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Digitalized communication within megaprojects

Utilizing information technology to improve communication and information sharing

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by

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Digitaliserad kommunikation inom megaprojekt

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Abstract

Conducting a megaproject is a large and complex commitment, which have been proven by many cases where megaprojects have exceeded budget, time-plan or have experienced quality issues. In fact, 90% of the conducted megaprojects faces these issues. Megaprojects as an area of research have lately experienced increased attention. The focus of this research has mainly been targeted on political, financial and psychological factors that have an influence on project failure. Less attention has been given to functional aspects regarding how to manage and perform a megaproject. However, one critical aspect that has been identified is communication and information sharing, which must be handled in an efficient and precise way. One way of doing this is to implement IT-systems, which is why this thesis aims to investigate how the utilization of information technology within megaprojects can improve and support communication and information sharing.

The research has been done by conducting a case study at an engineering consulting company within the division for infrastructure developments, where two independent megaprojects were analysed.

It was shown that two different types of information is shared within a megaproject, quantitative information which is of a status reporting kind, and qualitative information that is of a more descriptive nature. To communicate this varying information, an IT-system could be used. However, for the IT-system to be effectively utilized it is required that the system is able to manage various types of information differently. If this is achieved, an IT-system can make sure that project members in an effective way are provided with the information necessary for their work, and thus provide with increased control and a more efficient coordination.

Key-words: Megaproject, IT-system utilization, communication process, information sharing and knowledge sharing.

KTH Industriell teknik och management

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Digitaliserad kommunikation inom megaprojekt

Användning av informationsteknologi för att förbättra kommunikation och informationsdelning

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Sammanfattning

Genomförandet av ett megaprojekt är ett stort och komplext åtagande, vilket har bevisats av de många fall där megaprojekt har överskridit budget, tidplan eller där kvalitetsproblem har påträffats. Faktum är att 90% av de genomförda megaprojekten står inför detta problem. Megaprojekt som forskningsområde har nyligen mötts av ökad uppmärksamhet. Fokus inom denna forskning har huvudsakligen varit inriktad på politiska, finansiella och psykologiska faktorer som påverkar projektets utgång. Mindre uppmärksamhet har lagts på funktionella aspekter som hantering och genomförande av ett megaprojekt. En kritisk aspekt som dock har identifierats är kommunikation och informationsdelning, som måste hanteras på ett effektivt och korrekt sätt. Ett tillvägagångssätt för att uppnå detta är att implementera IT-system, vilket är orsaken till detta examensarbete som syftar att undersöka hur användningen av informationsteknologi inom megaprojekt kan förbättra samt stödja kommunikation och informationsdelning

Studien har genomförts genom en kvalitativ fallstudie av ett teknikkonsultbolag på deras avdelning för infrastruktur, där två oberoende megaprojekt har analyserats.

Det påvisades att två olika typer av information skapas och delas inom ett megaprojekt, kvantitativ information som är av en statusrapporterande typ och kvalitativ information som är av en mer beskrivande och tolkningsbar natur. För att kommunicera denna varierande information kan ett IT-system användas. För att detta ska kunna användas effektivt är det dock nödvändigt att systemet klarar av att hantera olika typer av information på olika sätt. Om detta uppnås kan ett IT-system säkerställa att projektmedlemmarna på ett effektivt sätt blir försedda med den information som behövs för att genomföra deras arbete, och därigenom bidra till att öka kontrollen samt få en effektivare samordning.

Nyckelord: Megaprojekt, IT-system användning, kommunikation, informationsdelning, och kunskapsdelning.

Table of Content

List of Figures

List of Tables

Foreword

The master thesis has been conducted at the Royal Institute of Technology within the department of Industrial Economics and Management in the unit Organization and Management.

First of all, we would like to thank our contact persons at Company A for their support and help throughout the master thesis. During the case study, various interviews have been held with employees from different divisions in the company. These people showed a lot of commitment and helped us by providing with the information needed in order to investigate the phenomenon of the study. Without these people, the utilization of information technology in megaprojects would not have been able to be studied, and we are therefore very thankful to these individuals.

Furthermore, we would also like to express our gratitude to our supervisor at KTH, Johann Packendorff who is Professor of Industrial Economics and Management with specialization in Industrial Project Management. Johann has helped us with guidance and valuable discussions in the research process of conducting the master thesis.

Lastly, we want to thank Georg Silber from Ln4 Solutions AB who has provided us with knowledge in the field of IT- systems that can support the communication process in these large and complex projects.

Stockholm, May 2017
Ludvig Rogberg & Joakim Wretskog

1. Introduction

In this chapter an initial presentation of the studied research area will be given. Further, the studied phenomenon will be contextualized by relating it to previous research on the area. Lastly, the purpose and research questions will be presented as well as the delimitations of the thesis.

1.1 Background

The term megaproject refers to the larger type of projects conducted in society. These projects typically involve large infrastructure and construction developments. Flyvbjerg (2014) defined megaprojects as follows *"Megaprojects are large-scale, complex ventures that typically cost a billion dollars or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people"*. The extent of this type of projects comes with several challenges which, if not properly handled, can result in either cost overruns, quality issues or delays. In fact, performance data on megaprojects shows that 90% of the performed megaprojects have cost overruns and, interestingly enough, there have been no improvements in these numbers for the last 70 years, regardless of where the project has taken place. Famous examples of megaprojects facing these issues are the underwater rail tunnel built between United Kingdom and France that had cost overruns of 80% and the Sidney opera house that missed its budget with 1400% (Flyvbjerg, 2014). When conducting a megaproject, it is not unusual that the scope changes over time and that the complexity of the extensive planning result in high risk taking. This type of projects typically involves several strong stakeholders, both private and public ones, which can affect the complexity of decision making activities (Aaltonen and Kujala, 2010). Also, the duration of the projects commonly leads to several management changes throughout the project, resulting in challenges regarding project leadership. Furthermore, various competences are needed in advanced technical areas and the projects usually differ from regular work, thus managers often establish a bias where they see it as a unique project which inhibits the process of learning from earlier projects (Flyvbjerg 2014). As a result of the high complexity in this type of projects, the control is often left inadequate and the communication of risks, benefits, costs and schedules are easily defective. Factors that are valid in order to prevent delays and cost overruns that may end in fatal consequences (Flyvbjerg 2014).

Previous research on project management are diverse and detailed which have established a wide and accepted theoretical foundation for the field. This research has in general focused on normal scale projects and has provided with insights in how for example time, cost, quality, risks and communication could and should be handled (Maylor, 2010). A research area that has experienced less attention is the area of megaprojects, although this area of research has grown a lot lately. Flyvbjerg (2014) has been a driving factor in the understanding of the megaproject phenomenon by describing and defining its content and characteristics. Flyvbjerg (2014) also examined what factors that have great impact on the performance of megaprojects where psychological, political and technical factors have been discussed.

One research area which is closely connected with megaprojects is program management where functional aspects have taken more space. One crucial aspect that has been emphasized both within megaprojects and program management is communication. Sowden (2011) discussed the usage of program management offices which purpose is to provide the program organization with standardized ways of sharing and communicating information. Blomquist and Müller (2006) assessed the importance of a well-developed communication plan that is customized to the specific project. Further, Kendall and Rollins (2003), Thiry (2002) and Dietrich and Lehtonen (2005) emphasized the importance of effective communication of project data and information.

1.2 Problematization

In the previous research on megaprojects, the focus has continuously been on an industrial and individual level targeted on more holistic and strategical issues regarding the undertaking of megaprojects. Less effort has been invested in the actual management of megaprojects on a functional level. It has however been stated that communication is crucial for successful management and control of megaprojects (Sowden, 2011; Müller, 2006; Kendall & Rollins, 2003; Thiry, 2002; Dietrich & Lehtonen, 2005).

One way to support and streamline the communication is to utilize information technology. Several studies have been made on IT-system utilization within projects, however, the focus of the studies have been limited to why IT-systems are used and to what extent (Liberatore & Pollack-Johnson, 2003; Ali et al. 2008). How IT-systems can be used within megaprojects to

support information sharing have not been emphasized and that is the research gap that this thesis will investigate further. This will be done through a case study at the technique consulting Company A.

1.3 Purpose and research question

The purpose of this study is to explore how communication and information sharing within large and complex megaprojects can be streamlined through the utilization of IT-systems and thereby enhance project control. Further, the findings from this study will seek to contribute to the previous research on megaprojects by the establishment of an initial description on how to work with IT-systems within megaprojects.

In order to fulfill this purpose, the study will aim to answer the following research question and sub questions:

- *How can the utilization of information technology within megaprojects improve and support communication and information sharing?*
    - *What is required of an IT-system in order to meet the needs of a megaproject organization?*
    - *What types of information are present when conducting a technically complex megaproject?*

1.4 Delimitations

In order to establish the scope of the research, a thorough delimitation has been made (Collis & Hussey, 2014). The study will investigate megaprojects within the infrastructure industry, and more specifically, infrastructure projects performed at Company A. The projects will not be studied from start to finish, however, the stages of the studied projects will be chosen so that all project phases are included in the investigation. Further, the study will assess how IT-systems can be used to streamline communication and information sharing, but will not discuss or describe any specific IT-system product.

Through a system perspective (Blomkvist & Hallin, 2014) the research will focus on the functional level, analyzing the complex communication processes in the megaprojects.

However, the study will also touch upon the other two levels. The individual level in aspects such as barriers for communication, but also the industrial level when it comes to reaching the overall goals of the project, where the results affect both the organization and society as a whole.

2. Methodology

This chapter describes the methodology used to study the stated phenomenon. The general research approach, the research design, interview method, literature study method and data analysis method will be discussed together with an assessment of the reliability, validity, generalizability and ethics of these chosen methods.

2.1 Research approach

In order to investigate how an IT-system can be utilized to support and further improve information sharing within megaprojects, an exploratory and inductive approach has been chosen. This approach was chosen with the aim of investigating the mentioned phenomenon, where the previous research mainly has been focused on what a megaproject is and why megaprojects are difficult to pursue. Hence, the scope of this study is to reach an understanding of how IT-systems can be used for information sharing, rather than statistically prove it. According to the nature of inductive research, the study was initiated with a broad perspective, without deciding on specific theoretical frameworks. Theoretical frameworks were instead implemented at a further stage of the study when relevant areas of the research phenomenon had been identified (Blomkvist & Hallin, 2014).

The background to the master thesis was based on a problem that Company A are facing, where the complexity of the larger projects requires an increased support for the information sharing process. To be able to investigate this problem, and contribute to the existing literature of the utilization of information technology within megaprojects, a case study was conducted at Company A. Thus, making it possible to contribute to the existing research in the field of megaprojects. This approach is supported in the literature, where Blomkvist and Hallin (2014) argue that a case study generates empirical material that can provide with a better view over a complex reality that can be difficult to capture in other type of studies. A case study also creates a possibility to discover new dimensions in which theory emerge from the empirical findings. How this case study was designed and performed will be further described in the following sections.

2.1.1 Object of Study

To be able to analyze the stated phenomenon of the research, Company A were chosen as the case company to be investigated. Company A is an engineering consulting firm with expertise

in a wide selection of technical areas. The study is performed at Company A's division for infrastructure developments. Their part of an infrastructure development is to prepare and plan how the construction should be formed and built. These projects are characterized by their long duration and high complexity due to the complexity of the task itself and the wide collection of technical specialists that are required to be coordinated. Thus, making it possible to evaluate the utilization of IT-systems in the conducted megaprojects and to see how this may support and further improve the information sharing.

Company A is conducting their business in the form of a matrix organization (Kerzner, 2001). This entails that Company A is organized according to function and that several projects are performed simultaneously, hence, individuals are participating in several of these megaprojects at the same time. This puts a lot of pressure on the communication process in the organization, which is a further reason to why this company was chosen as the case company in this study.

How Company A is organized within megaprojects is illustrated below in figure 1. From a bottom-up perspective, the project organization is built up by a large number of technical areas, technique A1 to B6. These technical areas comprise technical specialists led by a technique responsible for the specific area and they are the ones that are conducting the product development. These technical areas are grouped into large technique areas, technique A and B. For each area there is a technique coordinator appointed whose responsibility is to ensure coordination between the underlying techniques. Above the technique areas is the project management, which is led by the project manager. The responsibility for the project manager is to ensure that the project is proceeding according to plan and that the project organization have the needed conditions to perform the job. To ensure this, the project manager is supported by several support functions, illustrated in figure 1 as management support function A-H, as well as an assistant project manager. Furthermore, the project organization contains a project owner who support the project manager and represent the customer internally and keep contact with the customer externally. The internal control group consist of senior managers which also function as a support function to the project manager. Lastly, each described function have its own group manager that are responsible for resource distribution.

