financial) and diversified knowledge. Because to maintain process efficiency team members must be able to conduct the tasks of others when there is a lack of available resources, in addition to be able to cooperate well so that they can combine their capabilities that ultimately is what define the resource that the project management team represent.

Moreover, the interviewees argued that because project teams are knowledge intensive the project manager has to have knowledge about the available resources' capabilities, thus what resources are appropriate and available. An issue identified in the case was that knowledge about resources' capabilities was not documented, thus such knowledge was therefore limited to the managers' experience with, and knowledge about employees (tacit knowledge). Consequently, according to the interviewees, the project manager's knowledge about the technical and financial scope of the project, and knowledge about appropriate resources is critical in order to create a successful project team.

5.4.1.1.1 Coordination Mechanisms

It is evident that when there are limitations to the capacity of available resources, the CC often will choose to prioritize, both based on importance of projects and importance of functions within a project management team. It is indicated by the interviewees that the preconstruction phase is critical due to limited time, and the project manager does not have time to wait for necessary resources becoming available. Thus, prioritizing appears to be an accepted way of coping with such time restrictions.

However, as argued by the interviewees, prioritizing in such manners can have a direct influence on other processes. The interviewees argued that limited time and resources, and the consequent need for prioritization, could affect the quality of the project team, as the project manager could be put in a situation where he would have to accept inappropriate resources in order to quickly fill all functions in the team.
To ensure that the appropriate resources are assigned to a project team, according to the interviewees, the team members are selected based on four factors:

1. **Availability**: Which resources are actually available to join the project team.

2. **Project manager's preferences**: Thus, who the project manager prefers to join the team. The project manager's personal preferences are often based on his experiences with the members, where he thereby designs a team consisting of members that he believes can function together both socially and professionally.

3. **Team member's preferences**: Whether the member is motivated to join the team, and if the member is genuinely interested in the project. The project manager collects this information through interviews with the potential member prior to project startup.

4. **Team member's capabilities**: Thus, whether the member has knowledge and experience from similar projects. Information about the member's capabilities is collected through the managers' experiences with the member, and interviews in relation to the project.

According to the interviewees, the CC strives to take these factors into consideration. However, when the managers come across situations where available resources are limited, factor #1 becomes the most important point of consideration. This leads to a situation where the CC will have to assign the available resources to the project management team regardless of capabilities.

**5.4.1.1.2 Addressing Dependencies**

Leaning on the coordination theory framework, it is evident that when the CC project manager designs a project team, he comes across certain dependencies. It is argued in the theory that the relevant dependency in this context is the *Task uses resource dependency*, which coincides with the CC's process of creating project management teams. The project manager's main task in this part of the process is to assign the best possible resources to the team and, according to the interviewees, the CC has certain factors that affect the process of assigning (see steps above).
As argued in the theory, the first thing the project manager will have to do is to determine which resources or competences are necessary to each of the functions, and clarify whether he needs specialists or generalists to fill the functions. This coincides with the interviewees' argument that project managers knowledge about the scope of a project is essential for the project manager to be capable of gathering appropriate resources to the team.

Secondly, the theory argues that the project manager has to identify what resources are actually available to him. Here we can see a clear connection to what the interviewees defined as the most substantial issue when creating project teams, namely capacity.

Finally, the theory argues that, in addition to availability, quality is an important factor where the quality of team members' capabilities can affect quality of projects.

When analyzing the case interviews it is evident that the CC's managers have to deal with the *task uses resource* dependency when creating project teams. This dependency is created due to limited amount of resources available within the CC, and due to the fact that CC's construction projects often have to be managed by people with diversified general knowledge.

### 5.4.1.1.3 Comparative Analysis of Coordination Mechanisms

The CC usually prioritizes important projects and functions to overcome the issue of limited resource capacity. However, such a method may not be optimal considering the effects it has on the quality of other projects and teams. When continuously prioritizing some projects and postponing other due to limited resources, we question if acquiring necessary means from other sources may be a rational coordination mechanism.

Through the interviews it also became clear that how the CC selected the appropriate project team members was highly dependent on the project manager's personal preferences, where ensuring if the members' capabilities were sufficient was up to the project manager to decide. Further, only project managers have knowledge about members' capabilities, leading to the question if it is sufficient to base the choice of members on the project managers' impression of the members.
The interview responses illustrate that in terms of assigning resources to a project team, the CC operates under what the theory names *hierarchy*, which is based on specialization within the firm, where one uses a known set of internal resources. As a coordination mechanism, the theory suggests that it may be advisable for the project manager to branch out and utilize the two other organizational categories, *market or network*, where the resources determined to be necessary can be accessed on a wider scale. If the project manager chose to use market as a coordination mechanism he would seek necessary resources outside the firm, typically represented by consulting companies.

On the contrary, the project manager could employ network as a coordination mechanism, where he would use resources already available in the construction project, such as employees in an involved subcontractor to fill the necessary functions in the team. However, as bringing in resources from outside the firm will come with other constraints not covered by the theory study in this thesis (confidentiality, opportunistic behavior etc.) we will not argue for these types of solutions that involve seeking resources outside the firm as the consequences cannot be accounted for in this thesis. As the CC is a company consisting of several construction departments the project manager, by using the internal network, could search for necessary resources from other departments. The case interviewees argued that project teams require both general and specialized skills. Using an internal network as coordination mechanisms will be a good way to cope with the issue of limited capacity. This is due to how the project manager would be able to search for resources on a wider scale, beyond the resources/people he may know about. In addition this will give a firmer structure to the process of assigning resources to the project management team, where the decisions in a lesser degree will be based on tacit knowledge.

Internal networks as coordination mechanisms may be a way to avoid the need for prioritizing, thus this could positively affect productivity and more projects and teams would have a higher potential rate of success.

Further, the case interviewees indicated that it is essential for the project manager to have information about potential team members' capabilities. Using an ICT system, where employees' capabilities and preferences are available for the project manager could be a mechanism to handle the *task uses a resource* dependency when assigning members to a
project team. Although the ICT system would not eliminate the dependency, it could make it drastically easier for the project manager to identify skills and thereby allocate appropriate resources to the team.

5.4.1.2 Structure of the Project Management Team

As stated in the theory, dependencies within the structure of the project management team occur in the information flow between the various functions and how some functions rely on others to approve, and consequently perform their tasks.

The interviewees argued that ensuring sufficient sharing of information between team members can be complex. As exemplified by one of the interviewees (Department Director, CC), a common problem is to manage the information flow, where information may sometimes skip some levels, leaving certain members of the team unaware of decisions that have been made or situations that have occurred. It was further argued that it is challenging to ensure that responsibility is defined and clarified within the project team, which is also related to information transfer.

According to the interviewees, limited time makes the process even more complex and they argued that the preconstruction phase and the planning process is challenging because there is a lot of work to be done in a short period of time. The amount of work implies that there is a substantial amount of information that needs to be transferred between the different team members. However, as the transfer of information needs to happen in a short period of time, this stresses the importance of sufficient information flow between all members.

5.4.1.2.1 Coordination Mechanisms

According to the interviewees, midlevel managers often make decisions and the information concerning the decision is thereby communicated to whomever they find it relevant to share it with. Consequently other midlevel managers do not get hold of information concerning the decision made. This is a critical coordination issue because managers in the project team require all necessary information available to make the best decisions throughout the project.
A more rigid structure would require all managers in the hierarchy to continuously communicate information to their closest supervisor or subordinate, where all levels in the hierarchy would be involved and updated on relevant information.

To ensure that information is sufficiently shared amongst members in the project teams the team has continuous meetings. Reports are shared within the team, and the members have daily conversations regarding the project and the issues they come across. According to one interviewee "the project manager is obligated to assure that members are updated on necessary information throughout the project" (Project Manager, CC).

One interviewee pointed out that large amounts of information were stored in several different computer systems at various locations, which sometimes made it complicated to acquire and utilize information efficiently.

5.4.1.2.2 Addressing Dependencies

Leaning on the theory, the main dependency that will have to be considered when looking at the way in which the project management team functions internally is the shared resources dependency. Information is defined by the theory as a shareable resource, and all team members are dependent on the same resource, namely the information.

The interviewees argued that the management tends to only share vital information with other members they find relevant to share it with. Decisions made by one manager can be an important input to what decisions other managers make, which indicates that there is a shared resource dependency within the project team.

The interviewees also mentioned difficulties in regards to practically making the necessary information accessible, where the use of several computer systems was discussed. These issues are related to the flow dependency in the theory study, where the sub-dependency of information accessibility is what causes the dependency. Because of this dependency, information cannot always be accessed when needed. Arguably this creates considerable constraints if important decisions have to be made.
5.4.1.2.3 Comparative Analysis of Coordination Mechanisms

Through the interviews it became clear that the CC attempts to overcome the issue of transferring information by continuously having meetings within the project team. Further it was argued that the project manager was obligated to ensure that the members are updated on necessary information.

However, as transferring information still was recognized as an issue there might be a need for additional coordination mechanisms.

According to the theory study one way to overcome this issue could be to implement a system that notifies the members of the project management team when modifications have been made to the information/resource. Thereby the managers would be in possession of all information necessary and make decisions based on a more adequate basis. This can be a method to limit the shared resource dependency within the project team.

Further, the theory argues that due to the fact that information has to be accessible there is a flow dependency. The sub-dependency of accessibility (under flow dependency) essentially entails moving the resource (i.e. information) from where it is produced to where it is consumed. To manage this dependency in this context it is argued that using an ICT system can be a mechanism to ensure that information is actually communicated between the project team members.

5.4.2 Handling Changes to the Project Schedule

The project schedule is the most important tool the CC’s project management uses to control activities and resources in a construction process. The interviewees identified two main issues related to managing a project schedule, namely managing rescheduling and ensuring that schedules are in fact being followed.

The two main issues mentioned by the case interviewees do not fully correspond with the two causal mechanisms we have identified in the theory study. The issue of ensuring that schedules are in fact being followed is not addressed in the theory, as we considered following a schedule is a prerequisite for a schedule to have any purpose. However, the interviewees argued that managing changes to a schedule is a critical task of the project
management team. This is based on how the CC has experienced situations where the schedule has not been handled appropriately so efficiency has been reduced due to subcontractors being present at the construction site, not being able to perform their tasks as originally scheduled.

