Expanding Lean into Transportation Infrastructure Construction

Master of Science Thesis

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Abstract

The construction industry struggles with low productivity and low customer satisfaction. Lean Construction has been developed to counter these problems within the specific context, linked mainly with constructing buildings. The aim of this thesis is to expand the knowledge on Lean by identifying how Lean can be applied within transportation infrastructure construction. This thesis examines what principles of Lean that are applicable, what success factors that supports Lean and suggests how they can be achieved in practice.

Through an inductive case study the context was understood and knowledge expanded. The data was collected during three weeks of study on site of a highway intersection construction. Existing literature on Lean, Lean construction, Project Management and Organizational theory were used to interpret and conceptualize the data along with accomplish the purpose.

This thesis indicates that the five principles of Lean are applicable within transportation infrastructure projects. The main differences compared with Lean Construction are that; the value requires a holistic approach, the flow is within the construction site and the flow needs to be managed on different hierarchical levels. The identified success factors for becoming Lean in the construction of transportation infrastructure are: achieving cross functional integration, combing activities into processes, differentiating between required decision making capabilities and differentiating between the provided work descriptions. Practical implications for construction projects include increased partnering with customers, instituting a project management office, use visual flow maps, institute Last Planner System and provide work descriptions based on standardizing the skills, the outcome or the process.

Keywords: lean, lean construction, project management, lean infrastructure, ground works

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1 Introduction

This chapter explains the background of the thesis. The academic context and limits of current research is discussed, followed by an introduction to the practical setting of the research. The purpose and research questions are presented along with the delimitations. The chapter concludes with presenting the outline of the thesis.

1.1 Background

Within construction as much as 30-35% of the total cost can be due to waste (Josephson & Saukkoriipi, 2005), and a there is a relatively low customer satisfaction (Kärnä, 2004). In the fierce competition that characterizes today's markets, companies are pressured to be both efficient and effective hence highlighting the importance of reducing waste. One way of improving is through the application of Lean (Slack & Lewis, 2011).

Lean emerged in the late 1980's from Toyota Production System, and has since its conception become the normative management principle (Bergman & Klefsjö, 2010). Toyota was able to produce better quality products with fewer resources than the competition through focusing on the flow and reducing waste (Womack, et al., 1990).

The fundamental differences between the construction industry and the traditional manufacturing industry require a different way of applying Lean (Bertelsen, 2004). The construction industry is characterized by on-site projects, leading to high development costs and a lower degree of standardization (Slack & Lewis, 2011). Lean Construction is a recent development in how to reduce waste and manage the flow (Ballard & Howell, 1997), and it addresses the needs of the construction industry (Howell, 1999). Much attention has been placed on the unique characteristics of construction (Bertelsen, 2004). This indicates the need for addressing different kinds of construction projects in order to capture their unique characteristics.

The focus within Lean Construction has mainly been on the construction of buildings (Howell, 1999) (Salem, et al., 2006). The construction of transportation infrastructure is a multi-billion SEK industry within Sweden alone (National Institute of Economic Research, 2012). The lack of research within transportation infrastructure projects highlights the need to broaden the application of Lean.

The Swedish based construction company NCC AB, hereafter referred to as NCC, is active within several market segments. The one of particular interest for this thesis is the construction of transportation infrastructure. NCC itself suggests that there is a room for improvements in terms of efficiency and effectiveness. Improvements can be achieved through Lean and thus render in competitive advantages (Slack & Lewis, 2011), a more sustainable process (Fliedner, 2008) and increased employee motivation, (Rubenowitz, 2004).

To find the unique characteristics and the potential improvement a Case study was conducted at NCC's project Bårhultsmotet. This project has a turnover of approximately SEK 130 million and concerns the construction of a new highway intersection in the vicinity of Gothenburg.

1.2 Purpose

The potential benefits of applying Lean within transportation infrastructure projects in combination with the limited available research point out the need of this thesis. In order to expand the knowledge on Lean the purpose of this thesis is to:

Identify how Lean can be adapted and applied within the context of transportation infrastructure projects.

1.3 Framing of the problem

The first aspect that needs to be clarified in order to support the application of Lean is what principles to apply and adapt. Therefore the first research question of the thesis is:

What Lean associated principles are applicable on transportation infrastructure projects?

Determining what principles that are applicable is not sufficient. In order to realize the potential benefits it is of interest to determine what needs to be done to support the application of Lean. Therefore the second research question of the thesis is:

What are the success factors in order to become Lean in a transportation infrastructure project?

The final aspect to consider is how to achieve the success factors in practice. Therefore the third research question of the thesis is:

What actions can be taken in order to support the application of Lean in a transportation infrastructure project?

The answer to the first and second research questions identifies how Lean can be adapted to suit a specific context. The second and third research questions provide a suggestion to how Lean can be applied in practice within a transportation infrastructure project. All three questions combined identify how to adapt and apply Lean within a transportation infrastructure project.