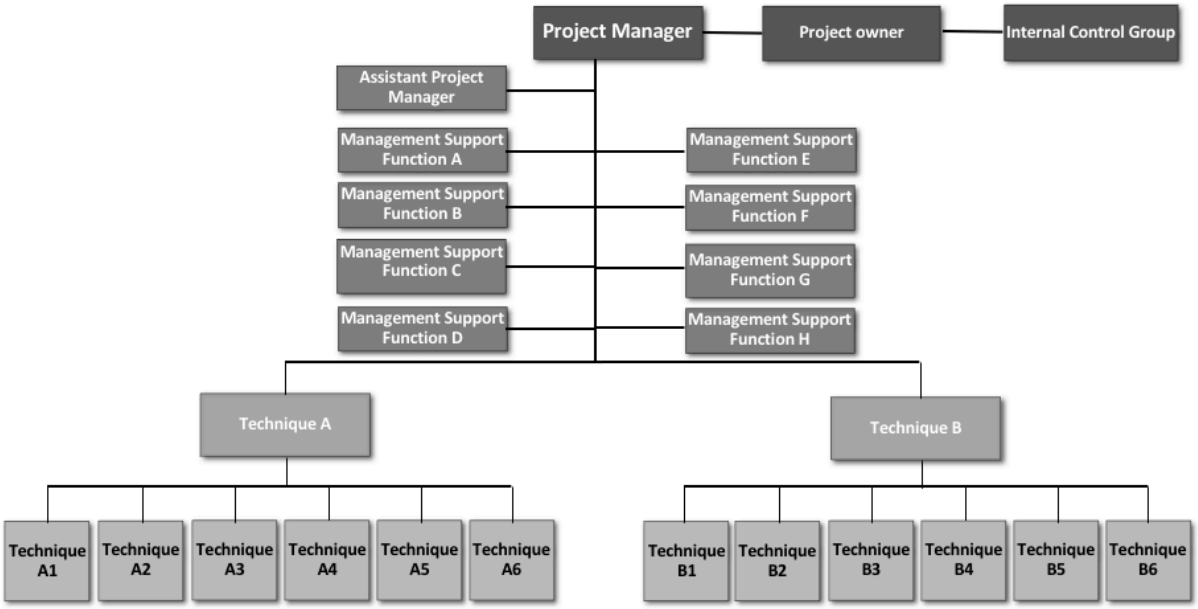

Figure 1: An illustration of the project organization at Company A.

2.2 Research design

In the early stages of the research, a pre-study was conducted through unstructured interviews with the aim of creating an understanding of the phenomenon that was intended to be studied. Further, a literature review was made in parallel to the unstructured interviews at Company A. Hence, providing with valid knowledge of the requirements needed for a project management system with regard to time-, economy-, quality-, risk-, communication- and knowledge management, but also supporting with a holistic view over the challenges and pitfalls in megaprojects.

Two independent infrastructure projects in the same business unit of Company A were analyzed in the case study. These were chosen aiming on covering the whole project lifecycle of the megaproject, choosing one project in the earlier phase and another in the ending phase. The reason to this is that there are so long time scopes in this type of projects, making it challenging to get a clear picture over the whole project lifecycle. The interviews were held with employees from the different levels of the respective project organizations to make it possible to see the specific requirements needed by an IT-system for the information sharing process on each level. These levels were also evaluated throughout the different phases of the project including the conceptualization, planning, execution and termination phase. Further, observations have also been made in one of the megaprojects, analyzing a weekly meeting where the different techniques are coordinated and important issues are discussed.

After having conducted the literature review combined with the empirical findings from the information sharing process conducted in the megaprojects at Company A, the research question was once again updated. This included the purpose and problem formulation of the study, where the writing process was revised in accordance to these findings. The topics in the research design is explained more in detail in the following chapters.

2.2.1 Pre-study

In order to become familiar with the organization and to get a holistic view over the utilization of information technology within the megaprojects, a pre-study was first conducted at Company A. Referring to Collis and Hussey (2014), this will help the investigator to reach an understanding of the context in which the case study will be performed. Open interviews were first held with the contact persons at Company A, where the setup of the case study was discussed, but also ethical aspects such as the importance of confidentiality and that the case company has to be anonymous throughout the report. In the pre-study, unstructured interviews were also held with individuals from each project level with the aim of understanding and formulating the problem, making it possible to analyze through a functional level. This included a project manager, technique coordinator, technique responsible, technical specialist, but also various coordinators supporting the project manager in these large and complex projects as shown in figure 1. This could then support the study by defining an exploratory purpose and problem formulation that could be used as a guidance in the case study. This way of conducting the research can also be related to Blomkvist & Hallin (2014), who argue that an exploratory purpose entails exploring something that has not yet been studied to any greater degree, and is often combined with an inductive research approach in these types of investigations. Hence, this entailed that the phenomenon could be studied in a manner that capture the complexity of the infrastructure projects that is conducted at Company A.

The pre-study also provided data about potential interviewees that would be most suitable for the case study in order to answer the phenomenon that was about to be studied. Further, as a result of the long lifecycles in the megaprojects, it became clear that the projects that were about to be investigated, also had to be chosen in regard to the project phase in which they

currently existed. Hence, capturing all the significant aspects, covering the process of the whole project lifespan with the aim of increasing the reliability and validity of the research.

A literature search on typical megaprojects, but also project management theories was conducted in parallel with the unstructured interviews. This, with the aim of building a competence of what type of areas that were valid to investigate and where there may be challenges and pitfalls in the information technology of such large projects.

2.2.2 Interviews

The majority of the gathered empirical material was collected through qualitative interviews in a semi-structured manner. Referring to (Collis & Hussey, 2014) semi-structured interviews implies that the interviewer organizes questions in forehand, with the intention of encouraging the interviewee to talk about the relevant topics of the phenomenon that is being studied. However, the interviews have not been completely locked to this prepared template, flexibility was given to discuss and explore other undefined areas as well (Blomkvist & Hallin, 2014). In order to understand the information technologies and complex communication processes at Company A, the interviewees have been probed by asking questions that require them to elaborate on their initial statement (Collis & Hussey, 2014). These types of questions were asked mostly in the beginning of the data collection stage, where the aim was to first determine how the various processes were conducted in these megaprojects, but also to gain a greater knowledge about the valid issues.

The interviews have mainly been conducted face to face and with a duration of one hour at the head office of Company A. All interviewees were asked the question if they allowed the conversation to be recorded. For those interviews where recording was accepted, the conversation was transcribed in proximity to the interview. Notes were taken during the interview when recording was not accepted. The videoconference tool Skype has been used for interviews with people on different geographical locations. All interviews in the main study were structured in accordance to the same focus areas. This created the opportunity to triangulate the collected data, and by that certify the validity of the data. However, certain questions were customized with regard to the project role of the interviewee. The data was then thematically organized in order to simplify the analysis.

The sample selection was based on the result from the pre-study and a discussion with the contact persons at Company A. In total, 23 individuals representing the organization were interviewed. Here, one project member for each project organization level was interviewed in an unstructured manner, and the rest of the interviews were conducted in a semi-structured approach. As mentioned earlier, as a result of the long lifecycles in the megaprojects, they had to be chosen in regard to the project phase in which they currently participated. Taking this into consideration, two megaprojects were chosen, one in the earlier stage, and the other closer to the ending stage of the project lifecycle. Hence, covering the process of the whole project lifespan in which the organization works in accordance to. This, with the aim of increasing the reliability and validity of the research.

Another important aspect when deciding the sample was to include all roles participating in the megaproject. A quota sampling method was therefore used, meaning that the studied group is divided into different categories, where interview objects then is chosen from each category (Collis & Hussey, 2014). The categories were in this case constructed in accordance to the mentioned project organization areas described in figure 1, and have been covered in the interviews regarding both megaprojects, where the number of interviewee for each project role is illustrated in table 1. In the interview process, the information concerning a specific role was considered saturated when an interviewee with that role not contributed with any new relevant information to the phenomenon that was being studied.

Furthermore, many of the individuals that were interviewed also have other roles in different projects. Thus, making it possible to gather information through various aspects of the communication process in the projects conducted at Company A. However, in table 1, these individuals are identified after their project role in the chosen megaprojects that was investigated during the case study.

Table 1: Number of interviewees for each project role.

Project Role	Number of Interviewees
Group Manager	2
Project Owner	2

Project Manager	4
Project Manager Assistant	1
Support/Coordinator	5
Technique Coordinator	4
Technique Responsible	3
Technical Specialist	2

Interviews were also held with experienced employees from Company A outside the chosen megaprojects, but in the same division. This was done with the aim of gathering further information regarding a specific role or process, where the research lacked data. This could then fill the knowledge gap of an area that was missing from the interviews, and could thus support the study with these important insights. This process can be referred to a snowball sampling method (Blomkvist & Hallin, 2014), implying that employees are asked to refer you to other relevant individuals that possesses the demanded information or knowledge needed. The project roles of these interviewees are also illustrated in table 1.

2.2.3 Observations

In order to support the studied phenomenon with further information regarding different communication processes conducted at Company A, observations have been made during the study. This have been done in both participant and non-participant observations at the case company. All the observations were conducted in regard to ethical aspects, where the observed individuals were told about the study and the purpose with the data that was collected. This is also supported by Collis and Hussey (2014), arguing that observations in a natural setting is preferred in a study because of the importance of its influence on the phenomenon that is investigated. The non-participant observation was made under a weekly meeting in one of the megaprojects, where the different techniques were coordinated and important issues were discussed. This made it possible to analyze the communication process and the information that was shared between the different parties, supporting both progress and decision making in the project.

The participant observation was made in parallel to the other activities in the research. Because of having the advantage of conducting the master thesis at the office of Company A, this made it possible to make observations in their everyday setting. Referring to Collis and Hussey (2014), this makes it possible to create a deeper understanding of the individuals being observed, including both practices, motives and values. Thus, contributing with a broader view in parallel to the interviews that was held at the case company.

2.2.4 Literature review

The collection of secondary data were performed with the purpose of creating a broader understanding of megaprojects, and what type of challenges and pitfalls that these projects faces. Furthermore, literature regarding critical project management areas were also reviewed in order to build a deeper insight of the factors affecting the project outcome. This included management theories in time, cost, quality, risk, communication and knowledge sharing processes. These areas were also investigated in regard to the phases in which the project passes throughout the project lifecycle. Lastly, earlier research on IT system utilization in project management were also analyzed. This could provide with knowledge in understanding the background to the IT support systems used in Company A, hence, contributing to the phenomenon being studied.

The literature review contributed with the existing knowledge about the phenomena that was intended to be investigated in the research, but also made it possible to identify the gaps in the existing theory of megaprojects. This knowledge gap was distinguished in how IT-systems can be used within these larger complex projects to support the information sharing process and improve the control.

The secondary sources were mainly constituted of scientific articles, scientific journals, academic books and reports. The search for sources have been performed using the databases Google Scholar and KTH primo, which is provided by the KTH library. KTH primo contains peer reviewed content which enhances the reliability of the gathered sources. Search words that frequently were used in the literature research in the field of project management were “megaprojects”, “cost management”, “time management”, “quality management”, “risk management”, “communication management”, “knowledge sharing”, “knowledge

management", "program management", "project management software" and "project lifecycles".

2.2.5 Data analysis

In order to analyze the gathered empirical material from interviews, the recorded interviews were transcribed in near proximity to the interview. The transcribed empirical material was then analyzed with the objective of thematically order the content, an approach called thematic analysis (Blomqvist & Hallin, 2014). The categories used when thematically ordering the data were based on the relevant areas found in the pre-study and in existing project management literature. These areas were time management, cost management, quality management, risk management, communication management and knowledge management. Following the categorization of the empirical material, it was further analyzed to highlight the relevant material from each category. In this way it was possible to reduce the material to only contain the relevant information for the study, which is in line with data reducing described by Collis and Hussey (2014). The data analysis was made in parallel by both authors in order to not get biased when interpreting and analyzing the material.

2.3 Quality of analysis

2.3.1 Reliability

Due to the qualitative method in this study, which is mainly based on semi structured interviews, the reliability could be argued to be rather low. This is because of that the gathered data from a semi structured interview can vary due to many aspects such as the focus areas of the interviews, the interviewees and interviewers mood and concentration, but also the interpretation of the gathered data (Blomkvist & Hallin, 2014).

Another aspect that could have a negative impact on the investigations reliability is the fact that the employee turnover is rather high within the studied projects due to the comprehensive durations of the projects. This gave rise to some interviews being held with employees that had not been involved in all project stages, which could have an impact on the communicated data. Furthermore, the fact that Company A, and thereby all interviewees, have chosen to be anonymous affects the reliability. Referring to (Collis & Hussey, 2014), the reliability of a scientific study is based on the probability of reaching the same result if the study was conducted again, using the same methodology. Hence, the anonymity of the individuals

interviewed in the case study, could be argued to lower the reliability of the research as a result.

The same interview template will be used while interviewing employees with the same project roles. This will create an opportunity to triangulate the collected data and through that decrease the presence of misleading information, thus also aiming on increasing the reliability of the study (Blomkvist & Hallin, 2014).

2.3.2 Validity

The validity of this study can be argued to be rather high because of the qualitative methodology used, which is aligned with the exploratory purpose of the research. Thus, studying the phenomenon that the research problematization states that the phenomenon should be (Blomkvist & Hallin, 2014).

Furthermore, the sample selection for the interviews have been customized to contribute to the perceived information demand. Hence, this made it possible to collect the data that has been anticipated to be needed. The theories used and discussed, does also logically relate to the research area that the study intends to explore and has been chosen based on the findings from the pre- and main-study.

Something that can affect the validity in a negative manner, is the high turnover rate within the project organizations and the extensive durations of the projects that were previously discussed. This could have had an impact on the collected data being weighted towards the project stages of which the interviewees have participated in or the project stage performed at the time of the interviews.

2.3.3 Generalizability

Blomkvist and Hallin (2014) argue that the generalizability of an investigation represents to what extent the findings from one particular study can be applicable to other situations. In a case study, this can be conducted through an analytical generalizability, meaning that this area is discussed in the end of the analysis section in order to illustrate and compare the findings of the studied phenomenon to other cases.

In the study, this process of analyzing the generalizability has been used, where we claim that this research can function as an initial investigation where the findings can be treated as guidance on the studied area. However, since this is made through a case study delimited to infrastructure projects including one case company, one could argue that the generalizability to other type of megaprojects is rather low.