5.4.2.1 Project Management Team’s Ability to Process Change Orders

According to the interviewees changes to a schedule can be necessary for several reasons, such as changes requested by clients or natural limitations.

One of the interviewees (Project Engineer, CC) exemplified a situation where the schedule needed to be changed due to natural limitations, where they were drilling tunnels and came across increasingly solid types of rock. Because they calculated risks of potential pitfalls during the planning phase, the problem that occurred was not surprising. However, the situation was in fact caused by uncontrollable factors, which implies that changes to schedules can happen regardless to how carefully one strives to plan a process.

The interviewees further mentioned that people solving problems on their own terms during an activity could cause a need for change to a schedule. Thus when people come across issues, they solve the problem as efficiently as possible without reporting it. As one of the interviewees stated: "One can solve a problem today, but the change can affect implementation of the overall process" (Department Director, CC).

There was a consensus among the interviewees that engaging competent/qualified people to manage the change process was important. Being flexible and able to adapt to change appear essential for managers in construction projects, where dynamic processes requires dynamic people.

5.4.2.1.1 Coordination Mechanisms

In regards to ensuring that the appropriate people are responsible for handling change the CC has a certain focus on hierarchy. This implies that members with certain skills and responsibilities are involved in change processes that specifically relate to their field, which appears to be a method the CC uses to ensure that appropriate people are indeed engaged in the rescheduling.
The management team also has continuous meetings regarding progress during the change process, and the project manager is obligated to follow up and ensure a sufficient change process.

According to the interviewees the change process depends on the nature of the required change, for example how comprehensive it is. However the members making decisions during the process is obligated to follow the CC's defined procedures for change.

5.4.2.1.2 Addressing Dependencies

It is argued in the theory study that when a change order requires rescheduling, the project management team will be in a situation where it will face both aspects of the task-resource dependency, namely *task uses a resource* dependency and *task produces a resource* dependency.

The task uses a resource dependency manifest itself by the team having to identify the appropriate resources to handle the rescheduling. The theory argues that this dependency requires management to go through the following steps: clarify the nature of the change, identify available resource to handle the change, choose the appropriate resource and assign the rescheduling to the resource. It was not defined through the interviews whether project managers go through similar steps when assigning team members to handle change. However, when analyzing the interviewees' explanation of the rescheduling process, it appears, as the CC's management should address the task uses a resource dependency, because the success of the rescheduling is dependent on the resources/members responsible for performing it.

5.4.2.1.3 Comparative Analysis of Coordination Mechanisms

Leaning on the theory framework there are several potential coordination mechanisms to address the *task uses a resource* dependency, where the task at hand is to reschedule and the resource is the team members. The theory suggests that the mechanism in this context consists of the following four elements:

1) Resource chosen based on specialization in the team
2) Resource chosen based on known set of resources in the team

3) Resource chosen based on resource's workload and finally

4) Resource chosen based on employment relations

When selecting which team members to manage rescheduling it appears as the CC comprehends all the elements above, with a main focus on specialization within the team. Thus they ensure that the members managing the change have sufficient knowledge about the tasks and resources involved in the process by having clear definitions of work responsibility.

The task produces a resource dependency addresses the issue from a somewhat different perspective, where the task at hand is to reschedule and the resource produced is the revised schedule. The theory argues that the task of rescheduling can be divided into subtasks, so actors can perform smaller tasks according to their specialization. After dividing the task of rescheduling into subtasks it is important to enforce GDM to gain a higher perceived task interdependence, which will enhance the quality of the new schedule.

5.4.2.2 Change Orders Caused by Other Parties

An essential issue identified in the case was inadequate job descriptions from design consultants. Due to the nature of the CC's strategy, they start to engage in the construction phase after the design has been completed. This means that the client, who has requested the construction work, hires external consultants to conduct the design activities. After the design has been completed, the specifications (drawings, technical specifications etc.) are transferred from the design consultant to the CC. The interviewees argued that this is often a challenge because it complicates the process of ensuring quality of the designer's work, and insufficient specifications can result in rescheduling.

We identified the following two main causes for rescheduling by other parties, in relation to the problem mentioned above by the interviewees.

1. A design consultant, which is not engaged in the physical construction process and not familiar with work procedures, may not be capable of making job descriptions
applicable to the construction personnel. The specifications may be too academic and not descriptive enough for a subcontractor to comprehend.

2. A subcontractor, mainly focused on doing physical work on the construction site, may not be capable of converting information from the specifications into physical tasks. As stated by one of the interviewees, "to ensure that the subcontractor has in fact understood his tasks is a challenge itself" (Project Manager, CC). This implies that the need for change orders can be outside the CC’s control, but still has to be managed/handled by the CC.

Although the CC may not be responsible for the quality of the design consultant's work, the design consultant is an important party within the construction project network, and lack of quality can result in the need for changes in the schedule, which further affects the CC's work. One interviewee argued that if the job descriptions are not sufficient a subcontractor may have to improvise on the construction site, making his own decision based on intuition and possibly request changes to the schedule (Project Engineer, CC).

5.4.2.2.1 Coordination Mechanisms

The CC handles these issues by setting certain requirements to the quality of the design consultants' work. The CC also strives to have a close relationship to all external parties, to increase the synergy between the parties and to avoid changes in the schedule. The interviewees argued that, if possible it is essential to avoid situations that lead to rescheduling. Continuous dialog about risk and progress with the client was considered important.

The interviewees also stressed the importance of having "slack" in the schedule as a proactive method to allow time for a change process. The interviewees argued that they put in "slack" in the schedule to reduce the effects rescheduling could have on critical phases of the construction project. Thus, if the client wanted to change certain parts of the project the "slack" would give management and involved actors time to adjust.
5.4.2.2 Addressing Dependencies

According to theory, the CC through the project management team will be directly dependent on the resources provided by the design consultants and client in order to perform the task of creating a well functioning project schedule.

As we identified in the case, inadequate work from design consultants can result in other parties not being able to do their job. The theory study argues that there is a flow dependency between the design consultants and the CC, where the sub-dependency of usability is essential. Thus to avoid rescheduling the CC depends on the documents made by the design consultants being applicable for the subcontractors using them.

5.4.2.3 Comparative Analysis of Coordination Mechanisms

It is argued in the theory that changes in a construction process will inevitably occur, either for controllable or uncontrollable reasons. Therefore, using "slack" seems as a rational proactive method to acknowledge that there will be changes to the schedule, and a reasonable mechanism to moderate the consequences of a change process.

However, using "slack" may not be necessary in the context of ensuring usability of documents transferred from design consultants to subcontractors. Evidently "slack" increases the time duration of a schedule, thus using "slack" in the schedule is not preferable in terms of process efficiency in this context.

In the theory study we argue that there should be a system in place to facilitate mutual information exchange between the design consultants, general contractor and subcontractors. This will enable the consumers (general contractor and subcontractor) to communicate their needs to the producer (design consultants), and also be able to do quality control of the design documents and specifications before they are handed over.
5.4.3 Managing Subcontractors

In our theory study we addressed the challenge of managing subcontractors as the main challenge in the construction phase when seen from the general contractor’s point of view.

It is argued in the theory study that coordination of subcontractors is especially important in order to maintain the flow of the project schedule where lack of knowledge by the subcontractor or misunderstandings in the communication between the general contractor and the subcontractors may lead to substantial delays.

The causal mechanisms as presented in the theory study are:

- Tasks that require specialized knowledge
- Several knowledge bases required to obtain a common goal
- The general contractor as a resource to subcontractors
- Spatial limitations
- Ensuring quality of subcontractor’s work

5.4.3.1 Tasks that Require Specialized Knowledge

According to the interviews with members of the CC, it is not unusual that situations occur where there is a lack of knowledge among subcontractors (when analyzing this statement it became clear that certain subcontractors sometimes are too ambitious when bidding for a contract).

In the outset of a construction project it is arguably the general contractor’s responsibility to ensure that the required specialized knowledge is indeed accounted for through making sure to contract all the specialized subcontractors required. However, as we presented the CC with this argument, it was claimed by the CC that it could sometimes be nearly impossible to do so if a situation occurs that is out of the ordinary. Such a situation was exemplified by how excavating a tunnel can sometimes result in unforeseen needs for specialized knowledge, as it can be difficult to predict what sort of stone/material that may be encountered.
This verifies that this is something that does cause complications when managing subcontractors. Further it was argued by the interviewees that when the need for specialized knowledge to perform a task have been overlooked, this leads to a situation where the job description of certain subcontractors/resources may have to be changed. This can generally be regarded as allocation of resources so that the need for covering a task that requires specialized knowledge at some point at the construction site may be covered by adding it to a subcontractor in possession of that required knowledge.

It was made clear by the CC that they do not regard this as a coordination mechanisms as it is only a quick response to covering a specific task, which in turn leads to the real problem of changing the subcontractor’s job description. These problems are related to how changing a job description will lead to process inefficiencies of the construction project. It was also pointed out that instead of engaging the general contractor in the matter, some subcontractors would rather resort to making decisions on their own and try to perform the task even though they may not possess the required specialized knowledge. This can arguably be traced back to how the subcontractor may perceive the changing of job descriptions as too tedious and instead decide on performing the task to best of their capabilities.

5.4.3.1.1 Coordination Mechanisms

The CC sometimes will choose to change job descriptions of the subcontractors in order to save time when an unforeseen task that requires specialized knowledge occurs. This is argued (as long as the situation allows it) for as saving time compared to contracting a completely new subcontractor if there already are subcontractors working on the construction project that may be able to perform the task.

However, as changing job descriptions is only possible to a certain extend, and ultimately will result in other further dependencies as it creates process inefficiencies for other tasks, it is not regarded as the main coordination mechanism by the CC.

When setting up the critical path in the project schedule, the CC applies “slack” to the schedule so that it will be possible to account for problems the subcontractors may run into during the construction phase. As this is the preplanned approach to such situations by the
CC, we will argue that this is the true coordination mechanism applied by the CC in solving problems revolving around tasks that require specialized knowledge.