1.4 Delimitations

Due to limited time available the case study has been restricted to the earth works. The bridge construction has not been studied in detail as it to its nature is associated with the already explored area of Lean Construction. The road and bridge construction does not share resources to any significant extent. Thus there are only minor interconnections between the earth work and the bridge construction. There are however some dependencies in terms of the planning and the technical sequence but they have been included in the thesis.

1.5 Outline of the report

The thesis is structured in eight chapters, including this introduction. Each chapter has a number of subsections to improve the reading experience.

Chapter 1 presents the background of the thesis. The academic and practical problems are discussed in order to present the purpose and the research questions of this report.

The methodology is presented in chapter 2. This chapter describes the research was conducted. It aims to provide the reader with an overview of the research process. The chapter gives insight in how to replicate the study, along with enabling a critical review of the assumptions and choices made by the authors.

In chapter 3 the Literature review is presented. It contains the main theoretical models used for examining the case. The intention is to provide the reader with a theoretical background concerning the field of Lean, along with key notions and models. This forms the basis for the reasoning and conceptualizations made in the analysis and synthesis.

Chapter 4, the Case description, presents the case and the collected empirical data.

The analysis is described in Chapter 5. Here the empirical data is analyzed and conceptualized. The aim is to identify important factors concerning the flow and resource efficiency.

The answers to the research questions discussed in the Synthesis, Chapter 6. It consists of four parts. Three are dedicated to answering the research questions while the last section is based on evaluating the suggested improvements. This is done in order to exemplify how Lean can improve a transportation infrastructure construction project.

Chapter 7 summarizes the findings and forms the Conclusions. Furthermore the applicability of the findings in other projects and situations are discussed along with the implications for further research. The thesis is concluded with Managerial implications where the practical implications of the findings are discussed.

2 Methodology

This chapter presents how the thesis was conducted, described in three sections. The first part, Work process, describes the methodology in general terms of what has been done. The second part, Research methodology, describes in greater detail how the research was conducted. The third part, Methodological considerations, contains reflections on the implications of the chosen methods.

2.1 Work process

The process of writing the thesis was done by combining a literature study and a case. Relevant literature about Lean was gathered continuously throughout the period. The case study was concentrated to approximately three weeks on site. The execution of thesis work, as well as, how the different elements of the work process relates to each another, are presented in Figure 1.

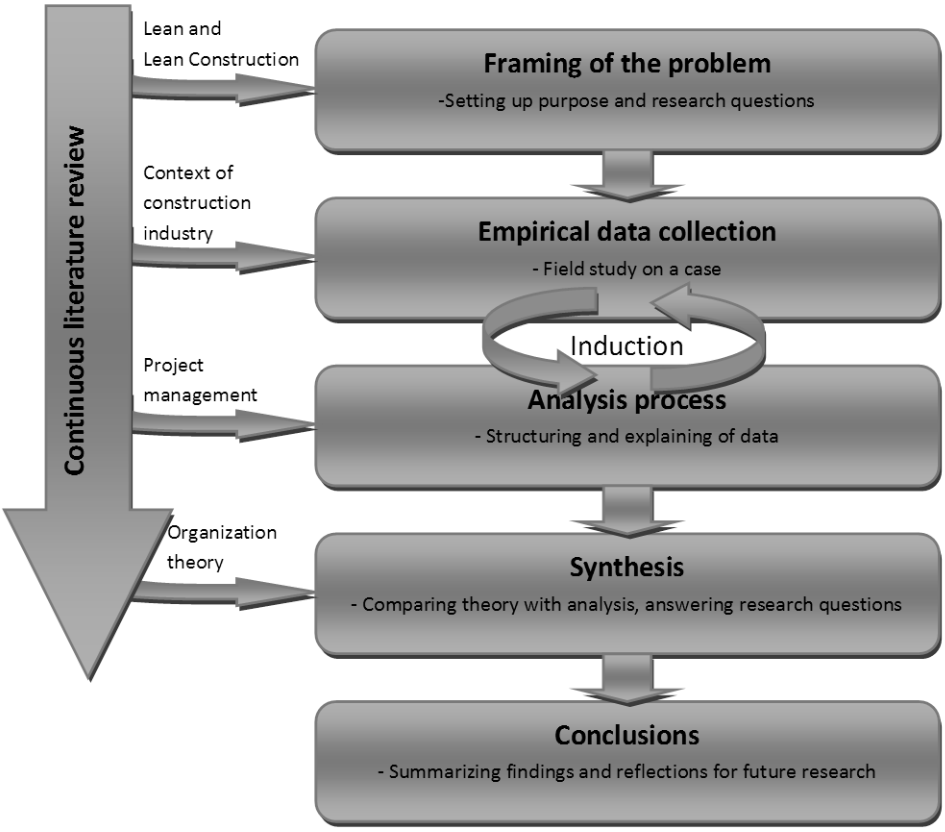


Figure 1 Illustration of work process

The initial focus was to identify the problem and generate research questions for the thesis. A process to find suitable research methods that could be used to explore the identified problem followed. A literature review on Lean and the characteristics of construction was carried out in order to build a frame for the empirical data collection. The empirical data was collected from four sources; observations, interviews, conversations and internal documents. Parallel to the data collection further literature review was carried out, in order to cover aspects that were found to be relevant. The literature review has been a continuous process in order to identify and analyze the empirical findings. The collected data was analyzed using whiteboards, matrixes et cetera to conceptualize the findings and relate to theory.