2.3.4 Ethics

It is important to be aware of the ethical aspects when carrying out the case study. According to Blomkvist and Hallin (2014), the ethical codes that are used mostly in Sweden in the field of social science are the Swedish Research Council's principles of ethical research for the humanities and social science. These principles consists of codes that all researchers must comply with when conducting their respectively study. Thus, the code of conduct (Vetenskapsrådet, 2016) was taken into consideration when the case study was held at Company A. The interviews were performed in regard to the four principal requirements stated by Blomkvist and Hallin (2014). The first principle, the information requirement, entails that the individuals that are interviewed needs to be informed about the purpose of the study. The second principle, the confidentiality requirement, entails that the material and information collected from the study must be treated with confidentiality. The third principle, the consent requirement, entails that the individuals who are being studied have to agree to be studied. The last requirement, the good use requirement, entails that the information and material that emerge from the investigation, should only be used for the stated purpose of the research.

Further, inquired by Company A, a non-disclosure agreement was signed between the researchers and the organization. This entails that Company A ascribes the right to make the information and documentation from the case study confidential, and must be approved before published. However, this has not affected the study to any further degree and has not prevented the investigation of the phenomenon analyzed in the research.

In the writing process, the ethical aspects were taken into consideration using the correct references regarding the sources used in the report. This also concerns the rules of plagiarism, stated by the Royal Institute of Technology.

3. Literature study

This chapter will assess the previous research on megaprojects and its related fields. This will provide with a conceptual background of the field of megaprojects and its adjacent research area program management. Further, an assessment of the previous research within project management standardization and project IT-systems will be performed.

3.1 Introduction Megaproject

When a project becomes larger in form of duration and budget, and more complicated due to a large number of stakeholders and complex end-products influencing a large number of people, the project becomes more difficult to handle and control. Projects with these characteristics have been named megaprojects (Flyvbjerg, 2014). Scholars have not yet reached a consensus regarding the exact definition of what a megaproject is. The US Federal Highway Administration defined it as follow *"major infrastructure projects that cost more than 1 billion USD, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and state budgets" (Capka, 2006).* The most common characteristic when it comes to defining megaprojects is the budget, however there is no agreed definite budget limit that defines when a project should be called a megaproject or not. As described in the definition, the US Federal Highway Administration states that a megaproject should have a budget of one billion US dollars or more (Capka 2006), whereas the International Project Management Association (2011) argues for a budget limit on 100 million euro.

Despite the fact that budget is a frequently used topic when it comes to defining megaprojects, there are other factors that are relevant as well. Mutual for the majority of the definitions written regarding megaprojects is the duration of the project, the complexity of the project and the number of people that are affected by the project (Flyvbjerg, 2014). Thus, a megaproject should:

- have a large budget,
- extend over a large time period,
- have a high level of complexity,
- have an impact on a large number of people.

What a project with high complexity mean was defined by Homer-Dixon (2011). It implies that the project requires competences in a large number of knowledge areas, from now on called technologies or functions. That the technologies are dependent to each other, meaning that a change within one technology affects other technologies. The complexity is even higher if the impact on other technologies is nonlinear, meaning that the impact on other technologies not is proportional to the change. Furthermore, project complexity is characterized by vague project boundaries with various stakeholders.

This factors combined increases one crucial aspect of megaprojects which is high uncertainty and thereby high project risk. Fiori and Kovaka (2005) took this into account during the development of their five-criterion framework for megaproject definition. The five criterions declared were:

1. Cost
2. Complexity
3. Risk
4. Ideals
5. Visibility.

Due to these factors, there are certain types of projects that are frequently called and referred to as megaprojects, this is infrastructure projects, railway projects and large construction projects.

These types of projects are becoming increasingly conventional (Flyvbjerg, 2014). For example, China spent more money on infrastructure development during the time period 2004 to 2008, than they did throughout the whole 20th century. Flyvbjerg (2014) considered four factors that have a positive impact on this increase in megaproject developments, those are political, technological, economic and aesthetic. The political factor refers to the incentives that politicians have when investing in large projects. Their megaprojects can for example act as monuments of a politician's career and these projects often gets a lot of attention in media. The technological factor refers to the incentives that engineers and architects have when it comes to develop bigger, faster and higher constructions. The economical factor involves the economical gaining's that can be made by the involved parties. Contractors from various industries can get considerable revenue streams through participation in such a project. Lastly,

the aesthetic factor refers to why designers want to participate in megaprojects, it creates the opportunity to build something large and iconic (Flyvbjerg, 2014). Hence, the incentives of making a megaproject happen are several and they come from a diversified group of parties.

3.1.1 Challenges and pitfalls in megaprojects

The high complexity and volume of the megaprojects puts a lot of pressure on the organization behind the project, thus often result in various pitfalls. Flyvbjerg (2014) discusses the characteristics of these challenges and also refers to examples of megaprojects, where the outcome of these pitfalls ended in large overruns in both cost and time. Statistics of performance data of megaprojects states that 90% of these projects go over budget. Here, it is often common with overruns up to 50% which reflects the public sector as well as the private sector.

In the study conducted by Flyvbjerg (2014), unsuccessful megaprojects around the globe are analysed where the cost-overruns are represented. An example is the cost overrun during the building of the longest underwater rail tunnel between France and the United Kingdom. A project that ended in costs that were 80% more than expected from the beginning. Further, the International Airport in Denver resulted in a cost- overrun of 200%. Lastly, the Sydney Opera House is also an example where the project resulted in a negative outcome through economical aspects, a budget that was exceeded with as much as 1400%. The mentioned illustrations of unsuccessful megaprojects show the impact of a manager that loses control over their budget and thus indicates on the importance of a functioning project management that supports the organization behind these larger projects. The megaprojects may be a technological success that enables various benefits for individuals in the society. However, even if there is a technological success in these projects, there are often financial failure that affect project owners and shareholders in a negative way. Flyvbjerg (2007) argue that many of the megaprojects have long construction periods and are financed through loans, thus making them highly vulnerable to delays. This will in turn lead to increase in interest payments and by that also longer payback periods. In the study conducted by Flyvbjerg (2007), an investigation was made in relation to the cost estimations done in the transportation industry. The research was done in 20 nations where the cost overrun is constant for the 70 year period that the study covers. The result is presented in table 2.

Table 2: Cost estimations in the transportation industry.

Project characteristic	**Number of projects**	**Average cost overrun**
Road	167	20.4 %
Rail	58	44.7 %
Tunnels and Bridges	33	33.8 %

In order to understand the background to the failure of these type of complex projects, Flyvbjerg (2014) stated the 10 most common pitfalls and challenges when conducting the project lifecycles:

1. There is often multiple actors and stakeholders involved in the projects that can include both private and public sector. This result in conflicting interests that makes the planning and decision making difficult to accomplish.
2. As a result of a long planning horizon, the Mega project are risky and complex to go through with.
3. There is a high turnover of planners and managers in the megaprojects that often lack experience and deeper knowledge. This result in weak leadership and loss of control in the projects.
4. A lock-in effect is often created as a result to over commitment in the early stages of the project. This leads to an absence of other alternatives that could have given a better outcome in the end. Further, the early lock-in also leads to an escalating commitment in the later stages.
5. A phenomenon called the uniqueness bias can be created as an outcome to the non-standard technology. This is making the planners and managers viewing their project as singular, thus contradicts the willingness to learn from other projects.
6. Over time, the ambition of the project as well as the scope will change crucially.
7. A principle-agent problem may arise because of the large amount of money involved in the megaprojects. According to Leopold-Wildburger and Mietek (2010), this means that one manager who serves as an agent for the owner, will act in the interest of him- or herself

instead of the shareholders. Thus, making sure that their own needs are satisfied and not the owners.

8. Statistics show that the unplanned events and the high level of complexity in megaprojects, result in budget and time overruns.
9. Managers often have an illusion that they have control over their projects and thus ignore the high risks. However, this may lead to "Black Swans" meaning that this type of behaviour will result in a catastrophic outcome as a consequence.
10. Failure and misinformation in areas such as risks, schedules, benefits and costs is a norm throughout the different phases of the Megaprojects. This leads to consequences where cost overruns and delays are the outcome.

According to Flyvbjerg (2014), the concept of delivering value through megaprojects to both public and private sectors is increasing in demand. However, the performance in managing these projects in aspects of cost overruns, benefit shortfalls and schedule delays has not decreased throughout the 70-year period for which data have been available to evaluate. A common problem is that planners and managers in the organizations lack the incentives or do not know how to deliver successful megaprojects in practice. Thus, projects tend to "break" and later must be reorganized with the aim of "fixing" the problems to deliver a version that is as similar to the initial plan as possible. This often have consequences where the stakeholders are affected negatively before they have time to pull out. In theory, this is called the "break-fix model" and often happens when reality catches up with unrealistic or over optimistic plans. Furthermore, because of that the megaprojects are easy to begin with but difficult and expensive to finalize, these projects have also been called "Vietnams" (Ross & Staw, 1993).

In the study conducted by Flyvbjerg (2014), the author argue that the promoters of the megaprojects tend to believe that their project will be beneficial to the society and thus makes them justified into underestimating costs and overestimating benefits. This is however a problem that have critical consequences as a result to the false benefit-cost ratio. The first problem is that managers start their projects, even though they are not financially viable. Secondly, it can also result in a situation where another project idea is rejected, that could have been more successful, with higher return for the investors and shareholders. Both situations have an outcome that result in Pareto-inefficiency (Flyvbjerg, 2007) a misallocation of resources, thus leading to losses in money for shareholders as well as taxpayers. Referring to Flyvbjerg (2014), this also leads to a climate of an inverted Darwinism where the law of

“survival of the unfittest” rules, an outcome where projects that looks best on paper survives but in reality contains large underestimation of costs and high overestimations of benefits.

In the research made by Flyvbjerg (2007), the author argue that cost overruns and benefit shortfalls can be classified into three main areas of explanation; psychological-, political/economic- and technical explanations. The psychological explanations are based on the optimism bias that according to Sharot (2011) is defined as “the difference between a person’s expectation and the outcome that follows”. A human behaviour that makes us underestimate the likelihood of negative events and is substituted with scenarios of success, resulting in projects that go over budget with less returns. Political-economic explanations is based on a strategy where managers have the desire to increase the possibility that their project is provided with funding and not the competitors. This leads to a climate where the planners overestimate benefits and underestimate costs when they are conducting their respectively forecast. This is founded in political and organizational pressure that result in projects that do not deliver as expected. Lastly, the technical explanations are based on unreliable data, lack of experience and wrong forecasting models. This will in turn contribute to the problem of cost overruns and benefit shortfalls in megaprojects.

Flyvbjerg, (2007) make a conclusion that the most critical factors in underestimation of costs and overestimation of benefits in megaprojects is a relation between the psychological and political-economic explanations shown in figure 2. The psychological explanation is illustrated by the level of optimism bias and the political-economic explanation is illustrated by the level of strategic misrepresentation. By analysing figure 2, it is clear that the optimism bias is increased when the political and organizational pressure is low. This in relation to the strategic misrepresentation that increases with the rising level of political and organizational pressure that often occur in large public projects with powerful stakeholders.

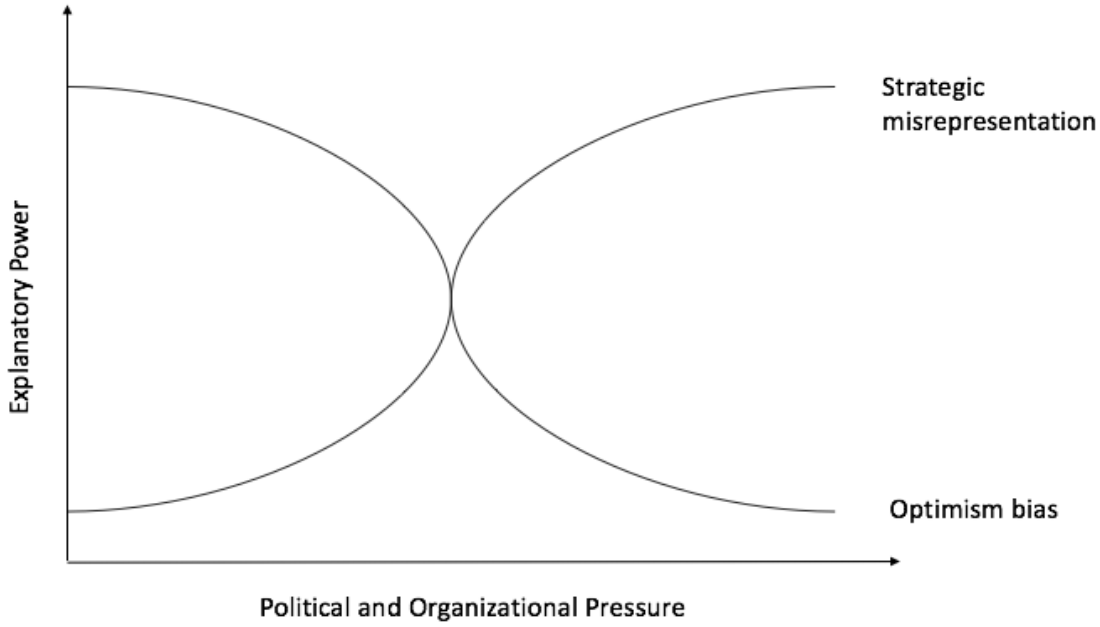

Figure 1: Relation between the psychological and political- economic explanations.

Flyvbjerg (2007) demonstrates how the two explanations is the foundation to the incorrect forecasting methods and how they complement each other in the inaccuracy of decision making.

3.2 Performing multiple related projects simultaneously towards the same objective

When projects become bigger and more complex the project organization become more extensive, divided and specialized. In a railway development project for example, the number of different technique specialists involved are large. This fact creates a situation where different technique specialists perform their work isolated from other techniques, which can be likened with projects within the megaproject. This way of organizing a project is usual within megaprojects (Badman & Sjöberg, 2016), there is therefore a close connection between megaprojects and the theoretical area of program management.