5.4.3.1.2 Addressing Dependencies

The dependency for this particular causal mechanism uncovered in the theory study is the flow dependency with the “prerequisite” sub-dependency. When an unforeseen need for a specialized resource to perform a task occurs, as explained in the example brought up by the interviewees, the flow dependency is still valid.

The validity of the flow dependency with the “prerequisite” sub-dependency can be argued for by how an unforeseen need to perform a task requiring a specialized resource seems to interfere with the flow of tasks being performed as the immediate solution considered is changing job descriptions.

Next, this task becomes a prerequisite for the continuation/performance of other tasks that depend on the task requiring the specialized knowledge being performed. This can be both directly but also indirectly if a certain subcontractor must temporarily leave one task to perform the task requiring his specialized knowledge.

We argue that the coordination mechanism as proposed by the CC does not properly address the flow dependency and the “prerequisite” sub-dependency. As already argued, changing job descriptions among already contracted subcontractors will most likely cause further process inefficiency and create more dependencies elsewhere. This can create a highly volatile situation that can be very difficult to manage.

For the “main” coordination mechanism of implementing “slack” in the project schedule, this will not directly deal with the problem, as it will only allow time to deal with it. However, for unforeseen situations where a task that requires specialized resources occur this can still prove a good coordination mechanism in itself as long as there is certain guidelines as to how to utilize this “slack” in order to actually solve the problem.
5.4.3.1.3 Comparative Analysis of Coordination Mechanisms

When comparing the suggestions for coordination mechanisms for this causal mechanism in the theory study versus the empirical study there is one fundamental difference that sets the two apart. The theory study focuses on making sure that the tasks that require specialized resources are performed in a manner so that they indeed become the correct input for the following general tasks. In the empirical study the interviewees of the CC have focused on how such situations can be dealt with when they occur as unforeseen problems.

Because of this it is difficult to provide a proper comparative analysis of the coordination mechanisms. However, when implementing the coordination mechanism of the CC to this causal mechanism (implementing “slack” in the project schedule) it is possible to elaborate on this coordination mechanism by the CC, by using the findings of the coordination mechanism in the theory study.

When applying the findings of the theory study there should be a system in place that enables quality control to ensure that the task performed by the specialized resource will be the correct input for the following tasks.

In sum this means that there should be allowed a certain “slack” in the project schedule to encompass unforeseen situations where an unplanned need for a specialized resource occurs. Next, there should also be a quality control system in place that enables, among others, the general contractor and the subcontractors depending on the task being performed to ensure that it is being performed to their needs. By combining elements from the coordination mechanisms in both theory and empiric, it will be given time to handle unforeseen needs for specialized knowledge and the time given will not be prolonged by the task not being performed to a satisfactory level.

However, besides allowing time to handle these types of problems and ensuring no further delays by ensuring the quality of the task, this does not in itself address how such a problem should be solved.
5.4.3.2 Several Knowledge Bases Required to Obtain a Goal

According to the theory study the knowledge bases in a construction project exist on three levels, namely within the organizations (e.g. subcontractors) involved, the project management knowledge base (general contractor) and the project specific knowledge base (knowledge specific to the project acquired over the project life cycle).

In the empirical study this is confirmed by the CC in how they state it is difficult to know exactly what the subcontractor’s capabilities are. It is also mentioned by the interviewees how it is complex to ensure sufficient communication between all parties and thereby problematic to be certain that all parties know what to do.

These arguments given by the interviewees indicate that there is a certain disconnect between the three levels of knowledge base.

5.4.3.2.1 Coordination Mechanisms

As presented above the causal mechanism of “several knowledge bases required obtaining a common goal” relates to two main problems according to the CC, these know the capabilities of the subcontractor and making certain all parties know what to do.

In response to how these problems are addressed the interviewees stated that the first problem of knowing the capabilities of the subcontractor is solved by ensuring capabilities based on past experience of working with the subcontractor, subcontractor’s CV and references. Further, it is argued that trust between the subcontractor and the general contractor is also emphasized as well as close follow up by the CC.

Next, for the problem of making certain all parties know what to do, sufficient planning is mentioned as the main coordination mechanism. This means that the quality of the project schedule in itself will be the coordination mechanisms. Further it is mentioned that there exist an information system, but according to one of the interviewees this is mainly “outdated information systems, where reports and transcripts are stored on several separate systems” (Department Director, CC).
To recap the coordination mechanisms employed by the CC address two problems, these are:

- Knowing the capabilities of the subcontractor
- Making certain all parties know what to do.

These problems are addressed by the following coordination mechanisms, ensuring capabilities based on experience, CV and references and trust. For the second problem the following coordination mechanisms are mentioned, ("outdated") information systems and sufficient planning.

5.4.3.2.2 Addressing Dependencies

This causal mechanism has been determined to have two dependencies in the theory study; these are task uses a resource dependency and flow dependency as a result of dependencies among multiple resources. These dependencies represent the constraints of managing resources across the whole specter of the three levels of knowledgebase presented in the theory study.

When looking at the responses given by the interviewees it is clear that they also consider the dependencies to represent constraints across the same levels as in theory study. This is because the CC as the representative of the 2nd level (the project management knowledgebase) experience constraints in managing the tasks of the subcontractor in the 1st level (The organization/company/subcontractor knowledgebase), where also the 3rd level (the project-specific knowledgebase) is addressed through constraints in making certain all parties know what to do.

Arguably the coordination mechanisms of the CC do address these dependencies. However, it can also be argued that this sufficient planning is something that will always be strived for and that trust between the CC and the subcontractor is too intangible to represent an actual coordination mechanism.

Ensuring capabilities of the subcontractor through experience, CV and references can be a good method, but is at the same time a potentially tedious process. This coordination mechanism will potentially not suffice, if for example a situation requires the general
contractor immediate/or further insight in this knowledgebase during the construction process.

In sum it can be argued that the coordination mechanisms of the CC does to a certain degree address the dependencies in this causal mechanism, but that one may raise questions as to how effective they may be.

5.4.3.2.3 Comparative Analysis of Coordination Mechanisms

As already established, the coordination mechanism in use by the CC today may not be sufficient to be able to deal with the dependencies as efficiently as possible. This is partially due to how some of the coordination mechanisms are somewhat intangible and that they can also, in certain circumstances, take too long to execute.

For addressing the task uses a resource dependency, the theory study suggests an ICT based database where information about subcontractors’ specialties and competences as well as the tasks they are assigned to perform is readily available. Such an ICT database/system could enable both a “network” category based on the fields of specialization among the subcontractors, as well as a “market” category if the CC needs to make a quick decision among multiple potential resources (a “market” category would enable the CC to receive bids from the subcontractors already involved at the construction site).

For the flow dependency it is recommended that the consumer is involved in ensuring the right output of the task. This could be incorporated in the same ICT system where other subcontractors could get a clearer view of what is going on in the various activities being performed that may later be a resource to them.

5.4.3.3 General Contractor as a Resources to Subcontractors

In the theory study the casual mechanism of the general contractor functioning as a resource to the subcontractor, is presented in the following way. The general contractor must consider himself as a resource when managing subcontractors as he; sets the “state of the world” the subcontractors operate under, the subcontractor’s work being reliant on how it is organized in the project schedule by the general contractor and how the subcontractor will rely on the general contractor for information as a resource to perform tasks.
According to our findings in the interviews and observations of the CC, they have a more “direct” view on how the general contractor works as a resource to the subcontractors. What we mean about this “direct” view is how the CC focuses on how this causal mechanism practically plays out during the construction phase. The interviewees have focused on four main points of where the general contractor becomes an important resource to the subcontractor, these are: it is complicated to clarify responsibilities between general contractor and subcontractor, the subcontractor may not have the capacity expected by the general contractor, communication between the two parties is time consuming –especially during change orders and finally, ensuring that subcontractors have understood their tasks.

These responses by the CC do fit with how the subcontractor will rely on the general contractor in terms how and when to perform the tasks. By adding the responses of the CC to what has been already stated in the theory study, this elaborate on how the dependencies between the general contractor (as a resource) and subcontractor manifest itself in more practical scenarios.

5.4.3.3.1 Coordination Mechanisms

For addressing the coordination problem of complications in clarifying the responsibilities between the general contractor and the subcontractor, and when the subcontractors are not able to exercise the capacity expected by the general contractor, the CC has a particular coordination mechanism in place. This coordination mechanism is having a person in the project management team with the specific responsibility of monitoring the subcontractor’s work. If the subcontractor’s does not satisfy the agreed terms, the subcontractor will get fined as per defined in the contract.

When facing the problems of communication between general contractor and the subcontractor, which is especially important during change orders, we could not uncover any specific coordination mechanisms. However, we expect that the person that has the responsibility of monitoring subcontractor’s work also will be important for the communication between the two parties.
To ensure that the subcontractors have understood their tasks there will be put emphasis on the quality of the job description. Further the coordination mechanisms if implementing “slack” in the project schedule will allow time to deal with problems.

5.4.3.3.2 Addressing Dependencies

The dependency argued for in the theory study for this causal mechanism is flow dependency including all three sub-dependencies. This because of how the general contractor is the main source of information that the subcontractor will rely on in order to perform his tasks.

Even though this causal mechanism in the case of the CC has a more mutual relationship of the dependencies between the CC and the subcontractor it is still a flow dependency despite it not being as rigidly top-down as presented in the theory study (note: for example a more mutual relationship due to the capacities of the subcontractor, which in turn could be regarded as resource to the general contractor for performing his task of completing the construction project on time). This is because there is still a clear need for a flow of resources where these are dependent on each other for tasks to be performed.

5.4.3.3.3 Comparative Analysis of Coordination Mechanisms

The coordination mechanism proposed in the theory study is an ICT system that will facilitate the exchange of information through the actors involved in the process and allow insight into tasks that are being performed. This insight can be valuable in ensuring that resources and tasks have a good fit.

When implementing “slack” and emphasizing the quality of the job descriptions as a coordination mechanism, the CC may be able to account for making sure that subcontractors have understood their tasks. However they will note have addressed how the need for communication between the CC and the subcontractor is time consuming, or eliminating unclear responsibilities between CC and subcontractor, as well as making sure the subcontractor has the required capacity.