Program management is defined as the process of coordinating several related projects, usually divided by function, in order to gain synergies and thereby reach a better result compared to if the projects were performed individually (Badman & Sjöberg, 2016). One large task for a program manager is to identify which projects that are related to each other

and how they affect each other, so that the projects are aligned and have the same objectives. According to Blomquist and Müller (2006), there is a distinct difference between the program manager role and the project manager role within a program. The project manager's role is to make sure that the assigned sub project is performing on target. This comes with responsibilities for both planning and execution of the sub project on a detailed level, whereas the program manager is assessing the holistic program performance and the coordination between sub projects. One crucial task for a project manager within a program is to handle communication, both from the own sub project up to the program organization and vice versa.

The main challenge within a program is to enhance coordination between the sub projects, to maintain this, a robust communication and information sharing plan is needed. Badman & Sjöberg (2016) assessed the previous research on communication and information sharing within programs and identified three challenges among with solutions to the challenges.

- The first area is the management of large quantities of data. A large amount of data is created from a large amount of activities in a program. This creates the need for a common data storage system where the data is stored and available. However, resources should also be invested in data coordination, ensuring that the shared data is of high quality and is easy to find.
- The second area to consider is cross functional communication. Since several interrelated projects are conducted simultaneously within a program, there is a vital need for communication on a cross functional manner to align the different projects. The projects are usually separated from each other which makes cross functional communication overlooked.
- Thirdly, the program manager should focus on the right things. A common challenge when conducting programs is that the program manager take on too much work. A program manager should, as mentioned, focus on coordinating the projects by the implementation of adequate communication tools and guidance of the project managers. If the program manager focus too much on project specific issues, there is a high risk that the coordination decreases.

In order to handle these three common challenges, previous scholars suggests several actions (Badman & Sjöberg, 2016).

- The first is to establish a program management office, whose responsibility is to establish standards for communication and information sharing and to ensure these

standards. Program management office responsibilities can also be to manage finance, coordination, quality, risk and schedule (Sowden, 2011). Establishing a program management office would help the program manager to handle the large amounts of data, giving the program manager time to focus on the right things. It can also enhance cross functional communication efficiency through the implementation of communication standards.

- A communication plan should be created, covering the communication standards, which can act as a guide for communication to all members of the program organization. It is important that this plan is developed in close collaboration with the different functions of the organization to assure that all relevant aspects of communication can be handled, at all levels. The plan should explain when, how, to whom and level of detail of the communicated information (Blomquist & Müller, 2006).
- A program information system should be implemented. This system should provide data storage for the whole program. All program relevant information should be stored in this system and it should be up to date. In this way, there is one place where program data and information can be found and gathered. This system should also contain the information and templates needed to ensure the communication plan (Kendall & Rollins, 2003). It is important that the communication plan and information system is developed in conjunction with the program organization. In this way the communication plan and information system can be created based on the organizational needs and not the other way around (Thiry, 2002).
- Lastly, even though previous actions have been about standardizing communication, informal communication is still an important part to the program progress (Dietrich & Lehtonen, 2005). Enhancing informal communication between program members creates an organizational environment where information is shared instead of restrained. This can give program members a good understanding of the program as a whole and the progress of it. However, it is important that the informal communication is accurate so that misinterpretations can be handled (Altwies et al. 2008).

3.3 Project standardization & information technology utilization

Standardization is a hot topic within many research areas. Within project management however, it is a rather recent area of research. As in other areas, standardization is also within

project management a compromise between efficiency and flexibility. To a certain degree, standardization of parts of the project process could increase the project success. However, above that degree of standardization, it could have a negative impact since it could hamper flexibility (Milosevic & Patanakul, 2005). Three project areas were especially shown to increase project success when standardized: project management tools, leadership and project process. Implementing a standardized project process entails the establishment of a repeatable process including determined phases and states that should be used for projects throughout the organization. Standardized project management tools imply that a selected number of tools should be used consistently within projects and be implemented in the standardized project process. Furthermore, a standardized leadership within projects refers to that all project managers should hold a standardized set of managerial and leadership skills (Milosevic & Patanakul, 2005). A key finding from the study by Milosevic and Patanakul (2005) is that establishing a collection of standardized procedures and methods for the project organization to choose from is a good way of enhancing both standardized procedures and flexibility.

A contributing factor to the escalation of project management standardization is the entrance of project management software and IT-systems. Furthermore, according to Habison (1985), a precise time and cost planning system is needed to measure delays and cost increases in complex large scale projects in order to enhance control and to be able to determine the responsibility for the resulting costs. Since the release of the personal computer, studies show that the project management software usage has increased rapidly and steadily. In a study by Liberatore and Pollack-Johnson (2003), investigating the factors influencing project management software usage, it was found that project management software is used in 90%-95% of the projects conducted within companies. Furthermore, it was shown that the strongest factor affecting project management software usage was the complexity of the project and the number of activities within the project. The project size and complexity also had effects on what the software was used for. For smaller projects, project management software was predominantly used for planning. However, with increased size and complexity, project management software was also used for project monitor and control (Liberatore & Pollack-Johnson, 2003).

A more recent research on the subject was conducted by Ali et al. (2008), which findings confirmed these mentioned correlations, their study did also confirm the correlations for project driven companies. Furthermore, it was shown that software functionality, ease of use,

information quality, organization size, user experience, education, and project complexity have a positive influence on software utilization. The quality of the information provided by the software was the strongest factor to use a project management software, followed by the project complexity. Ali et al. (2008) also investigated the correlation between project management software utilization and project success. It was found that there was a correlation between increased software utilization and project success.

4. Theoretical framework - Contextualizing project critical areas

In this section a review of the present project management theory will be performed. This will be used to develop a theoretical framework that later will be used to analyze the gathered empirical data. Due to the limited previous research on the management of megaprojects, the framework will be constructed of research and theory on critical areas within traditional project management.

4.1 The project life cycle

The broadest accepted description of the project life cycle was first suggested by Adam and Barndt (1983) and is built up by four different phases, the conceptualization, planning, execution and termination phase. Adams and Barndt (1983) argued that projects and programs could be interchangeable in theory. Both exist due to the purpose of reaching a specified goal under a specified time-plan and budget. When the goal has been met, the project or program is dissolved. From this definition of a project, a predictable project life cycle could be identified, with different phases characterized by the type of tasks and points of decision within them. The level of effort invested in each phase is largest in the execution and planning phase, as shown in figure 3. Adams and Barndt (1983) argued both for what managerial actions that should be part of each phase and also what tasks that is needed to be completed in order to move on to the next phase.

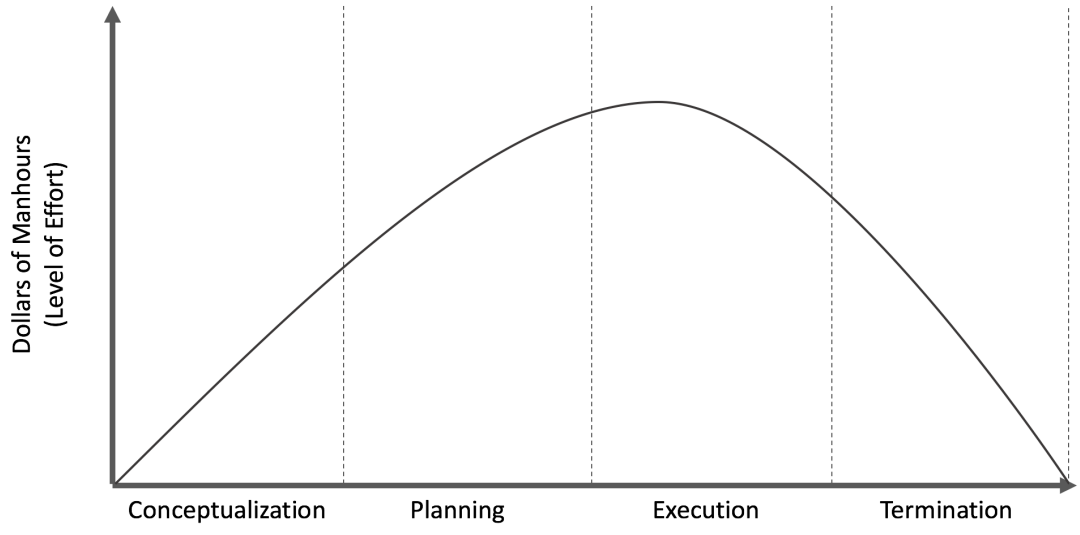

Figure 2: Effort level divided by project phase (Adams & Barndt, 1983).

4.1.1 Conceptualization

This initiating phase of a project is taking part when the need for a project has been perceived. According to that, the first task within the conceptualization phase is to determine that a project is needed. Following this, the feasibility of the suggested project should be evaluated and alternative actions should also be assessed. Furthermore, a project proposal should be prepared with the objective to sell the project to the involved stakeholders and argue for the relevance of the project. Within this work, a holistic estimation of the project's budget should be performed together with a basic schedule containing the overall milestones of the project (Adams & Barndt, 1983; Westland, 2007).

The actions that should be made by the project manager within the conceptualization phase are initially to identify the need for the project and to establish the project goals. The project manager should also sell the project to the organization and the possible stakeholders. Lastly, the project manager should appoint employees to the key roles of the project organization (Adams & Barndt, 1983).

4.1.2 Planning

The planning phase of a project addresses, as its name suggests, when, how and by whom the project and its associated tasks should be performed. The project should be planned in detail and beside a time-plan for the different activities, a plan should be established for resources, budget, quality, risk, communication, procurement and contractors. This is made in order to ensure that the goals and objectives stated in the conceptualization phase are reached, under the right time and budget (Adams & Barndt, 1983; Westland, 2007). The content and purpose of each plan is presented in the following table 3 based on the work by Westland (2007).

Table 3: Description of the areas of project planning (Westland, 2007).

Time plan	The time-plan should contain a work breakdown structure (WBS) consisting of hierarchical structure of the different phases, activities and tasks of the project. This WBS can then be used by the project management to control and compare the actual project progress to the plan.

Resource plan	The resource plan should comprise estimations of what resources that are needed for the activities stated in the WBS. In this resource plan, the type of resource, the quantity of each resource, roles and skill requirements of human resources should be assessed.
Budget plan	With data from the time and resource plan a budget plan can be created since time and resources for each project activity have been estimated. This plan should present the estimated cost of the project as a whole as well as for each activity.
Quality plan	The quality plan should specify the quality expectations of each deliverable in order to control that the project deliverables are meeting their expectations.
Risk plan	A risk plan should assess the different risks with the project and actions that can be taken in order to prevent them from happen and to reduce the negative impact if they should happen.
Communication plan	The communication plan should state how information should be communicated to stakeholders and project members. It should describe what information that should be shared, who should do it and when it should be done.
Procurement plan	This plan should describe which products or services that should be procured from suppliers during the project. It should also describe how a supplier should be selected and when the product or service should be procured.

4.1.3 Execution

In the execution phase of a project, the actual work or development is performed through the implementation of the plans established in the planning phase (Adams & Barndt, 1983). In order to build the deliverables in accordance with the plans, an important part of the execution phase is monitoring and control. This is the project manager's responsibility during the execution and involves time management, cost management, quality management, change management, risk management, issue management, procurement management and

communication management. While the majority of these areas are about controlling that the work is performed in line with the plans, issue management refers to the handling of appearing problems that are hindering the development work. It is the project manager's responsibility to evaluate the problem and decide on actions to solve the occurring problem (Westland, 2007). These management areas will be further discussed in chapter 4.2.

4.1.4 Termination

The termination phase involves activities to finishing the project, which is mainly the project manager's responsibility (Adams & Barndt, 1983). This involves ensuring that the project objectives have been met and that the developed product or service fulfils the quality specifications stated in the quality plan. Any unimplemented project activity or remaining risk or issue should be identified and in that case be handled. When these activities have been performed, the project can be delivered to the customer with an assured delivery. The activities following the delivery are to realize the resources that are linked to the project and cancel the contracts that have been set up with suppliers.

4.2 Critical project management areas

In order to succeed with a project, a project organization has to adapt to the different previously described phases of the project life cycle: conceptualization, planning, execution and termination. Furthermore, during the undertaking of the different phases, there are several aspects and management areas needed to be controlled. The project management institute have established a widely accepted selection of critical theoretical project management areas. These include the following (Snyder, 2014):

- Project integration management
- Scope management
- Time management
- Cost management
- Quality management
- Human resource management
- Communication management
- Risk management
- Procurement management

From this list of project management fields, time, cost, quality, communication and risk management have been chosen to be further reviewed and analysed. Furthermore, the area of knowledge management will also be assessed. This is since those areas were emphasized to a larger extent during the conducted pre-study and were mutually seen as the most critical areas.

4.2.1 The iron triangle of project management

One of the main objectives when conducting a project is to develop or deliver something at a certain and specific time. In order to ensure that the project deliverables are completed in time, time management is of large importance. However, time is not usually the only project objective, the developed product should also satisfy certain quality and functionality specifications. When trying to reach time and quality objectives simultaneously, there is one factor that can usually be affected, the cost of the project. This connection between project time, quality and cost is a phenomenon that by scholars often has been called the iron triangle of project management (Atkinson, 1999), which is illustrated in figure 4.