These problems can arguably be addressed in the coordination mechanism proposed in the theory study, where an ICT system could give the subcontractor the proper insight needed
regarding the required capacities. It would also make the distribution of information between the CC and subcontractor quicker as well as facilitating communication/information exchange between the subcontractors involved in the flow.

5.4.3.4 Spatial Limitations

Spatial limitations are presented in the theory study as a factor that can have substantial effects on the productivity and flow of tasks at the construction site. The spatial resources are divided into three types of spaces: resource space, topology space and process space. These spaces represent potential conflicts between tasks on two accountabilities, the share-ability of one type and the conflicts between the three types.

According to the CC ensuring the subcontractors’ needs on the construction site is important to be better suited to face this causal mechanism. In order to do so it is important to be aware of the priorities and needs of all parties involved.

Further, the interviewees argue that generally low time margins underpin the importance of always maintaining a good flow among the tasks in the construction phase. These low time margins get increasingly difficult to handle depending on the spatial limitations at the given construction site. This has to do with the share-ability of the different types of space as well as how spatial conflicts take time if one task, for example, has to be put on hold because of a space cannot be shared or if two spatial types conflict.

5.4.3.4.1 Coordination Mechanisms

According to the interviewees there are several ways of solving the issues that comes from spatial limitations. When analyzing the responses provided by the interviewees it seems that the CC has both proactive and reactive methods of solving the problems of spatial limitations. We will now present these various methods.

As a proactive response to spatial limitations the CC employs two methods. As mentioned before, the CC argues that knowing the priorities and needs of all parties involved is imperil for the success in coordinating space as a resource.
The first coordination mechanisms mentioned as a proactive method in dealing with spatial limitations is to conduct continuous coordination meetings so that the CC and other parties involved will be able to stay up to speed on needs of upcoming tasks in terms of, for example, space.

The second proactive coordination mechanism is to once again make use of the “slack” in the project schedule so that if an unexpected situation occurs, there should be sufficient time available to deal with the situation, or alternatively, for one task to wait for another.

For the reactive methods, the CC will have a person/function responsible for coordinating the subcontractors. This person will be responsible for coordinating spatial limitations when they occur.

5.4.3.4.2 Addressing Dependencies

With the division of the causal mechanism of spatial limitations into two scenarios where there will either be a conflicting need for resources within one spatial type or there being a conflict between the spatial types themselves, this also leads to two different dependencies (according to the findings in the theory study).

First there will be a flow dependency between the conflicting types of spaces as exemplified in the theory study by the tower crane. This is typical for when one task requires the space to be designated as, for example, a process (hazard) area before it can be re-designated back to a resource space.

Second there is the share-ability of a spatial type when there are two or more tasks that are mutually reliant on the same spatial resource.

In the empirical evidence uncovered through the interviews and observations we argue that the same dependencies are acknowledged in the case of the CC. This is because of how the importance of encompassing all parties’ priorities and needs indicate a share-ability constraint, and how flow is important due to low time margins and that spatial conflicts are experienced as causing tasks to be put on hold.

By the coordination mechanisms used by the CC (continuous coordination meetings, “slack” in the project schedule and a person/function responsible for coordination of
subcontractors) the CC does cover these dependencies. The dependencies are covered by how continuous coordination meetings together with a person/function responsible for coordinating subcontractors can deal with the share-ability dependency that typically may not have been possible to cover during the scheduling of the construction project.

Next, as the emphasis on the aspect of flow by the CC indicates that this is important in order to stay within the low time margins, the flow dependency can be limited and dealt with due to the “slack” in the project schedule. However, this raises another question of when will this “slack” be depleted.

5.4.3.4.3 Comparative Analysis of Coordination Mechanisms

In the theory study under coordination mechanisms for conflicting types of space, it is suggested a system that warns the subcontractors about when a space will change type. This is meant to ensure that tasks do not get put on hold as it can give the subcontractor a chance to perform other tasks in the meantime (if the project schedule have failed to already relocate the subcontractor’s task for the time being). The coordination mechanisms of the CC, (more specifically continuous coordination meetings, the person/function in charge of coordination subcontractors and “slack” in the project schedule) do already address this flow dependency. However, as we throughout this thesis seek to also study the implications of ICTs in the construction project, we will suggest that these coordination mechanisms of the CC can be made more effective through the use of ICTs.

The use of ICTs as indicated in the theory study will make the continuous coordination meetings more effective by enabling the members to also access a real time progress feed in-between meetings. This would also potentially lay the grounds for an even better foresight of issues that may occur, making the coordination mechanism even more proactive than before. Along with this added foresight we argue that the need to use “slack” would be limited, this is important to us as we perceive “slack” to be something that will have an inevitable point of depletion where the progress of the construction project will indeed start to suffer.

These arguments transcends into the dependency of share-ability where a system enabling the spatial resources be marked as “in use” would limit the chances of unexpected conflict
between subcontractors relying on, for example, the same resource space. This could be an extension of the ICT system mentioned above, where spatial resources can be marked as “in use” and for what duration of time.

5.4.3.5 Ensuring Quality of Subcontractor’s Work

The theoretical basis for this causal mechanism revolves around how managing the quality of the work performed by the subcontractors must conform to expectations of the client. This is done through a quality plan that is created for each individual construction project, by the general contractor. It is then the responsibility of the general contractor that the construction project meets the requirements in the quality plan and thereby also the expectations of the client.

By the CC this causal mechanism is explained through how the potential lack of knowledge among the subcontractors can have serious effects to the success of the construction project. This lack of knowledge can be deriving from inadequate capabilities, but also by faulty specifications provided by the design consultants, or in some cases, the subcontractor not being able to understand the specifications. According to the CC, all these aspects are what make it difficult to ensure the quality of the various subcontractors’ work.

5.4.3.5.1 Coordination Mechanisms

The coordination mechanisms employed by the CC can be divided into three mechanisms.

First, the CC will strive to involve the subcontractors as early as possible in order to create a close relationship based on sufficient communication.

Second, there will continuously be performed quality controls were also the quality of the specifications sent in by design consultants will be controlled. The subcontractors will also be proactively involved in these quality controls so that they can monitor each other’s work in order to ensure the correct input-output relation between their tasks.

Third, the “slack” in the project schedule will be a coordination mechanism when failures to comply with the quality plan occur.
5.4.3.5.2 Addressing Dependencies

This causal mechanism was argued for having a task uses a resource dependency with the sub-dependency of identifying necessary resources. The reason for this is how this dependency was identified through the top down point of view of the general contractor (see argumentation for why in the theory study).

Arguably the CC has the same point of view in how they regard the causal mechanism as a situation that requires the CC to make sure that the subcontractors act according to the quality plan so that the expected results can be achieved. This makes the subcontractor a resource to the CC for them to be able to achieve their ultimate goal and fulfill the commitment to the client.

5.4.3.5.3 Comparative Analysis of Coordination Mechanisms

In the theory study it is stated that when first contracting the subcontractors the general contractor should use the marked category when contracting the subcontractors where the quality plan will be implemented in the bid.

However, in order to ensure the quality of the construction project, if the need for changes is to occur after the subcontractors have all been contracted to the construction project, other coordination mechanisms will be necessary. It is argued that the general contractor should employ a coordination mechanism of the network category. This will enable the general contractor to ensure the continued quality of the construction project by identifying the appropriate resource for the various tasks the change has created, within the actors involved in the construction project.

The coordination mechanisms used by the CC seem to cover the continued quality control throughout the construction project in a good way. This is achieved by the early involvement of subcontractors.

As we do find the “slack” in the project schedule as a threat to the efficiency of the construction project, we suggest using the coordination mechanism proposed in the theory study to limit the time lost through the “slack” coordination mechanisms.
This means that to best coordinate the quality of subcontractor’s work, the subcontractors should be involved early. There should also be some “slack” in the schedule available to deal with sudden changes. The changes should be addressed through a database of the specialties of the subcontractors involved in the construction project so that a potential problem can be dealt with quickly while at the same time ensure a continued quality of the work being done.
6 Principal Findings

In this chapter, we will present the coordination mechanisms that we have deemed relevant in terms of coordinating the construction project in the best possible way. The coordination mechanisms summarized here are based on the findings in the “comparative analysis of coordination mechanisms” which are a combination of coordination mechanisms found in the theory study and coordination mechanisms used by the CC. This combination is an attempt to bring out the best of the theory whilst keeping a realistic scope by implementing some of the actual coordination mechanisms used by the CC.

In the following we will list the coordination mechanisms based on phase, challenge and causal mechanism:

6.1 Preconstruction Phase

6.1.1 Project Management Team

Assigning Resources to the Project Management Team

- Branch out and utilize other coordination categories such as “market” and “network” to access resources on a wider scale within the organization or even among other parties involved in the construction project. This will help the CC to cope with limited capacity and possibly avoid the need for prioritizing.
- An ICT system where the capabilities and preferences of the employees are available. This will provide the CC with a tool to readily access all the skills of available resources within the organization.

Structure of the project management team

- The CC conducts continuous coordination meetings to transfer information. This enables more active discussion in a co-present setting that benefits communication.
• When changes in the general information base is done outside of the coordination meetings, an ICT system should notify all parties so that decisions can be made on adequate grounds.
• An ICT system to allow better communication/flow of information between all parties at all time.

6.1.2 Handling Changes to Project Schedule

Project Management Team’s ability to process change orders
• Divide rescheduling into subtasks so that it can be performed according to the specialization of the team members.

Change Orders Caused by Other Parties
• “Slack” in the project schedule acts as a proactive coordination mechanism. This allows time to deal with putting through a change order when the change proposal, often unexpectedly, comes from a party outside the project management team.

• An ICT system where consumers can clearly communicate their needs to the producers would reduce the chances of the “slack” getting depleted to a point where project efficiency could suffer.
6.2 Construction Phase

6.2.1 Managing Subcontractors

Tasks that require specialized knowledge

- An ICT system that can help ensure that the tasks performed by specialists will be the correct input to other subcontractors. This entails a platform for easy communication between subcontractors (and the general contractor).

- Allow “slack” in the project schedule to encompass unforeseen situations where an unplanned need for a specialized resource occurs. This is because locating and assigning a new task may be time consuming.

Several Knowledge bases required obtaining a common goal

- An ICT database where information about subcontractor’s fields of expertise and competences, as well as the tasks they are assigned to perform, is readily available. This will provide the CC with a complete overview of all knowledge bases involved in the construction project.
  - This ICT database should contain a “network” based on fields of specialization.
  - It should also have a “market” function so that the general contractor can put out a bid to easily identify available resources.

- The same ICT system can help ensure the correct output of the tasks performed by the various knowledge bases so that they fit in flow of interdependent tasks that have to be performed.
The general contractor as a resource to subcontractors

- An ICT system that provides the subcontractor information about the task being performed, and the tasks planned by the general contractor to be performed.
  - This system can also give the subcontractor insight into the required capacities to perform tasks, so that he is fully aware of what is expected.
  - A system like this will also in this situation make the transfer of information quicker and more efficient (between general contractor -> subcontractor and subcontractor -> subcontractor)

Spatial Limitations

- An ICT system to warn subcontractors when a space will change “type”, so that tasks do not have to be put on hold.
- Continuous coordination meetings backed up by an ICT system facilitating efficient communication outside of the meetings.
- Real time progress feed by ICT system that provide foresight of potential spatial conflicts. This will reduce the use of “slack time”.
  - Spaces can be marked as “in use”.

Ensuring quality of subcontractors’ work

- Introduce the subcontractors early in the (pre)construction phase.
- Implement “slack” in the project plan to ensure time to deal with situations where the standards in the project quality plan are not met.
- Through an ICT system introduce a “network” category to locate appropriate resources within the project, if a sudden need to perform a task occurs.
Below we will briefly state the three general coordination mechanisms. We call these general coordination mechanisms as each of them can entail several coordination mechanisms (as summarized above).

All mentioning of the ICT systems are meant to be a part of the same ICT system. The ICT system is thought of as a platform where the general contractor and the subcontractors can mutually benefit from an optimized information flow. The ICT system will serve as an addition to the traditional coordination mechanisms found in construction projects (as based on empirical findings through the CC), which will still be the core coordination mechanisms.

**An ICT System/Platform**

The general contractor will use the platform to communicate more directly and gain an instant awareness of the actual events that take place at the construction site. This will improve the capabilities and means to manage the construction project in a more contemporaneous way according to the current conditions at the construction site.

For the subcontractors this platform will make them more directly involved in the construction project, not just as a single unit but also as a member of a unity. This means that the subcontractor will have a more direct way of communicating needs and concerns to the general contractor. The subcontractor will also gain a greater awareness of what other tasks are being performed at the construction site as well as being able to communicate better with other subcontractors.
Continuous Coordination Meetings

The continuous coordination meetings, as being performed by the CC, will still serve as the backbone in the coordination of the tasks performed by the subcontractors. This is because no ICT system can defeat the benefits of co-present interaction that will stimulate discussions that would not be feasible to keep up on a virtual platform. These meetings will however be limited by how they represent a dependency in how all parties should be present.

“Slack” in the Project Schedule

The “slack” in the project schedule will still be an important proactive coordination mechanism, as it will ensure that there is time to deal with various issues when they occur. An ICT system will not be able to prevent these unexpected issues, but could limit the time spent dealing with them. However, the “slack” is not unlimited and will therefore have its natural limitations.
7 Discussion

The theoretical findings show that there are reasonable grounds for the argument that there is potential for improvement in the coordination of construction projects. These arguments are based on the fact that the theory study shows where, why and how there are alternatives to the ways in which the construction projects can be managed.

However, as these findings are solely based on theoretical possibilities, there was a need to put them in an empirical context to further explore the relevance of the proposed alternative approaches to managing the processes in a construction project. These further findings have been established under the principal findings in the previous chapter.

By suggesting the implementation of an ICT system to incorporate the coordination mechanisms proposed through the theory study and the empirical analysis, this raises another question, is this implementation feasible?

Arguably, the adaptation to a new ICT system by a general contractor, as proposed in this thesis, will come with certain constraints. Acquiring and running an ICT system for the purpose of improving coordination in a construction project will require a substantial amount of capital, manpower and knowledge, knowledge that most general contractors may typically not possess. Acquiring such a system will also require a change in the mindset towards innovation that is outside of what most general contractors may perceive as their core competence.

At the same time we see through this thesis that a revised approach to coordination could be needed within the construction industry as this industry, has been stagnating in productivity. In most industries today, acquiring IT competences from outside the company is getting increasingly common. This has created a brand new market for companies within the IT sector, where several of these types of companies now run virtual computer clouds for various clients.
This development could provide the opportunity needed for an ICT solution, like the ones mentioned in this thesis, to become reality. This could be put into reality by creating a cloud where everything is run by a third party, including the storage of hardware and software. As a result, this could become a realistic option to today's typically co-presence intensive management systems in the construction industry.

Besides focusing on performing the coordination mechanisms proposed in this thesis through an ICT system, we still believe this thesis adds value even if an ICT system were not to be used. By analyzing the processes in the preconstruction and the construction phase through the theoretical framework, we believe this provides a nuanced perspective to where and why the need for, and a focus on, coordination is important in the construction industry. It is also important to state that although there is a focus on executing the various coordination mechanisms through an ICT system, such a system is not a must for addressing the dependencies that create the need for coordination. As the coordination theory by Crowston and Malone (1994) is meant as a tool for process reconfiguration, it can be argued that this thesis provides the reader with both an insight into where the grounds for such a reconfiguration can be found (causal mechanisms, dependencies), as well as a proposal for actual reconfiguration (causal mechanisms).

This thesis does coincide with other studies in regards to the fact that there is general belief that there is a need for better coordination of the processes in a construction project (Thomassen, 2003). However, the coordination theory and subsequently the framework used in this thesis, have previously not been used in reconfiguring coordination in a construction project. To our knowledge this theory has mostly been applied to reconfiguring coordination in IT businesses (Crowston, 1997).

By using one of the largest general contractors in Norway for the empirical analysis, we hope the findings in this thesis can be generalized in terms of their applicability among other larger general contractors. We therefore view the external validity, through analytical generalization, as adequate.

However, the quality of the findings is arguably the factor that is most important when considering the applicability of this study. The quality of this thesis mainly relies on two
things, how the theory has been used and the success in uncovering the true situation of the case company.

As a concrete theoretical framework has been used in the theory study, the findings here should be applicable if someone else were to perform a similar theoretical study involving the same causal mechanisms. As our chain of evidence further documents important decisions and steps throughout the thesis, the reliability should be sufficient.

However, for the empirical analysis the findings are more dependent on our success in uncovering how the case company experiences the challenge of coordination in a construction project. Besides the interviews, we found the collection of empirical data as challenging because it was not common for the CC to document experience reports regarding coordination of construction projects, which would be an essential empirical source for this thesis. The lack of documentation and archival records has certainly affected the construct validity of this thesis. However we regard the construct validity as adequate as we recognized the limitations through the methodology and therefore made sure to compare and crosscheck the different interviewees` replies. Further we have triangulated the interview responses with the accessible secondary data.
8 Conclusion

This thesis consists of an analysis of the causes for why, where and when the need for coordination in a generic construction project occurs, and how this coordination can be performed in an optimized manner.

Through a theoretical and empirical study we have identified various coordination mechanisms that we suggest be enforced through the implementation of ICT systems.

This has been done with the goal of proposing an alternative way of managing coordination constraints in the construction industry and to possibly obtain a higher rate of productivity.

We will now proceed by answering the research question and the empirical question.

8.1 Research Question

What determines the coordination constraints in a construction project, and how can they be limited?

Coordination constraints in construction projects derive from the fact that there are always several parties involved that are all important for the completion of the project. This situation causes dependencies between these parties and the tasks that they are performing. These dependencies also occur between actors within various parties or teams.

When breaking down the various processes to the level where the dependencies can be found, these dependencies can be limited or possibly eliminated through coordination mechanisms.

In this thesis, the findings indicate that there are dependencies that are possible to generalize between theory and the empiric reality. These dependencies have been located in the relationships between various resources and tasks. The dependencies between resources and tasks occur within the project management team and between the general
contractor and the subcontractors performing the tasks on the construction site (based on the general contractor’s point of view). It is evident that these constraints deriving from the dependencies generate the need for a managerial process that has the potential to limit them.

Certain coordination mechanisms identified in the theory have been argued for having the potential of limiting dependencies, and thereby the coordination constraints in a generic construction process.

8.2 Empirical Question

What are the appropriate coordination mechanisms for a construction project, and what are the implications of using ICTs as a coordination tool?

The appropriate coordination mechanisms as uncovered in this thesis, have been grouped in three main categories. Each of these categories contains several coordination mechanisms as presented in the thesis.

The three categories are:

- An ICT System/Platform
- Continuous Coordination Meetings
- “Slack” in the Project Schedule

It is argued that an ICT system will enforce the coordination mechanisms identified in this thesis, however employing such an ICT system will most likely have to be performed by a third party that could potentially run the system through a “cloud”.

In sum, the findings in this thesis conclude that there is a potential for limiting coordination constraints in the construction process beyond what the case company is exercising today. However, to utilize this potential to the full, general contractors will have to be willing to
explore new methods and strategies, which should include the transition to using ICT based systems to enhance the coordination mechanisms.

9 Future Research

As this thesis have only included the preconstruction phase and the construction phase due to scope constraints, it would have been interesting to have conducted this study across the whole specter of a construction project. This would also increase the validity of this study as other future research would most likely depend on an as complete as possible basis.

Further, the way in which the empirical research had to be done in this thesis has probably not provided a one hundred percent complete impression of the case company. In a future study this could have been revisited, where a wider timeframe could have helped in gaining an even deeper understanding of the coordination constraints experienced by the case company. Coupled with a wider understanding of the theoretical understanding of coordination constraints in the construction industry, this should have represented a solid basis of determining the even further implications of this study.