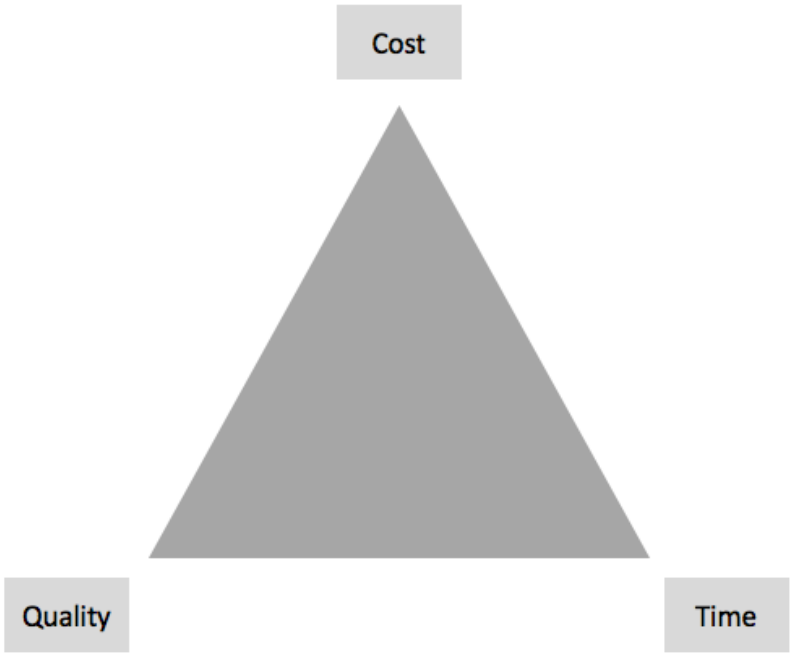

Figure 3: The iron triangle of project management (Atkinson, 1999).

The iron triangle describes the relationship between time, quality and cost objectives of a project and that it is difficult to change or improve one of the objectives without affecting the two other objectives. For example, achieving higher quality would either demand for an

increased cost or an increased time duration. On the other hand, achieving a shorter completion time would either increase the cost, if the same quality should be obtained during a shorter time frame, or simply decrease the quality, if the project budget cannot be increased (Ebbesen & Hope, 2013). This way of describing project performance has lately met critique to not be sufficient. Ebbesen & Hope (2013) argued that sustainability should be incorporated in the model and that the model has a lack of focus on business aspects such as customer satisfaction and profitability.

To control the time, quality and cost of a project, these aspects needs to be under careful consideration throughout the project. During the initiation, it is important that the objectives stated are reasonable and possible to reach. Following this, a valid plan for how these objectives should be reach must be created, as discussed in section 4.1.2. Furthermore, during the execution phase, the plans and objectives have to be carefully monitored in order to assure a demanded result. There are several tools and techniques developed that have been proven to achieve this, which will be discussed hereinafter.

In order to create a manageable understanding of the time, quality and cost implications of the project, it is useful to evaluate what tasks and activities that have to be completed in order to reach stated goals (Iewwongcharoen, 2010). A work breakdown structure (WBS), mentioned in section 4.1.2, has shown to be a contributing factor in increasing project success. A WBS is when a holistic project plan is broken down into smaller tasks and activities. This breakdown of activities defines the work that is needed in order to achieve the project objectives. The main aspect of value creation using a WBS is that it helps ensuring that project deliverables meet their requirements since each deliverable is broken down in detail. Hence, it adds value when used during the termination phase (Iewwongcharoen et al. 2010). Furthermore, Fleming and Koppleman (1996) described WBS as follows *"the WBS provided an opportunity for all key functions on a project to view the project in the same manner, to speak a common project language for the first time"*.

When the project has been broken down into detailed tasks and activities, a schematic workflow can be established by sequencing the tasks and activities in a chronological order. A critical path can be developed, mapping which activities that have to be performed before other activities are initiated. By sequencing the tasks with duration estimations for each task and activity, the total duration of the project can be estimated and furthermore, the relation

between different tasks and how they affect each other during eventual changes is shown. This method is called critical path method (CPM) (Izmailov et al. 2016). According to Iewwongcharoen et al. (2010), a CPM is primarily adding value to the control of time, cost and quality during the planning and execution phase. This is since it helps the project manager to focus on the areas that are critical for the project to be delivered on time and on budget.

When tasks and activities have been sequenced in a chronological order a detailed cost estimation can be made. This is called a cost baseline plan and it is an estimation of the project cost distributed over the planned project time. A cost baseline is usually created through bottom up calculations, estimating the cost of every activity defined in the sequenced WBS (Maylor, 2010). The cost baseline estimations can then be used to control budget throughout the progression of the project. This type of cost estimation has shown to be contributing to project success, from its establishment in the planning phase until the project termination since it give the project manager the ability to control project costs at any time of the project (Iewwongcharoen et al, 2010).

In order to control the quality during the ongoing project the WBS has shown to be useful. With the WBS as a reference, the project development can be divided into several logical phases. During the planning phase, clear objectives should be established for what the quality of the developed product should be at the end of each logical phase. A continuous quality analysis can then be performed at the end of each logical development phase, meaning that the current state of the project is compared to the requested state at the end of the phase. This way of assessing quality has by scholars usually been called milestone analysis. It is important that the milestone states are clearly described and possible to compare with the actual performance (Andersen et al. 2009). According to Iewwongcharoen et al. (2010), milestone analysis is effectively contributing to project success when used in the execution and termination phase, since it facilitates the control of quality and thereby of cost and time. Furthermore, since quality can be defined as the gap between the expected performance and the actual performance of the developed product (Maylor, 2010), it is of great importance that the stated quality specifications are based on the expectations of the project stakeholders with regard to the different interests between different stakeholders. In that way, ensuring quality throughout the project also entails ensuring that the demanded product is developed.

4.2.2 Risk Management

Risk management can be defined as a process where selected decision-agents control and evaluates the risks throughout the project life cycle. This, with support from the organizational and administrative methods used to take decisions in accordance to the risks with the aim of managing the project successfully (Crispim & Rodrigues-da-Silva, 2014). An essential part in the risk management process entails prioritisation of various risks that may affect the project. These priorities are often different depending on the actors and their respective interests and criterions for success. In the study conducted by Krane, et al. (2012), the authors state that the project risk management can be divided between strategic and operational risks. The operational risks are considering the direct result and accomplishments throughout the project phases where the project manager has the responsibility. The strategic risk consists of both short-term risks in terms of success factors for the project owner and long-term risks regarding sustainable aspects that affects the society. However, result from the research show that a majority of the identified risks in the study contains of operational risks, thus indicating on shortcoming in strategic risk management of the projects.

There are various benefits that follows by conducting a thorough risk management strategy throughout the project phases. Hwang et al. (2014) argue that project risk management enhance the formulation of a realistic project plan, generating an understanding and identification of the individuals in the organization that is most suitable to be responsible for the specific risks. This leads to a situation where it is easier to confront risks and thus improves the decision making in the projects. Further, Mills (2001), writes about the advantages of risk management and how they improve the outcome of the projects. This include acceptance of risks in the initial phase of the project resulting in lower costs, cost-benefit assessment of risk control, but also removal of unnecessary contingencies.

To manage the risk identification throughout the project lifecycle Crispim and Rodrigues-da-Silva (2014) have developed a framework that evaluate the practises used by managers in the different phases of the project. Depending on the maturity, to which degree the organization proactively takes action in accordance to the identified risks, and complexity, the risk management practises should be structured in relation to the management process of the project in the following structure:

- ➢ Identification of risks
- ➢ Evaluation and analysis of risks
- ➢ Planning and acting against the risks
- ➢ Controlling the risks
- ➢ Reporting and integrating against the risks
- ➢ Supporting risk project management

The risk management process conducted by Crispim and Rodrigues-da-Silva (2014) should be used in all of the project phases when identifying and acting against the strategic and operational risks that come up through the project life cycle.

4.2.3 Managing the communication process in projects

Kerzner (2001) define communication management as a formal or informal process of managing the exchange and transfer of information effectively throughout the organization. Zulch (2014) writes that information flows in four directions in a project. Downward communication is conducted with the aim of sharing policies, strategies and goals from top management down to the worker level of the project, and is filtered in this process for each level. The upward communication on the other hand, provides the top level of the project hierarchy with information of progress and challenges in the project. Further, the horizontal communication is made between individuals on the same levels and support the coordination of the work. Lastly, the diagonal communication makes it possible for individuals on different levels to provide each other with information that is needed for either one or both parties.

By taking the four communication directions into consideration, it becomes clear of the importance of the project manager's role and his or her ability to manage the communication process. In practise, this requires that the correct information needs to be managed to the right individuals in the organization, on the right time and in an efficient way when it comes to costs. However, this is easier said than done. There are a lot of barriers when it comes to managing the sharing of information in an organization (Kerzner, 2001). Challenges may arise because of perception barriers that is based on messages that are viewed in different ways depending on the individual that are interpreting the message. This can be the result of an organization that consist of individuals with different background such as education or experience. Further, barriers affected by personality and interests can also prevent the

managing of communication in the way that individuals have different likes and dislikes. It makes the employees listen to the information that are suited to their own interests, and let the rest of the information float by. Lastly, prejudices, emotions, and attitudes are factors that influence the interpretation of information. This can result in situations where people try to protect themselves by trying to distort the communication processes in their own favour.

In order to reach the project objectives, Zulch (2014) argue that the people communicating with each other in the team needs to integrate, share their knowledge and collaborate successfully. It is thus necessary that that the communication process is understood in accordance to the three main stages; an individual sends the message, the message is sent through a transmission channel and lastly picked up by the receiver that will use the information. However, it is one more area that is vital in this process and that is described as the communication medium, meaning that the message has to be transmitted into a specific code. The transmitter encodes the message through the communication channel by a verbal or non-verbal process, and is later decoded by the receiver. All these mentioned areas need to be managed correctly to reach an efficient communication process throughout the project phases. To ensure this, Zulch (2014) states that a project communication plan needs to be conducted in the following structure illustrated in table 4. This should be arranged before the project starts so that all the participants involved can send and receive the information that they need to proceed their respectively work. This will at the same time increase the control over the project throughout the project lifecycle and keeps the key stakeholders informed.

Table 4: Structure of communication plan (Zulch, 2014).

Who	Sender and receiver of the message including responsibility and authority.
What	The scope of the communication and format of the information.
When	Planning and scheduling when to send the message.
Feedback	Receiver confirms the message and that the information is understood.
Filing	Retrieval, storing and recovery.
How	Meeting, document and email etc.

4.2.4 The importance of a knowledge sharing organisation

There are a lot of information that is communicated in a megaproject and there is often a large number of individuals that interacts through the different phases of the projects. This puts a lot of pressure on the knowledge sharing process in the organization in order to manage the projects successfully. However, in order to first define knowledge management, it is important to understand the difference between knowledge, information and data. This is described by Ackoff (1989) in table 5.

Table 5: The difference between knowledge, information and data (Ackoff, 1989).

Knowledge	Knowledge is information that has been organized and authenticated in a way that makes it useful
Information	Information is data that has been connected and thus given a meaning. This can be both useful and unuseful depending on the context
Data	Data can exist in various forms and does not contribute with a specific purpose and has therefore no meaning by itself

Further, Alavi and Leidner (1999) argue that knowledge is a result of information that has been processed and filtered by an individual. This is made through different aspects such as judgement, observation and interpretation that differ depending on the individual that receives the information, thus making it personal. The personalized knowledge is therefore needed to be structured in a way that makes it interpretable in order to be useful to other people in the organization. Nonaka (1994) writes about the knowledge creation process and how it can be divided between two types of knowledge; tacit knowledge and explicit knowledge. Tacit knowledge is personalized and involves both cognitive and technical factors, thus making it difficult to communicate to other individuals in the organization. The explicit knowledge on the other hand, also defined as codified knowledge, is knowledge that can be transferred through a systematic language. Knowledge management can thus be defined as a "systemic and organizationally specified process for acquiring, organizing and communicating both tacit and explicit knowledge of employees so that other employees may make use of it to be more effective and productive in their work" (Alavi & Leidner, 1999).

4.2.4.1 Knowledge Management Systems

The need of sharing and communicating knowledge has encouraged organizations to develop information systems that supports the process of facilitating and integrating knowledge (Alavi & Leidner, 1999). This is a system called Knowledge Management System (KMS) and focus on organizing, creating and gathering an organization's knowledge. KMS raise the ability to respond more quickly to the changing and harsh market of today. Furthermore, it improves the decision making and thus increases the productivity and performance of the firm. Alavi and Leidner (1999) argue that the KMS also is used as a repository system where the knowledge in the organization can be stored and communicated to other divisions and functions within the company. It is based on an IT system that enables the knowledge to be shared through a network, connecting the users and contributors of the system. In practise, this is conducted through different collaboration and communication techniques that make it possible to transfer the tacit knowledge between the users. In figure 5 Bolisani & Handzic (2014) illustrates the correlation and interaction between technology, process and the people behind the KMS infrastructure. It shows how the organizational aspects, communication technology, and information affects each other in the KMS network.

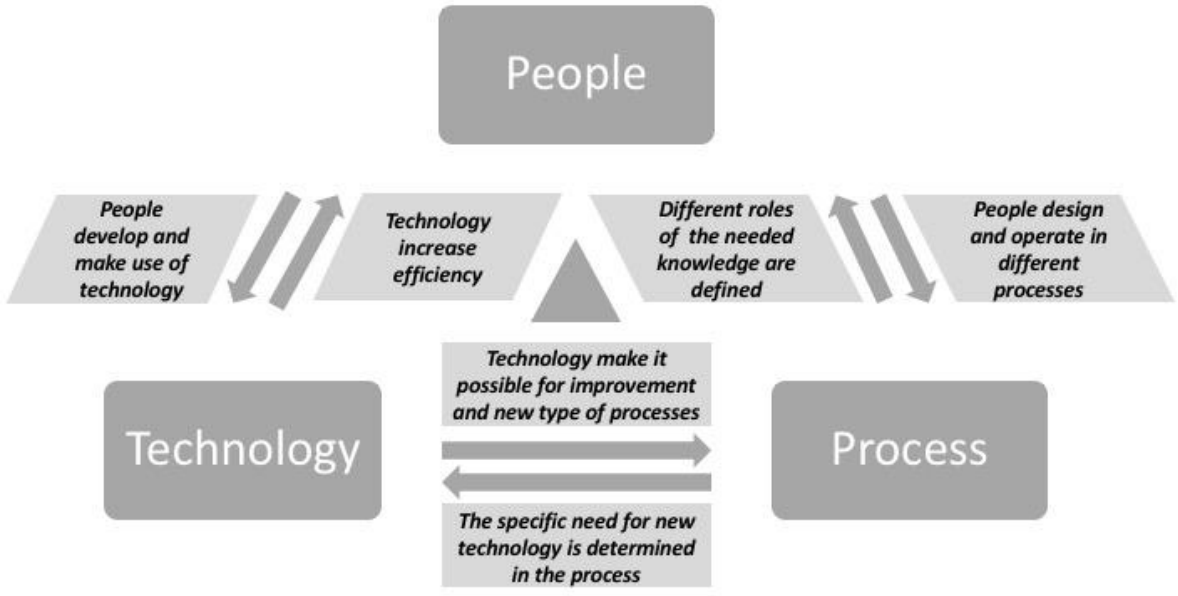

Figure 4: Interaction between technology, process and people in the KMS infrastructure (Bolisani & Handzic, 2014).

It is however vital that the whole organization adapt and participate in the KMS to fully utilize the benefits and success factors. According to Alavi and Leidner (1999), the KMS is

highly dependent on the organizational and company culture. This is because of that the users are both beneficiaries and contributors of the KMS, resulting in a system that requires constant maintenance. Thus, it is also important to build a cultural acceptance around the KMS in order to encourage employees to share their knowledge to other individuals in the organization.

5. Analysis

In this chapter the gathered empirical material will be presented and analyzed in an intertwined manner. The analysis will first address common challenges during the implementation of a megaproject that have been identified. Furthermore, the different types of information and data that are needed to be shared and controlled will be examined. This type of information and data have been divided into two holistic categories, quantitative and qualitative.

5.1 Common challenges throughout the megaproject lifecycle

The way to structure a project is in many ways similar when comparing smaller projects to larger projects. The project lifecycle phases conceptualization, planning, execution and termination developed by Adams and Barndt (1983) are also found within the investigated megaprojects, although in modified and adapted versions. The size, complexity and duration of a megaproject are factors that affects the content and workload within the different phases. In accordance with Adams and Barndt (1983), the level of effort invested in the different project phases are largest within the planning and execution phase also within the studied megaprojects. These differences have a logical connection to the number of activities that are allocated to each phase, which is largest within planning and execution. However, there are distinctions between how project management theory describes project phases and how the phases are used within the studied megaprojects. One example of this is that the boundary between different phases can be rather vague. The phases often overlap each other. A clear illustration of this is the boundary between the planning and execution phase. As one of the project managers at Company A described it

> *"We divide the planning into different stages, the nearest stage is planned in detail whereas the planning of succeeding stages is left for later. One fact within large projects is that nothing will end up as planned".*

Thus, project planning and execution is performed in an intertwined manner. One logical reason to this is that it requires such an extensive initial workload to plan the whole project in detail at an early stage and to create a WBS as Westland (2007) suggests. Also, as stated in the quotation, things rarely unfold as planned when it comes to larger projects. Which is why

a detailed and long term WBS can be considered as a waste of useful time. However, to not develop a comprehensive and detailed time-plan may result in that some of the benefits of having a WBS are missed, and further that nothing end up as planned within larger projects may also be the result of insufficient planning. As described by Maylor (2010), Andersen et al. (2009) and Iewwongcharoen et al. (2010), a WBS is a powerful tool to use in order to control that the project is continuing as requested during the execution and termination phase. Furthermore, as stated by Westland (2007), the planning of time, resources, budget, quality, risks, communication and procurements are all based on a detailed WBS. This entails that the different areas of planning can only be evaluated for the nearest project stage. It is therefore logical to say that large projects never end up as planned if the projects are not thoroughly planned in the first place.

When asked if it is even possible to break down a whole project with a duration of several years into its underlying tasks and activities, one of the project managers at Company A responded that it is. However, for that to happen, the project manager said that it is important to not bring the project into the execution phase to quickly but to let the project planning take time. Further on this issue it was mentioned that

> *"People are often eager to start working on the execution because that is where they have their interest and line of expertise".*

It may be favorable to keep clear distinctions between the different phases of a project, especially between the planning and execution phase, because in order to monitor and control the work within the execution phase, one is dependent of the project plan (Adams & Barndt, 1983).

A large challenge with megaprojects that was frequently mentioned during the case study is the numerous number of technology specialists and areas of expertise involved in the execution phase and which are active during the same time. This creates a clear source of complexity within megaprojects and it is in line with the definition of project complexity stated by Homer-Dixon (2011). A definition which is also included in the five-criterion framework for megaproject-definition developed by Fiori and Kovaka (2005). For example, when asked why megaprojects are so complex to conduct, one of the project members responded:

"It is the fact that the different technologies have to be coordinated and developed in coherence with each other that makes it complex. Without coordination, the end product would be a gathering of different technologies not compatible with each other."

Within the studied megaprojects, the execution phase is also the most extensive project phase in terms of duration and in number of activities. An inefficient way of conducting the work within the execution phase may therefore result in large overruns considering both time and cost, even though the overrun for each separate activity would appear rather reasonable. To monitor and control the progress during the execution phase is therefore of outmost importance and this was frequently mentioned as a key factor during the conducted interviews. This challenge and the dynamics of it will be further analyzed in the following sections.

5.1.1 Appointing resources throughout the megaproject lifecycle

A common challenge is to manage the distribution of resources in these types of projects. As mentioned earlier, megaprojects consist of many individuals with a high employee turnover throughout the project lifecycle. In Company A, this responsibility lies on the group manager that are responsible for a specific function, described in figure 1, that in turn is decided by the regional manager. One of the technique group managers described this process as follows:

"I am responsible to provide resources from my technique to the projects that my group is involved in. This can be complicated if the number of projects is large since my technique specialists are involved in several projects simultaneously."

One of the reasons for this process is that Company A consist of a matrix organization, meaning that each individual in the organization is involved in multiple projects on the same time, as mentioned in the quotation. The manager responsible for a specific technique can then make sure that the employees are fully utilized and that the projects are supported with new resources when it is needed. Another reason to this is that Company A wants to build competence on a broader level. According to a project manager that was interviewed, it is very obvious who you want to have in your team to deliver the project successfully. Although,

by having the process of distributing resources in accordance to Company A, this leads to a broader competence in the company, thus also lowering the risks of knowledge leaving the organization.

By analyzing the results from the interviews, it is clear that Company A have a lot of challenges in this area. Looking back at how the resources have been distributed earlier in Company A, this process resulted in a situation where the employees thought it was difficult to know what individual you should turn to when asking for new resources. One of the project members expressed it as follows

"I do not know who has mandate to allocate new resources to the project."

To face this problem, a project owner from Company A has now been appointed with this responsibility, together with the group managers responsible for the different techniques, shown in figure 1. This, with the aim of providing the projects with the specific competence needed. However, in the case study, it was clear that the lack of competence of whom to ask for new resources, still is a challenge that the organization is facing.

In order to make this process more efficient and to increase the control, an IT system could be used to support the resource distribution in the megaprojects. An organization that are handling these type of large projects needs to know the status of the resource capabilities, not just in the initial and planning phase, but also throughout the rest of the project lifecycle. As one of the group managers commented the present control of resources:

> *"We do not have any simple way of controlling how occupied our resources are in other projects, even though this is crucial to know."*

This implies that a lot of manual work and communication is needed from the group manager to verify how occupied the group's resources are. Furthermore, as most of the managers argued in the interviews, losing resources often result in delays that affect the customer relation negatively. Thus, the process of distributing resources needs to be coordinated and handled in a way that easily can supply the project organization with new resources, but at the same time do this in regard to the authority and process that the organization works in

accordance to. This is something that an IT-system could provide the organizations with, and therefore also induce awareness and control of the resources in all of the project phases.

5.2 Two different types of information

It was identified during the case study that the information and data that are created and shared within the technically complex megaproject at Company A can be divided into two different categories. The first category of information and data identified is of a status reporting character which is possible to break into simple constituents. This type of information and data we have chosen to name quantitative. The other information and data type identified is of a more qualitative nature. This kind of information requires more explanation which is why it is harder to simplify and standardized. This type of information and data we have chosen to name qualitative.

How to take on the challenge to control and share these different types of information will be further analyzed in the following sections. The current way of handling this will be described and analyzed with the objective of finding areas of improvement through the implementation of IT-systems.

5.2.1 Communication of quantitative data supported by information technology

A large amount of data and information are created and shared during the undertaking of a project, and the larger the project, the more data and information are created. Thus, within a megaproject we can conclude that the amount of data and information are high. A large part of this data is of a status reporting nature. Meaning that it is data that reports the status of time consumed, progress of project activities and costs. We have chosen to name this type of status data for quantitative data. In order for the project management to control that the project proceeds as planned, there is a demand for time, cost and progress data from all active project activities in order to be able to compare this with the planned consumption of time and money. One of the project managers described this control in the following way:

> *"In order to control the project budget, I need information from every individual in the project organization regarding how much time they have used and what progress this has resulted in."*

This management of time, cost and progress can be called the cornerstone of project management (Atkinson, 1999). The gathering of this quantitative data can quickly become unmanageable when projects increases in size and complexity. The usage of a supporting IT-system is therefore necessary for this type of data sharing and gathering. Within the studied projects, the sharing of quantitative data has been standardized and supported by IT-systems to a varying degree.

Starting with the reporting of time, it is something that every individual within the project organization does. The time spent on different project activities is documented into an IT-system on a daily basis. In this way project management can control the total amount of time spent on the project and thereby the current total cost of the project. However, as described by Iewwongcharoen et al. (2010), this type of data is of little to no use if it is not put in relation to the planned consumption of time and money according to the WBS. It was found during the case study that in order for the project management to put this data in context, there was a lot of manual work needed. As one of the interviewed project managers described it:

> "*Reported time is today exported out of the IT-system and is then administered and compiled manually in an excel document. This is since the IT-system for time reporting is not sophisticated enough to control and manage project time within large projects*."

As the quotation describes, this way of handling time data requires a significant amount of administrative work that is not creating value to project stakeholders. As of today, the time reporting IT-system is used as a tool to gather project time data and not as a tool to manage and control time data. As Liberatore and Pollack-Johnson (2003) argued, IT-systems can also be used to monitor and control aspects within a project and are increasingly used in that way the larger and more complex projects there are. However, as described by the quotation, an IT-system has to be accustomed and sufficient for the project needs in order to do so. The administrative work invested in the management of time data is manly about following up and updating the time-plan. This is to see how activities are proceeding and to control the costs of the time invested in each activity compared to the planned cost. As Maylor (2010) stated on the subject of time and cost management, it is favorable to be able to refer the time invested in project activities to the activities stated in the WBS and the planned time for each of them. If

an IT-system could demonstrate these relations and update the WBS with the actual invested hours in real time, it would result in a decrease in needed administrative work and an increased control over where time and money are spent.

Not only the project management have an outspoken demand for time control, also project members benefit from getting insights in planned and consumed time. As one of the interviewees responsible for one of the project technologies described it:

> *"In theory, every project member should keep track of their own time consumption and further how much time that are left to be used for their assigned activities."*

This is however something that is hard to control as of today, as another technology responsible outlined it:

> *"One problem with the present time IT-system is that you can not examine the budget, you can see how many hours you have used for a certain activity; however, you can not see how many hours that are left to be spent on each activity."*

These insights in consumed and total time for activities are something that an IT-system could help to enhance. To create an understanding regarding how one's own reported time affects the settled time-plan. This is in line with what time management theory says, as Fleming and Koppleman (1996) argued for, a WBS and time-plan creates a shared understanding throughout the project organization regarding how the project is planned to be pursued. Furthermore, a detailed time-plan that is constantly updated with the actual invested time in the different activities would create a better and shared understanding of how the project is progressing. Hence, the whole organization can benefit from getting an insight in a continuously updated and understandable WBS and time-plan.

Another problem that was identified during the case study, which an updated and transparent time-plan could be helpful in handling, is when project members communicate that their activities have progressed further than the actual activity progress. As one of the managers responsible for one of the project technologies addressed the problem:

"Sometimes it is difficult to anticipate delays since some individuals do not really want to share their actual activity status. They say that they are progressing according to time-plan, but it is shown later that they are delayed."

A regularly updated and detailed time-plan, as discussed previously, could be helpful in handling these difficulties. Again, the shared project understanding that a detailed time-plan creates (Fleming & Koppleman, 1996) can contribute to a better insight into whether an activity is delayed or according to plan. Further, if the reported time by the project members is directly linked to the time-plan, it would create a transparent image of how much effort that has been invested in the different prevailing activities.