As one of the factors that that inspired us to write this thesis was the low productivity within the construction industry, it would be rational to investigate what the exact implications coordination have on productivity. By elaborating on this current study like presented above, there should be relevant information in place to base an investigation of the relationship between improved coordination and productivity.
**Terms and Abbreviations**

In the following we present the terms and abbreviations according to the order in which they appear in the thesis.

**SINTEF** – Stiftelsen for Industriell og Teknisk Forskning.

**NTNU** – Norges Tekniske-Naturvitenskapelige Universitet.

**ICT** – Informations and Communications Technology.

**Coordination Tool** – A coordination tool is an instrument for employing the coordination mechanisms.

**General Contractor** – The general contractor is the lead contractor in the construction project and is directly responsible for all the process and tasks that are to be performed in order for the construction project to achieve the expected goals.

**Actors/Parties** – this term is used as a general-collective term to describe subcontractors and other functions involved in the construction project.

**Coordination Constraints** – This is essentially the same as coordination challenges, describing how dependencies impedes the execution and performance of tasks.

**Construction Management** – The task of managing all subcontractors and process involving the construction project.

**Subcontractor** – A subcontractor is a contractor hired by the general contractor through a bidding process. The subcontractor will be hired to conduct various tasks within its specialization.

**Client** – The client is the owner of the project and is paying for the construction to be performed. Once the construction is completed the, for example, building will be officially handed over to the client.

**Active Life-Cycle** – This is the part of the construction project where the construction schedule is being executed, practically this means that construction has started.
**Change Proposal** – A change proposal can be issued by e.g. a subcontractor when a need for change to the schedule or specifications is discovered.

**Change Order** – A change order is issued by the general contractor, making a change official.

**Other Parties** – This term is used to refer to parties that are not addressed in particular in this thesis. These actors can be design consultants, municipal planning and zoning authorities etc.

**Inventory System** – This is a system used in supply chain management, where the production of a resource/product is (automatically) ordered when the consumer’s inventory reaches a certain point.

**The CC** – This is an abbreviation of “the case company”.

**Job Description** – Job descriptions are often issues by the civil engineers along with the technical specifications. This state of a particular job is to be executed.

**Cloud** – A cloud is a virtual computer resource that can be accesses from anywhere through the internet. These are often operated by third parties that are experts on running such systems.
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Appendix

Appendix 1

Friedrich A. von Hayek

Friedrich A. von Hayek, similarly to Smith, asked himself the question “how does order emerge unintended from the actions of millions of economic actors?” Starting with his first essay in 1928, Hayek was to establish *coordination* as a central problem of economics. Hayek addressed the division of labor by pointing out that alongside the division of labor goes the *division of knowledge*, which raises the problem of “...how the spontaneous interaction of a number of people, each possessing only bits of knowledge, brings about a state of affairs in which prices correspond to costs, etc., and which could be brought about by deliberate direction only by somebody who possessed the combined knowledge of all those individuals” (Boettke, Coyne, & Leeson, 2008).

In this quote Hayek points out that if all actions involved in a process are to result in a common goal, there needs to be an overall common plan that every individual responsible for each action will have to follow. To make such an overall plan, the combined knowledge of all individuals involved is required.

However, this knowledge will not be available at the start of the process due to the division of knowledge. Because of changes that will occur during the process, actors will deviate from the overall plan, loosing coherence of the actions and no longer be able to reach a common goal. In order to obtain a coherence of actions in a situation with occurring changes, and without correct foresight, there is a need for an inter-compatibility of individual plans to coordinate the dispersed knowledge (Thomassen, 2003).

Hayek gives the following example of inter-compatibility of individual plans: “Consider the preparations which will be going on at any moment for the production of houses. Brick makers, plumbers and others will all be producing materials which in each case will correspond to a certain quantity of houses for which just this quantity of the particular material will be required. If all these activities represent preparations for the production
(and acquisition) of the same amount of houses we can say that there is equilibrium between them in the sense that all the people engaged in them may find that they can carry out their plans” (Thomassen, 2003).

**Ronald Coase**

Around the same time as when Hayek publishes his works on the division of knowledge, Ronald Coase publishes “The Nature of the Firm” (1937). In this article Coase indirectly describes where coordination takes place, namely in the firm or on the market. Coase describes the firms and markets as the two basic ways by which coordination can take place, outside the firm (market) coordination of the production is decided by price movements, whereas inside the firm coordination is done by, for example, the production manager (Thomassen, 2003). Later Coase’s ideas on the firm and the market being the principles in which coordination can take place, was brought further by Oliver E. Williamson in “Markets and Hierarchies” (1975).

**George B. Richardson**

“The Organisation of Industry” (1972) by George B. Richardson introduces more nuances to the information-based organization of coordination. Richardson argued that if different capabilities are involved in production of specific products, such as in a construction process, interfirm coordination of a more far reaching character than market transactions arises.

Similar to Coase, Richardson does acknowledge markets and firms as two important means for coordination. He also defines the market as opposed to the firm, just like Coase. However, the nuances that Richardson introduces are related to the timeline of the process. Where Coase’s view entails a “here and now” point of view, Richardson states that “future obligations do not necessarily equal a firm, since future obligations can also be established between firms” (Richardson, The Organization of Industry Revisited, 2003). Richardson calls this kind of interfirm coordination cooperation. Cooperation differs from Coase’s “markets” because it revolves around a future conduct (between firms).

The reason for the need for cooperation derives from how planned coordination within a firm will encounter, according to Richardson (2003), certain difficulties related to *capabilities*. In his (1972) article in the Economic Journal, Richardson first introduces the
term capabilities to explain how well the firm is suited to perform and coordinate its activities, and most importantly, whether these activities can be coordinated within the firm itself. The activities are divided into two categories, *complementary* and *similar*.

Richardson refers to activities as being complementary when they are required for the production of a particular product, and as similar when the activity require a firm with the appropriate capability in order to result in a successful product.

For a firm to have the appropriate capability entails certain organization, knowledge, skills reputation and market connections –required for undertaking the activity (Richardson, The Organization of Industry Re-visited, 2003). Because of this a firm will find it challenging to coordinate activities where its capabilities are unsuited, and will therefore have to seek cooperation with other firms in order to secure the proper coordination of the activities leading to the end product.

*James D. Thompson*

In Thompson’s “Organizations in Action” from (1967) he brings up the aspect of interdependence, according to him different types of interdependence is what creates the need for several modes of coordinating actions with different dependencies. The coordination modes presented by Thompson are:

- **Pooled interdependence**: Activities that belong to the same system, but are not directly interdependent.

- **Sequential interdependence**: A direct, non-systematical relation between activities. This means that action A has to be carried out before action B can start or proceed.

- **Reciprocal interdependence**: A direct and ongoing relation between two activities, where there is a mutual dependency between action A and B.

Thompson then explains these coordination modes further by explaining how they should be coordinated and when they are applicable.

*Pooled interdependence* should be coordinated through standardization. This will require standardized routines that will limit each action to fall into a path consistent with the path of other actions that are a part of the same interdependent process. A
requirement/assumption for this to work is that the actions performed are internally consistent, which will require a situation that is relatively stable, of a certain repetition and where the tasks performed are few enough to permit matching of actions under the same standard.

**Sequential interdependence** should be coordinated through schedules for the interdependent units, whereby their actions can be governed. Coordination through schedules will not require the same degree of stability such as in pooled interdependence (coordination by standardization). This makes this mode better suited for dynamic situations where the organization needs to be able to respond quicker to the changes in the environment.

**Reciprocal interdependence** is suggested to be coordinated through feedback—or mutual adjustment. Coordination through feedback entails transmitting of information *during* the process of performing an action. As observed through the works of March and Simon, Thompson states that the reliance on coordination through mutual adjustment will be higher the more unpredictable the situation.

An important aspect of these three coordination modes is that the way coordination is done within the three different modes, also comes with different costs, where “...standardization requires less frequent decision and a smaller volume of communication during a specific period of operations than does mutual adjustment” (Thompson, 1967).

**Anna Grandori**

Grandori (1997) have contributed to the body of coordination theories by addressing coordination modes with an emphasis on the information flow. The focus of Grandori’s studies is coordination between networks of companies involved in international business.

**Appendix 2**

First out is the pre-bid phase. This is where the general contractor will be issuing invitations to the subcontractors that will be needed to go through with the construction project. Typically these subcontractors are specialists in fields of expertise that the general
contractor does not possess in-house. However, subcontractors are also used to extend the workforce of the general contractor.

In the bid invitation the general contractor will provide the various subcontractors with the opportunity to review the project documents prepared by the estimators and actors responsible for the design and specifications, such as time scope, budgets and technical drawings. The subcontractor will then have to prepare a responsible and realistic bid. It is especially important that the general contractor is aware of the project financing information, which will reflect the client’s ability to pay.

Once the subcontractor has prepared a bid, the bid should be offered to the general contractor no less than 24 hours before the bid hour. The bid must contain estimated cost, proposed scope, alternates, unit prices, addenda and or bulletins (AGC, ASA & ASC, 2008).

Bids from a subcontractor known to be unqualified or who has no possibility of being awarded the contract, should not be considered.

Next there will be a bid period where the general contractor will be reviewing the bids by the subcontractor and later award contracts. The general contractor will have to maintain absolute secrecy considering the bids that have been received, as it is illegal for the general contractor to reveal to other subcontractors which bids have been received so that these can adjust their bids.

However, the general contractor will be allowed to contact a subcontractor if a bid is substantially lower than other bids, indicating an error. The subcontractor will then be faced with the option of either stand on its bid or withdraw.

When all bids have been received and reviewed there will be an award of contract. It is important that the general contractor and the subcontractor have an absolutely coinciding understanding of the contract agreements, obligations and terms. A payment procedure that has to be approved by a client will also be established at this stage. The general contractor will also be responsible for setting up a system to notify the subcontractor when he will start his work and alternately give a prompt and timely notification if the given date will change (AGC, ASA & ASC, 2008).
Appendix 3

We will now take a closer look at each of the main functions in the project management team to better understand what role they play and later, what their role may be in contributing to a better coordinated preconstruction phase.

Project Manager:

As mentioned, the project manager is the team leader and is directly responsible for how the team performs. A project manager will have extensive experience and a broad background that will enable him to understand and take all aspects of the construction project into account in a way that encompasses the interests of all parties directly involved, or affiliated with the project.