There is however, as shown by the latest example, not entirely sufficient to just control and monitor the time invested in different activities. The progress of the activities must also be controlled and thereby communicated in an efficient and preferable simple way. For example, if you have an activity that is scheduled to take 100 hours to complete, then it is not enough to only report time on that activity. Because if the time reported on that activity for instance would be 50 hours, it could imply that there is 50 hours of work left in order to complete the activity. However, it could also mean that the activity is completed and that it went faster than planned to complete. It is apparent that data on task and activity progress also have to be communicated, which is in line with the theory on upward communication discussed by Zulch (2014). This activity progress reporting is within Company A as of today handled on a weekly basis, during several meetings, using face to face communication. This way of reporting activity status has been frequently discussed and questioned by the interviewees. It has for example been mentioned by interviewees that this way of reporting status through meetings is a waste of valuable time that could be allocated to other activities. As one project member expressed it:

"It is a lot of money in form of billable man hours that are wasted on meetings which are essentially about status reporting"

The alternative to sharing status information orally would be to sharing it digitally. That could result in streamlined ways of communicating large amounts of status data, which is the reason why project organizations choose to implement digital project management tools (Liberatore & Pollack-Johnson, 2003). However, only using digital tools to share status data with the

project organization may not be an optimal solution. As mentioned by one of the project managers of Company A:

> *"There would be a significant risk that project critical information does not reach those affected by it, if it not brought up and discussed during weekly meetings."*

This is in line with the discussion on standardized projects of Dietrich and Lehtonen (2005), if communication is only performed in a standardized manner, there is a risk for the project organization to become inflexible and slow in reacting to changes. In line with the project manager's statement, informal communication is important in order to give project members a good picture of the project as a whole and the progress of it (Altwies et al. 2008). Although, even if one should conclude that weekly status reporting meetings is important in order to update the project members on the latest happenings regarding the project, it was shown while observing one of these meetings that those could be considerably streamlined by making use of digital status reporting tools as well. If status information was shared digitally and updated in real time, meeting participants could be given a good understanding of the project and its progress already before the meeting has started. In that way, the focus can be placed on the actual challenges that the project organization faces, instead of using large parts of the meeting on reporting status.

5.2.2 Communication of qualitative data supported by information technology

As a result of the long planning horizon and the various technical competences needed in the megaprojects, the communication process needs to be managed effectively throughout the project organization. Referring to Zulch (2014), this process needs to be taken into regard of the four directions where the information flows in such project organization; Downward communication, upward communication, horizontal communication and diagonal communication.

5.2.2.1 Enhancing project quality through coordination and control

The downward communication, with the goal of sharing policies, strategies, and goals from top management, is a significant part of the communication process. In the megaprojects conducted at Company A, goals and strategies are decided in the beginning of the projects,

but can also change over time. The high employee turnover in these projects however, makes this process even more important, where the goals and strategies constantly needs to be communicated and managed downward throughout the whole project organization. With a changing climate both internally and externally, clear goals needs to be communicated to the different project levels in order to manage such large number of individuals in this type of changing climate. This has been an outspoken challenge during the case study at Company A, as one of the project managers described it:

> *"When new project members enter the organization, it is always a significant amount of time that has to be invested on familiarizing themselves with the project. This is a difficult process and responsibility often lies with the nearest manager."*

This is logically a challenge when the project member is new to Company A but also when a person who has been in the company for a long time is introduced to a new project. There is a standardized model of how a project should be performed that all employees should be familiar with. However, the way to manage the projects are always more or less tailored to the specific project, which can be explained by the complexity of these megaprojects (Homer-Dixon, 2011). As explained by one of the project members:

> *"It has been difficult to find one standardized way of work for all different kinds of projects."*

This is in accordance with the findings by Milosevic and Patanakul (2005) in their research on standardization within project management. It is successful to standardize projects to a certain degree, however it is important to also ensure flexibility in the way of performing projects. Regardless of the way one chose to manage the project, it is important that stated goals and processes are informatively described and that all project members have access to these descriptions, as argued by Kendall & Rollins (2003). A logical place to store this kind of project information would be in a project information system, a system which Company A in the current situation possesses and uses. The project information system is a database where all project files and working documents are saved and shared with the project organization.

The correspondence of quality information and issues is also something that is performed partly through downward communication. Within the large scale infrastructure projects at

Company A, one project member, who is not the project manager, is given the responsibility to handle the role as quality coordinator, as shown by one of the support functions in figure 1. This is to facilitate and support the project manager's overall responsibility. This role was described by the quality coordinator as follows:

> *"I am responsible for developing and planning how the work on quality assurance should be performed."*

These quality plans are developed according to current standards and requirements regarding the relevant technologies included in the project. These quality plans are created before the development work is initiated. This way of stating how the quality assurance of the project content should be achieved is in line with what Andersen et al. (2009) described quality management in the planning phase. This part of the quality management is managed through downward communication, from the project management to the technique specialists. This kind of communication could be argued to work well in a standardized manner. Instructions are developed by the quality coordinator and are then shared to the different technologies using the project information system.

When the quality assurance then is controlled during the execution phase of the project, it is performed in a standardized sequence. It begins with that the technology specialist who has developed the product are examining his or her own work based on the quality instructions. The self-examined document is then handed over to an internal quality expert who goes through the document once more to ensure its quality. This quality examination is supported and controlled by the quality coordinator who also reviews the work one last time before it can be delivered. This procedure is used for every sub delivery during the performance of the project. Hence, it follows the continuous quality assurance approach emphasized by Andersen et al. (2009) and further fulfills the definition of quality stated by Maylor (2010) since the quality guidelines are based on technology standards and customer requirements. When the quality assurance is performed in the manner just described, through upward communication from technology specialist up to the quality coordinator, it could be performed in a simple way by reporting in an IT-system. There is however another quality aspect that needs to be controlled, which is that products developed by different technologies have to be compatible with each other. This aspect is the most critical one, as presented in an earlier quotation:

"It is the fact that the different technologies have to be coordinated and developed in coherence with each other that makes it complex. Without coordination, the end product would be a gathering of different technologies not compatible with each other."

This coordination requires close collaboration between the techniques through physical meetings where the interfaces between the techniques can be discussed in a detailed manner. Something that can not be done just by communicating through an IT-system. As one of the project managers of Company A expressed it.

"It is important for all techniques to participate in coordinating meetings because the techniques always need to be coordinated. The different techniques can benefit a lot from each other and it also creates a sense of participation in the overall project."

This can be linked to horizontal communication since it is conducted between the individuals on the same project level. Here, as mentioned in the quotation, the technical areas need to be coordinated in order to proceed with the project. In Company A, this is done with regular meetings coordinated by a manager that makes sure that all the challenges that have emerged in the different technical areas are brought up to the surface. However, it was shown while observing one of these meetings that the result of this type of meetings is that one technique report their status, and the other techniques wait quietly until it is their turn to talk. A meeting that can be seen as a standardized and nonproductive way of transferring the respective information horizontally. One of the factors to this situation is because of the lack of competence of the other techniques. One of the technique specialists described it as follows:

"I have no deep knowledge in the other technical areas, so it's hard for me to understand and discuss them."

Referring to Kerzner (2001) this communication flaw can be related to the perception barriers, that in this case is based on different educational expertise. This leads to a meeting where the topics that are brought up in the meeting, only are discussed by the individuals that have the specific technical background in relation to that specific topic. An additional problem that was identified during the study, which also origins from the perception barrier (Kerzner, 2001), was that it can be difficult to understand documents that have been produced by other

technical areas than one's own. This is especially relevant for the project members which to a large extent work with and reviews documents from other technological areas. For a person who has a lack of competence in that specific technology it can be difficult to understand what is shown in the technical document. One interviewee that expressed this specific problem regarding the own work pronounced that:

> *"An explanatory text attached to the technical document would be helpful when trying to interpret what is shown in the technical document."*

In the current situation, technical documents such as drawings and calculations are shared throughout the whole project organization using the earlier mentioned project information system. Through this system, the project members have access to all technical documents, both the ones who are under development and the ones that have been completed. Thanks to this access, a direct coordination between different technologies is enhanced since the documents can be co-controlled on compatibility. However, as discussed above, the perception barrier (Kerzner, 2001) that is a result of that project members usually are not familiar with other techniques than their own, may complicate this kind of coordination. An explanatory text document, documented together with the technical document in the project information system, may facilitate this. That could however also have negative effects, as mentioned by the same interviewee:

> *"It is a risk that additional explanatory documents would end up in a large amount of administrative work that will not create value to the customer."*

Another problem on horizontal communication identified in the studied megaprojects conducted at Company A is that both internal and external deadlines are present throughout the project life cycle. Thus, indicating on the importance of the coordination of the technical areas and their internal deadlines. However, as shown from the study, it is very common that technique coordinators often have a difficult time to control this communication process. One technical coordinator argued that:

> *"In some situations, the techniques have interpreted the internal deadline as an external deadline, resulting in a displacement of the activities in the project plan."*

However, after having interviewed the data coordinator, it was found that the organization have an IT-system that can support these type of communication issues. The problem here, according to this employee, lies in the flaws of the knowledge of the systems that the organization possesses. Individuals that work in the projects have a low motivation to learn and change their working routines in accordance to this IT-system that can be utilized to a further extent than today.

Referring to the upward communication, the goal is to provide the top level of the project organization with information of progress and challenges. As a result to the enormous amount of information that flows in this direction of the megaprojects, Kerzner (2001) argue that it is important that the information is filtered for each project level so that the vital information is delivered to top management on the right time in an efficient way. In reality however, this communication process becomes far more complex when it comes to megaproject than described in regular project management theory. In Company A, various technical areas are involved in the project organization, where each unit report their own progress. Thus, resulting in a situation where a high amount of information is needed to be processed in combination with a large amount of decisions that are needed to be taken in order to proceed as planned. Further, these decisions affect all the business areas in a way that management not always are being able to predict. The high number of activities make it difficult to keep track of the decisions being made, thus creating a situation where the management team loses the control over the project. As one project manager described it

> "*The difficulty with the larger projects is that they consist of so many technical areas that needs to be coordinated"*

This statement is something that the majority of the managers in Company A could relate to, thus indicating on the importance of a functioning communication plan that can support these complex technical projects.

5.2.2.2 Sharing knowledge within a megaproject organization

Evaluating a megaproject in the aspects of both challenges and success factors, there are a lot of valuable knowledge that is created when having conducted a complex project of this size. This indicates on the importance of having a knowledge sharing organization, both in regard

to the success of existing projects, but also in regard to learning and creating value for future projects. Analyzing the knowledge management process in Company A, the existing and created knowledge could be utilized to a larger extent than today. One technical specialist expressed it as follows:

"I do not know if we work with knowledge management in any way."

Furthermore, one of the project managers argued:

> *"The knowledge sharing process is mostly about bringing with you your own experiences. The idea is that you should write a report when the project is finished, but this is not always done.*

It was further mentioned by the same project manager that:

> *"Reading the reports of projects that you have not been part of yourself can be very useful in your own work."*

These statements does also reflect most of the other interviewed project members, where these individuals often go and ask a person face to face if looking for help to manage their respective problem. This is a very fragile way of sharing the knowledge, especially in an organization such as Company A, where there is a high employee turnover in the projects. This is because of the possibility that the knowledge may be lost when individuals chooses to leave projects internally or take the decision to leave the whole organization.

Referring to Nonaka (1994), in order to manage the knowledge sharing process, it is important to understand the two types of knowledge. Tacit knowledge that is personalized, and explicit knowledge that differ in the way that it is codified and can be transferred through a systematic language. This way of viewing knowledge is something that should be taken into consideration in Company A. As a computer coordinator argued

> *"The way of operating and structuring the documents varies depending on the coordinator. This leads to a situation where project members are confused depending on the specific project that they are working towards."*

Instead, it would be better to have a standardized way of handling this type of explicit knowledge, thus also ease and shorten the learning process for new project members that lack the knowledge of the new system. This can also be supported by other individuals in the organization, as one person responsible for a technique said,

> "*It is really difficult to know where the different files are placed in the different documentation systems"*

It would therefore be better with a process supported by an IT-system that helps the organization to share their tacit and explicit knowledge in a standardized way throughout the project organization. As mentioned by Alavi and Leidner (1999), the need to sharing and communicating knowledge has encouraged organizations to develop information systems that supports the process of facilitating and integrating knowledge, so called knowledge management systems. The KM system is a repository system where the knowledge in an organization can be stored and shared in a network, as shown in figure 5, and illustrates the correlation and interaction between technology, process and people in the KMS infrastructure network. As observed at Company A, they have a system on the intra network where this type of collaboration exists. It is based on an internal communication platform where employees can ask questions in different fields depending on the issue that they want help with. This, with the aim of sharing the knowledge between the functions and divisions in the organization. In reality however, after having interviewed the different project members, nearly no one was using this KM system to a larger extent. According to Alavi and Leidner (1999), the KM system needs be adapted and participated by the whole organization, to fully utilize the benefits and success-factors. To manage this process, a cultural acceptance needs to be built around the KM system in order to encourage employees to share their own knowledge to other individuals. Analyzing the KM system at Company A, it is clear that this system not is adapted by the whole organization, and thus inhibits the success-factors that can be received by implementing this throughout the whole Company.

5.2.2.3 Managing risks within megaprojects

In the coordination of the different techniques involved in a megaproject, the risks in each individual technique have to be communicated throughout the project organization. It is therefore important to support this process in the communication platform, both in regard to

risks affecting the own technical area, but also in order to inform the other techniques about potential risks that may affect them in ways that can be difficult to predict.

Referring to Krane et al. (2012), project risk management can be divided between two areas. Strategic risks, reflecting both short term factors for the project owner, and long term risks in regard to sustainability aspects that affects the society. But also operational risks, considering the direct result and accomplishment throughout the project phases. In the case study conducted at Company A, the questions about the risk management process (Crispim & Rodrigues-da-Silva, 2014) in the megaprojects were divided in accordance to these two project risk management areas. Analyzing the result, the identification of operational risks is handled in the respective technique. As described by one of the technique responsible:

> *"Each technique is individually reviewing and documenting eventual upcoming risks."*

These risks are then compiled and summarized in a list that later are classified regarding the implications of the identified risks. In some cases, the customer also want a mutual risk plan where they often have responsibility over some part of the risk plan themselves. The mentioned risk plan that Company A have got internally, is available for all the employees involved in the project and is updated as the project moves on. The communication of operational risks is one example of diagonal communication (Zulch, 2014) that is needed to be handled. Referring to a project manager in one of the projects:

> *"It can be difficult to get a holistic view over the whole list. In stressful times, project members may also forget to update the list, which then affect the outcome of the risk plan."*

Analyzing the strategic risk area, this is a field where the project members lacked information of how the organization handle this process. This result can be explained either by a lack of a strategic risk management plan, or that the existing strategic risks not are communicated throughout the project organization. In either case, referring to Krane et al. (2012) it is valid that an organization takes these two project risk management areas into account. According to Hwang et al. (2014), this will then lead to improved decision making in the projects and also result in lower costs and removal of unnecessary contingencies (Mills 2001).