The size of the general contractor employing the project manager and the size of the construction project will influence the specific duties of the project manager. However, there are generally four tasks that must always be covered by the project manager regardless of project or company size.

1) The project manager will be responsible for assembling the best possible team for the project at hand. This involves the characteristics mentioned above that are desirable to be transferred to the running of the project.

2) The project manager will be in charge of creating the overall project schedule that will define the path of the processes to take place in the future.

3) A cost control system that will keep track of the project’s costs and ensure a fair outcome for all contractors involved as well as making sure that unexpected cost overruns do not happen has to be set up.

4) Lastly, a quality control plan has to be established. This plan must create a means to ensure that everything is being done is done according to the plans of the designers and ultimately what the client has agreed to, forecasted by the estimators.

Overall, the project manager holds substantial power in the way he directs the project team (who in turn direct most other processes), how he monitors the schedule, cost and quality.
This also gives the project manager the power to make adjustments as they are needed. This means that the project manager has to be especially vigilant in order to meet his points of accountability. The project manager’s accountability is twofold and is found in the obligations in the contract. Firstly, what is agreed upon must ultimately reach the expectations of the client. Secondly, the project manager is obligated to make the project run as efficiently as possible by taking the opportunity whenever it presents itself to save both time and money (Jackson, 2010).

**Contract Administrator:**

The main task of the contract administrator is to assist the project manager and the superintendent with their work and provide a solid support base for these functions. This means that the contract administrator is required to know all the details of the contracts in order to perform his task in a manner that will not cause the project manager or the superintendent to make decisions that are not in the best interest to the outcome of the project. In this respect it is particularly important that the contract administrator has absolute control over the general and supplemental conditions of the contractors.

Often the contract administrator will also have to process the decisions or requests made by the project manager and others. This means that the contract administrator has to deal with progress payment applications, change orders and submittals on behalf of the project manager.

In order to perform these tasks the contract administrator needs to be familiar with the contract stipulations and policies as well as all the procedures that have to do with the running of the preconstruction and running of the project (Jackson, 2010).

**Superintendent:**

In the chain of command the superintendent is second after the project manager. The superintendent’s function is, although being second in command, maybe the most important function once the preconstruction phase is over and the actual construction phase sets in. The superintendent will be responsible for coordinating all activities once the construction starts, as well as keeping the various construction activities running on schedule at any time.
This requires the superintendent to be a professional in construction methods and to be accomplished in all details that the construction phase will entail. It is important that all work done at the construction site remains within, and complies with the various contract documents.

The typical day of the superintendent consists of managing the flow of materials, deliveries and equipment in order to create an as productive environment as possible. In addition to this, the superintendent is also responsible for safety planning.

However, perhaps the most important role the superintendent will play in the preconstruction phase is acting as the daily point of contact to the client and the client’s representative. According to Jackson (2010) one of the most common reasons for a construction project facing severe challenges right from the start, can be traced back to a poorly performing superintendent, and thereby a lacking relationship and communication base between the client and project management -and ultimately a disruption of the ability to achieve their common goal. As a well functioning relationship between the management team and the client is a critical challenge that by all means should be overcome, the most important initial/"preconstructual” task of the superintendent may be to perform like a diplomat and establish a solid base of communication toward the client (Jackson, 2010).

**Field Engineer:**

A position as a field engineer is typically an entry position that at some point will lead to a position as a project manager. In the construction project the field engineer handles most of the paperwork going in and out of the field office.

The field engineer’s work entails the processing and tracking of requests from various parties in and around the construction project. Typically this entails processing requests for information, submittals, drawings and other specifications in the shape of documents. Because of the close relation to the documents involved in the construction process, the field engineer is a close coworker of the superintendent, as he plays a vital role in supplying the superintendent with the information he needs.

Even though the project manager and the superintendent play the most obvious roles with regards to coordination, the field engineer is still vital in the coordination that takes place
behind the scenes in the form of distributing information that is fundamental for the overall coordination of all the activities within a construction project (Jackson, 2010).

Appendix 4

Case Interviews

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges for project team management?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capacity is a major challenge. To have enough resources (people) available. An individual's personal capabilities (knowledge, management capabilities etc.) are vital resources. The use of such resources is often limited to the presence of that individual.</td>
<td>One often has to prioritize certain projects due to lack of resources, which affects (delays) other projects. Coordination Mechanism: Prioritize most important tasks and projects</td>
</tr>
<tr>
<td>2</td>
<td>Managers have knowledge about employees' capabilities (i.e. what resources are appropriate and available).</td>
<td>Resource capabilities not documented. Knowledge about capabilities limited to manager.</td>
</tr>
<tr>
<td>3</td>
<td>The fact that people have different interests is an issue. A good project team needs engaged and interested people involved in the project. Common interest for the project is important.</td>
<td>Coordination Mechanism: Project manager chooses team members based on experience about the resources. Team members are asked if they wish to participate.</td>
</tr>
<tr>
<td>4</td>
<td>Geographical limitations. Important people may not be optimally located at the project. Close geographical connection to the project is important.</td>
<td>Cannot be two places at once.</td>
</tr>
<tr>
<td>5</td>
<td>Top management may focus solely on available resources, but common interest for the project is equally important.</td>
<td>Project team designed based on available resources. Common interest not taken into consideration.</td>
</tr>
<tr>
<td>6</td>
<td>There is an essential difference between theoretical and practical project managers. One prefers a theoretically strong manager, however the choice of manager also depends on available resources.</td>
<td>Availability can lead to inappropriate choice of managers. Coordination Mechanism: Have theoretically strong leaders (with diversified knowledge/generalist) surrounded by team of specialists</td>
</tr>
<tr>
<td>7</td>
<td>Flat structure (soft management strategy). People communicate across management levels in the hierarchy (e.g. superintendent talks to project manager and makes decisions that are not communicated to the rest of the team)</td>
<td>Information can be lost in certain levels of the hierarchy. Not everyone being updated and informed about vital decisions/changes etc.</td>
</tr>
<tr>
<td>8</td>
<td>Sufficient information sharing. Complicated to ensure both good information-flow and information-security at the same time.</td>
<td>Vital information not being sufficiently communicated due to security risks.</td>
</tr>
</tbody>
</table>
### PROJECT MANAGEMENT TEAM
- Interviewee 2 -

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges for project team management?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is a major challenge to design a team that covers all necessary knowledge bases (making a complete system). A good project team requires knowledge that covers all disciplines. The project team needs: 1. Members with social skills 2. Members that are &quot;doers&quot; 3. Members with analytical capabilities (assessing consequences) 4. Members with people skills</td>
<td>Project teams are knowledge intensive</td>
</tr>
<tr>
<td>2</td>
<td>Lack of resources available is a challenge.</td>
<td>Project managers knowledge about scope of the project and necessary resources is critical for success. Coordination Mechanism: Project manager focuses on critical roles in the team, and ensures those resources first. Using project managers with experience is important.</td>
</tr>
<tr>
<td>3</td>
<td>An inadequate project manager can be a major challenge.</td>
<td>This can lead to disputes in the project team. The success of a project highly depends on project manager's capabilities. PM=vital=weak link?</td>
</tr>
<tr>
<td>4</td>
<td>Complex projects in e.g. cities are challenging because it affects the community and general public.</td>
<td>The community's opinion becomes relevant and affects the project success. Coordination Mechanism: Have team members that are capable of handling external factors.</td>
</tr>
</tbody>
</table>

### PROJECT MANAGEMENT TEAM
- Interviewee 3 -

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges for project team management?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is a challenge to acquire all necessary resources with appropriate skills that can work independently and conduct their tasks.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>It is a challenge to design a team where members complement each other's roles, where the members have both specific knowledge about their tasks and diversified knowledge across disciplines.</td>
<td>Coordination Mechanism: When there is a lack of resources the team members must at times be able to take over each other's tasks to keep the project going.</td>
</tr>
<tr>
<td>3</td>
<td>Early stages in projects are challenging because there is a lot of work</td>
<td>Dynamic process requires dynamic</td>
</tr>
</tbody>
</table>
that needs to be done, and much information that needs to be shared within a short period of time.

PROJECT MANAGEMENT TEAM
-Interviewee 4-

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges for project team management?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is a challenge to cover all competences that a project team requires and to avoid an unequal distributed &quot;organization&quot; (project team).</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>It is a challenge to ensure that responsibility is defined and clarified within the project team, that all team members know what to do and their scope of responsibility. Lack of focus on project team structure. &quot;Less important&quot; issues such as maintenance of tools and machinery is &quot;every ones&quot; responsibility.</td>
<td>After inadequate phases in projects it is experienced that certain processes have not been covered (work has not been done), and no one knows who is responsible, and therefore it is complicated to clarify the cause of inadequacy.</td>
</tr>
<tr>
<td>3</td>
<td>The planning phase is busy and it is challenging to uncover all the work that needs to be done.</td>
<td><strong>Coordination Mechanism:</strong> Definition of functions and cooperation should be established earlier in the process.</td>
</tr>
<tr>
<td>4</td>
<td>Lack of capacity and resources when planning is a challenge</td>
<td>Can result in wrong focus from the starting point, which can later affect the project.</td>
</tr>
<tr>
<td>5</td>
<td>It is a challenge that management is too distanced from the operational phase of the project.</td>
<td><strong>Coordination Mechanism:</strong> Management further engaged in operations.</td>
</tr>
</tbody>
</table>

RESCHEDULING
-Interviewee 1-

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges when managing a schedule?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is a challenge to ensure that the schedule is in fact being followed.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>When actors come across issues that require a change to the schedule they often solve the issue on site, because they tend to &quot;know best&quot; how to solve it. &quot;One can solve a problem today, but it can affect implementation of the overall process&quot;</td>
<td>An important consequence of this challenge is that the schedule may not be updated and changes not communicated. This can negatively affect later tasks in the schedule.</td>
</tr>
<tr>
<td>3</td>
<td>Changes in a schedule affect subcontractors' work.</td>
<td><strong>Coordination Mechanism:</strong> Continuously meetings with subcontractors. Major changes to</td>
</tr>
</tbody>
</table>
schedule documented in writing.

| 4 | A schedule has certain critical phases, which can be a pitfall for a project. | Coordination Mechanism: Put in "slack" in the process, during the making of the schedule. This is to reduce the affects that changes to a schedule can have on critical phases. Also to give management and actors more time to adjust. |

**RESCHEDULING**  
-Interviewee 4-

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges when managing a schedule?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical complexity of the project can affect schedule and result in need for change in schedule. Can come across uncontrollable issues. &quot;When drilling tunnels geology and nature of the rock influences whether the schedule can be followed as intended&quot;</td>
<td>Coordination Mechanism: Analyzing risk in the schedule is an important part of planning. Put in &quot;slack&quot; in the schedule where there might be uncontrollable factors. If the causes for change are controllable the general contractor is responsible for the consequences (costs etc.). Coordination Mechanism: Continuous dialog about risk and progress. Communicate with client if schedule needs to be changes.</td>
</tr>
<tr>
<td>2</td>
<td>Important to avoid situations that lead to rescheduling, if the causes are controllable.</td>
<td></td>
</tr>
</tbody>
</table>

**MANAGING SUBCONTRACTORS**  
-Interviewee 1-

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges when managing subcontractors?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low time margins are a challenge, as coordinating subcontractors requires flow in the schedule.</td>
<td>Coordination Case Mechanism: Put in time buffers/slack in schedule when planning, so allocation of work goes smooth when changes occur. General contractor tries to take dependencies into account.</td>
</tr>
<tr>
<td>2</td>
<td>Complicated to clarify responsibility between general contractor and subcontractors.</td>
<td>This can lead to legal disputes between general contractor and subcontractors. Coordination Case Mechanism: If subcontractor is responsible for inadequacy the subcontractor will receive fines.</td>
</tr>
</tbody>
</table>
### MANAGING SUBCONTRACTORS
- Interviewee 2 -

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges when managing subcontractors</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
</table>
| 1   | It is a challenge to ensure that all parties know what to do, so that the work actually gets done. | Unclear job specifications can negatively affect progress of the project.  
**Coordination Case Mechanism:** Sufficient preparations and planning before the work starts. Trust between general contractor and subcontractor is important for the general contractor to be confident that the work is done. |
| 2   | Time is critical and one always has to know what one is looking for (purpose and objectives) | **Coordination Case Mechanism:** Always having a person that is responsible for coordinating subcontractors. |

### MANAGING SUBCONTRACTORS
- Interviewee 3 -

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges when managing subcontractors?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is a challenge to ensure that the subcontractors have understood their tasks.</td>
<td>These issues can result in process inefficiency because subcontractor does not know what tasks to do or</td>
</tr>
</tbody>
</table>

Lack of knowledge from subcontractor  
Inadequate work from subcontractors, affecting success of the overall process.  
**Coordination Case Mechanism:**  
General contractor uses resources to support and consult subcontractors with e.g. management knowledge. General contractor also involve subcontractor early in the process to keep a close relationship.

Complex to ensure sufficient communication of information between all parties  
"Some information systems are outdated, and reports and transcripts are stored on several separate systems"
## MANAGING SUBCONTRACTORS

### Interviewee 4

<table>
<thead>
<tr>
<th>Nr.</th>
<th>What are the main challenges when managing subcontractors?</th>
<th>Case Reply: Why &amp; Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is a challenge that the subcontractors may not have the same capacity at the general contractor (struggle to keep up with general contractor’s paste and expectations)</td>
<td>Coordination Case Mechanism: Have a person responsible for subcontractors' work and progress. If the subcontractors do not meet general contractor's expectations and agreed terms, they receive economical sanctions.</td>
</tr>
<tr>
<td>2</td>
<td>It is a challenge that changes to a process are more time consuming due to the need for communication between general contractor and subcontractors.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>It is a challenge that occasionally subcontractors do not contract or notify general contractor when they come across issues that they cannot solve.</td>
<td>This can delay the entire project.</td>
</tr>
</tbody>
</table>

## COORDINATION MECHANISMS

### Interviewee 1-4

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Question</th>
<th>Case Reply</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How do you ensure that the appropriate people are engaged in the different construction projects?</td>
<td>By making the team based on people that have worked together previously. Clarifying member's capabilities, motivation and experience through conversations and interviews.</td>
</tr>
<tr>
<td>2</td>
<td>How do you ensure that information is sufficiently shared amongst members in the project team?</td>
<td>This is done through continuous meetings and conversation between team members. Information reports are shared within the team. The</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>How does structure of the project team affect information sharing?</td>
<td>Differences between formal (hierarchy) and informal (flat) structure. Culture affects how the structure is in the team.</td>
</tr>
<tr>
<td>4</td>
<td>How do you ensure that the appropriate people in the project team are responsible for handling rescheduling?</td>
<td>Certain focus on hierarchy. Job descriptions and defined responsibilities clarify who should manage and implement the change. Meetings regarding progress, and follow up by project manager to secure a sufficient change process.</td>
</tr>
<tr>
<td>5</td>
<td>How are decisions regarding change implemented?</td>
<td>Depends on nature of the required change. However the people making the decisions shall follow defined procedures for change.</td>
</tr>
<tr>
<td>6</td>
<td>How do you ensure adequate quality of subcontractors work?</td>
<td>Continuous control of method of work and quality of work, according to defined requirements. The different subcontractors are involved in quality assurance, so that the subcontractors know that the work of previous subcontractors is sufficient. We strive to be proactive and avoid lack of quality before it becomes an issue. We are also reactive in the form of controls on the construction site.</td>
</tr>
<tr>
<td>7</td>
<td>How do you know involved subcontractors' capabilities, competences and resources?</td>
<td>We have often worked with subcontractors before, and we therefore know their capabilities through experience. We also request subcontractors' &quot;CV&quot;, and get information through their references. We also conduct SJA (&quot;Safe Job Analysis&quot;) for critical changes in work. Close follow-up by general contractor if there is doubt regarding subcontractors' capabilities.</td>
</tr>
<tr>
<td>8</td>
<td>How do you ensure that subcontractors are accepting each other's needs on the construction site?</td>
<td>We have continuous coordination meetings where we clarify all parties' priorities and needs. Follow-up on the construction site.</td>
</tr>
</tbody>
</table>
## Appendix 5
### Meeting Protocol

<table>
<thead>
<tr>
<th>People involved in meetings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>Professor Vang, Jan</td>
</tr>
<tr>
<td>Kayser, Dennis</td>
</tr>
<tr>
<td>Jacobsen, Gert</td>
</tr>
<tr>
<td>Hasselbelch, Henrik</td>
</tr>
</tbody>
</table>

- **02.09.2011 - Meeting at IBM with Kayser**
  - Started on discussing ideas and feasibility of the project. Also discussed project scope and whether ICTs and Cloud Services could be a potential subject. Kayser introduced us to relevant literature within IBM’s databases and linked us to other IBM employees we could discuss the subject with, namely Jacobsen, Gert & Hasselbelch, Henrik.

- **05.09.2011 - Telephone meeting with Jacobsen & Hasselbelch**
  - We introduced the project subject to the respondents and discussed potential scope and problem areas. We further discussed the subject of Cloud Services.

- **08.09.2011 - Meeting at IBM with Kayser**
  - Discussed scope of problem area. We got access to some of Kayser’s academic work and articles. We discussed where we could search for information within the IBM system, and whether there were some conferences we could join to gain more knowledge about Cloud Services.

- **15.09.2011 - Meeting at AAU with Vang**
  - Brief discussion regarding subject and scope of project. Vang found the subject interesting and suggested some project strategies. We also discussed some methodology.

- **16.09.2011 - Meeting at IBM with Kayser**
  - Discussed latest ideas with Kayser.

- **20.09.2011 - Attended Cloud Service conferences at IBM**
  - We joined a conference regarding Cloud Service Infrastructure and further gained knowledge about the IBM concept. Also engaged in discussions regarding what
potential issues and challenges IBM comes across in regards to Cloud Services, which could potentially be a project subject.

• **29.09.2011 - Meeting at IBM with Kayser, Hasselbelch and Jacobsen**
  o Further discussed potential problem area and discussed the findings of the Cloud Service conference. At this meeting we started to discuss whether the construction industry could be an interesting scope of the project, and whether the two topics (ICTs and Construction) could be merged as a problem area.

• **07.10.2011 - Meeting at AAU with Vang**
  o Further discussed our findings so far. Discussed theoretical limitations to the Cloud Service topic, and theoretical strategy. Vang coincided on the idea of investigating the construction industry, linked to the use of ICTs.

• **17.11.2011 - Meeting at AAU with Vang**
  o Started to discuss potential case scope and case companies. Vang mentioned that the subject coordination is essential in relation to construction. We did a preliminary draft of the "coordination within construction" topic, and agreed that we should continue to work on the scope. Vang also introduced some researchers (amongst others Thomassen, Mikkel), which we could use as sources.

• **12.01.2012 - Meeting at AAU with Vang**
  o We discussed methodology issues, i.e. how to formulate the problem statement, single vs. multiple cases, whether previous methods could be used. Also discussed formal subjects such as dates and requirements for the project. With help from Vang we changed some of the theory structure of the project. It becomes clear that we needed to have a stronger focus on the problem statement and use the theory in that sense. Cloud Service became a less important part of the theory, but rather something we discuss in the final discussion after conducting the case. We discussed unit of analysis.

• **26.01.2012 - Meeting with Kayser at IBM**
  o We discussed how Cloud Services could be designed appropriately for the construction industry. Brainstorming regarding a potential solution, to ensure that the project topic was possible. Also discussed further project strategy in relation to structure and how to solve the problem statement adequately.

• **08.03.2012 - Meeting with Kayser at IBM**
  o Kayser examined our work so far and came with certain corrections and advice in relation to structure and how to conduct a good case study. We also god advice
regarding how to write good case questions and how to conduct interviews sufficiently.

- **15.05.2012 - Meeting with Vang**
  
  - Vang had read our draft of the final product, and he gave us important pointers in relation to scope of theory and case. We made a "list" in cooperation with Vang with certain steps we should strive to go through.