5.3 The need of a functioning communication platform

In one of the megaprojects conducted at Company A, a communication process called ICE (Integrated Concurrent Engineering) were conducted. This is a way of inducing collaboration between the different parties, including all the techniques as well as the customer. In practice, a number of fixed meetings are decided throughout the project phases, where the ingoing parties sits down together, allowing a diagonal communication and an agile way of structuring the work. Different topics with valid decisions to discuss are decided before the meetings, which then are followed and lead by a coordinator that makes sure that the word are shared to all of the parties attending the meeting.

The individuals interviewed in this project were very positive toward this type of collaboration and according to one of the project managers, the customer had:

> *"a positive view and wanted to continue with the ICE structured meetings in other projects in the future."*

Referring to an interviewed project members that attended this form of meetings:

> *"The advantage is that the communication process is so much more efficient. Mostly because of that the customer is attending the meeting, making it possible to take decisions directly as the meeting goes on."*

The project member further expressed that:

> *"The technical specialists can then deliver solutions in a much faster way because of having the possibility to communicate directly to the other techniques."*

Thus, it is enabling the communication process to be shortened, reducing the amount of emails and documentation as a result.

The ICE meetings indicates clearly on how the challenge with these forms of megaprojects, not lies in the lack of competence in the organization, but rather in the communication process

and coordination of the expertise that the organization already possesses. Referring to Zulch (2014), in order to succeed with a project, the individuals in the team needs to integrate, share their knowledge and collaborate successfully. A statement that is supported in this study, where most of the interviewed project members in Company A argue that the biggest challenges lies in this area. Analyzing this necessity of a better communication platform in Company A, an IT system that supports the communication process and decreases the level of perception barriers could increase the control of the projects. Referring to Ali et al. (2008), there is a correlation between increased software utilization and project success. Further, the quality of the information provided by the software is a strong factor to use project management software. Based on this study, this also indicates on the importance of a communication process supported by a project management software in these large scale complex projects.

6. Discussion

In this chapter the findings and arguments presented in the analysis will be discussed with regard to their legitimacy. Further, advantages and challenges when utilizing an IT-system within a megaproject will be assessed.

6.1 Interpretation and discussion of analysis

Megaprojects are both large, comprehensive and complex (Flyvbjerg, 2014), something that also fits into the projects being performed at Company A. It has been shown through research by Ali et al (2008), Liberatore & Pollack-Johnson (2003), and Habison (1985) that IT-system utilization within projects have a correlation with project complexity and project size. The functionality, ease of use and information quality created by the system does also have positive influence of IT-system utilization. As the term IT (Information Technology) describes, using an IT-system is about simplifying the control and distribution of information through technology.

6.1.1 The different types of information

Two different types of information were identified during this study, quantitative information and qualitative information, and these can be handled in different ways. As described throughout the analysis, quantitative information or numerical status reporting data can in a more straightforward way be standardized and handled using an IT-system. This is since the type of information that we have chosen to call quantitative, namely time, cost and progress data for ones are able to be reported in the same units for every project. Secondly, the key indications that project management want to bring out from this data are the same between different projects. That is why we argue that this data in an effective way can be reported in into an IT-system and therein be handled in a standardized way. With that being said, not all standardizable data should be reported into an IT-system just because it is possible to do it. One must benefit from sharing and taking part of the information, otherwise reporting the data into an IT-system would just imply unnecessary administrative work. To utilize an IT-system within a project is about making information sharing more simple and more effective. At that point where the utilization only leads to excessive administrative work that not create value or leads to approaching project objectives, one could question its presence.

The information type we have chosen to call qualitative information is different from quantitative information in the way that it can not be standardized. Hence, the information can not be broken down into the same units for all situations and projects, such as knowledge, risk and quality information. This fact means that qualitative information not is able to be handled within the IT-system in the same way as quantitative information is handled. Quantitative information can be analyzed automatically by the software where important insights can be identified and highlighted. This opportunity is more complicated to reach and bring out from data that is not standardized. However, IT-system can still be useful in handling qualitative information. It can be successfully used to share the right information and documents to the right project members. Further, it can be used to make sure that project members have access to the, for their role, necessary information. This information distribution becomes even more important when the coordination between project members work is a necessity. An example of this from the analysis is the handling of quality information. Even though information and descriptions regarding quality and quality assurance are not standardized, it can be shared in a standardized way throughout the project organization using an IT-system.

6.1.2 Advantages with IT-system utilization

The advantage of using IT-systems to share and control information within a megaproject are several as noted in this report. Firstly and generally, utilizing an IT-system can contribute to a significant increase in efficiency in how information is shared within the project organization. This is since the information can be shared digitally to the desired recipients directly within the system, without intermediaries. For example when project status is communicated for each activity within the project, as discussed in the analysis chapter, it can be communicated through the IT-system instead of orally at weekly meetings.

IT-system utilization can contribute to an increased control of information that is critical to the project since it can constitute a gathering place for project information where all necessary information is saved and accessible to everyone authorized. Hence, that the organization possesses the necessary information would not only depend on the project members and their own documentation, but would be supported by the system. This accessibility to relevant project information further implies that the coordination between different technique groups and functions within the organization may be enhanced. It creates the opportunity to gain deeper insights into the work conducted in other parts of the project organization since it

enables access to information from other organization functions needed in order to enhance coordination. Lastly, the fact that information and knowledge can be documented in a system allows the organization to go back and learn from past experiences as well as creating an understanding of why certain decisions were made. Even though certain actions or happenings are not seen as critical while performed, utilizing an IT-system thoroughly would create an opportunity to review project events in hindsight, since all actions are documented.

6.1.3 Challenges with IT-system utilization

Implementing and using IT-systems would however not simply entail advantages by itself, there are certain challenges that needs to be considered and handled in a thoughtful manner. For example, reporting and documenting information in an IT-system may lead to an increase in administrative work. It is therefore important that the information that are stored in the system is relevant and not least useful for someone else, so that unnecessary time is not spent on documenting information in a system, not utilized by anyone. Furthermore, a system that provides too much information may also be challenging to handle. The information that it is necessary to have access to should be evaluated for each individual and role in the project organization so that one does not get overwhelmed with information that he or she do not benefit from. For every different role there is some information that is needed to be known and besides that, there is another type of information that is just good to know but not necessary.

Lastly, adapting the process of a megaproject to a static IT-system may prevent the flexibility when conducting the project. It is important for the system to be adaptable to a degree where the project process used is not prevented from being built as efficient as possible. Hence, before implementing and utilizing an IT-system for communication and information sharing, the organization should thoroughly consider what type of information that is needed by each project role and in each project phase. In that way, the organization can make sure that the administrative work that will be added when implementing the system is only invested on necessary components. In this way the organization is also able to ensure that project members are provided with the information relevant for their role.

7. Conclusion

In this section the stated research question and its associated sub questions will be answered in order meet the purpose of the thesis. Further, the main findings of this thesis will be summarized. Lastly, the quality of the presented findings will be assessed based on the used research methodology along with suggestions for further research on the area.

The purpose of this thesis was to investigate how information technology can be used to further streamline communication and information sharing in a megaproject. In order to reach this thesis purpose a case study was chosen to be conducted at Company A where two megaprojects were studied and analyzed on the basis of IT-system utilization and information sharing. To be able to gain findings on this subject the type of information that is created and shared during an infrastructure megaproject was needed to be identified, as implied by the first sub question.

- *What types of information are present when conducting a technically complex megaproject?*

It was found that the amount of information present during a megaproject was both large and diverse. Information regarding invested time and used budget are created and shared on a daily basis. The same applies to information concerning quality issues that appears and project risks that can disrupt or are disrupting the ongoing work. Although, in spite of the fact that there is a wide spread of different information, one can divide it into two holistic categories: Quantitative information and Qualitative information. Quantitative information that is more direct and standardized, for example the number of hours invested in a project activity and qualitative information which is of a more descriptive nature and which is possible to interpret.

- *What is required of an IT-system in order to meet the needs of a megaproject organization?*

It was found that the large amount of information present and the large project organization needed to be coordinated creates a demand for information sharing support. Overall, it is therefore required that an IT-system is able to support the information sharing process within the megaproject. However, for the IT-system to be effectively utilized it is required that the

system is able to manage various types of information differently. It is important that the right qualitative information is shared to the right project members, everyone should not have, and do not need to have all information. Furthermore, quantitative information has to be put in context in order to benefit from it. The IT-system should therefore be required to be able to analyze and bring out insights from quantitative information in addition to be able to sharing it.

- How can the utilization of information technology within megaprojects improve and support communication and information sharing?

Based on the previously described conditions, the utilization of IT-systems within megaprojects can improve and support communication and information sharing on several aspects. An IT-system can help an organization to make more use of the information that the organization possesses. This is since the IT-system can make sure that project members in an effective way are provided with the information necessary for their work which would provide with increased control and a more efficient coordination. Furthermore, an IT-system could bring out informational insights regarding the proceeding of the project from quantitative information which on one hand would support the project management in monitor and control. Further it can help with creating a shared view throughout the project organization concerning the project's status and how it develops. Lastly, a well utilized IT-system can help with enhancing a learning organization when experiences from earlier conducted projects are made possible to be tracked and studied in hindsight.

7.1 Reliability

This thesis has been developed through the performance of a case study at Company A. The fact that Company A has chosen to be anonymous throughout the thesis hinders the possibility to assess its reliability. As stated in the chapter 2.3, the reliability of a scientific study is based on the probability of reaching the same result if the study was conducted again, using the same methodology. The reliability of the study could therefore be argued to be rather low. However, since the purpose of the study is to explore how the utilization of IT-systems may support the communication process of information within megaprojects, rather than explaining it, this decreases the necessity of reaching a high reliability. Further, the interviews were conducted in Swedish which then were translated into English when using the

information and data in the report. This process could have affected the interpretation of the information provided by these individuals, and thereby decreasing the reliability as a result.

The large transparency that has been used while describing the characteristics of the studied projects and their associated project roles accentuates the possibility of assessing how findings have been drawn and where they have been drawn from. Further, the result that was provided from individuals in the case study could be supported by the larger part of the investigated sample. When discussing various topics of the phenomenon being studied, challenges could be related both between individuals on the different organizational levels, but also between the two unrelated megaprojects that was studied. Thus, indicating on an aspect that increases the reliability of the study.

7.2 Validity

Based on the scope of this thesis and the used methodology, its' validity could be argued to be high in relation to the exploratory purpose of the study. The large scale infrastructure projects that have been investigated in the research can be linked to and agreed with the definition of a megaproject. Because of this, one could argue that the resulting empirical material from the case study represents the dynamics of a megaproject, as intentional.

Based on the limited previous research on IT support system usage within megaprojects, the type of theoretical framework to use in order to analyze the phenomenon was diverse and the chosen theoretical framework could be discussed. We argue that basing the theoretical framework on the project management areas presented by the project management institute, is a valid approach. This, since it is the fundament on how to control the different information that needs to be communicated throughout the project organization in order to support the different functions within the project.

As stated in the analysis, there was a high employee turnover within the studied megaprojects, and many of the project members had not been participating from the beginning. A factor that could have affected the validity in a negative way when it comes to the investigation of the different phases of the project. In order to prevent this, the megaprojects were chosen in regard to their current state in relation to the different stages of the project lifecycle, thus improving the holistic view over the processes conducted throughout the whole project.

7.3 Generalizability

The results and findings from this investigation have mainly been based on two different infrastructure megaprojects performed at the engineering consultancy firm Company A. Using an analytical generalizability (Blomkvist & Hallin, 2014), one could argue that this fact may imply that it is not possible to generalize the findings from the study. However, based on the exploratory purpose of this study and the fact that previous research on the studied subject is nonexistent, the findings from this study could act as an initial guide regarding the utilization of IT-systems for support of communication and information sharing within megaprojects.

7.4 Contribution

As stated in the problematization, the previous research on project management have established a broad theoretical foundation for the field. The theories regarding megaprojects however, has experienced less attention, and is mostly focused on the individual and industrial level where Flyvbjerg (2014) has been a driving factor in the understanding of the megaproject phenomenon by describing and defining its content and characteristics. Taking this into consideration, the study intends to fill the knowledge gap by analyzing the functional level of a megaproject conducted in the infrastructure industry. This, with a purpose of exploring how communication and information sharing within large and complex megaprojects can be streamlined through the utilization of IT-systems and thereby enhance project control. Thus, the research contributes with knowledge in an area where we see a large potential of improvement, but also with the aim of functioning as an initial research in this field.

7.5 Future research

Due to the holistic contribution that this exploratory thesis brings to a field with limited previous research, we suggest that further research is done on the area of megaprojects from a functional perspective. We suggest that this phenomenon is further investigated by studying megaprojects conducted in industries different from infrastructure and in that way increase the generalizability of the findings. Furthermore, we suggest that the findings regarding the IT system supporting the qualitative and quantitative information communicated in these large complex projects, are tested in practice. This, by analyzing the market to see if the current IT

systems can meet this demand, but also to see how different information technologies can be integrated to support the relevant project management areas mentioned in this study.

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