2.2 Research methodology

The research methodology is the approach to achieve the goal of the research and it carries implications on the result of the research (Bryman & Bell, 2011). It also impacts which methods that are suitable for examining the problem, something that Bryman and Bell describe as the waterfall model seen in Figure 2.

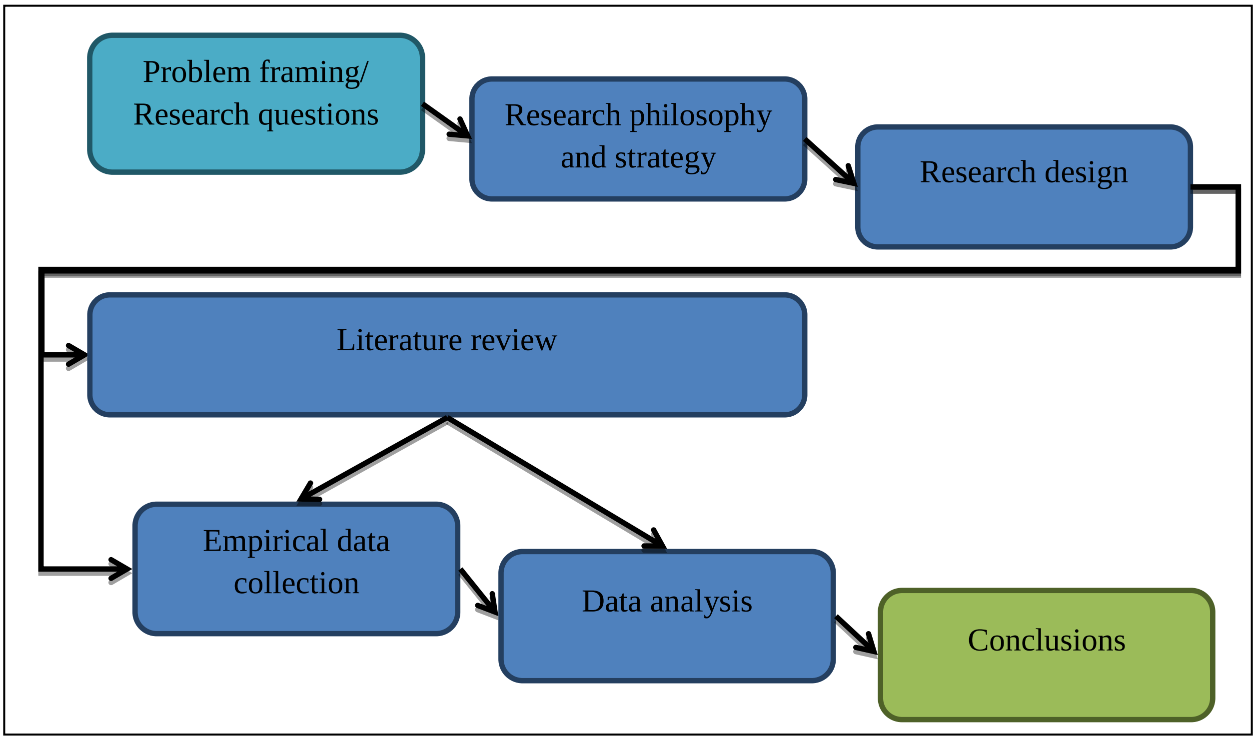


Figure 2 Research methodology (Blue) as a waterfall from research questions to delivering conclusions. Inspired by Bryman & Bell (2011)

As presented in Figure 2, the choices made on the higher level carry implications for what choices can be made later in the research. The research strategy concerns the choice of philosophical assumptions made in the thesis. The research design deals with the detailed choice of research methods used to carry out the literature review, the data collection and the analysis. In order to establish a congruency of the methods, all levels should be aligned towards the same purpose (Bryman & Bell, 2011). Therefore it is necessary to reflect on the choices on every level.

2.2.1 Philosophical orientation of the thesis

The philosophical orientation of the thesis sets the course for any research (Collis & Hussey, 2009). The basic choice is between the inductive and deductive approach. It is dependent on the level of previous research. Choosing either approach has implications on what can be regarded as acceptable knowledge, as well as the perspective on the social world. These two considerations are known as epistemology and ontology (Bryman & Bell, 2011).

The general philosophical orientation of this thesis is the combination of inductive reasoning, an interpretivistic position on knowledge and a constructionist view on social phenomena.

However there are elements of other orientations, therefore making this thesis of a mixed nature. This combination is very common today (Collis & Hussey, 2009), but the main orientation is towards the positions outlined above.

Induction versus deduction

There are two basic approaches to theory when conducting research, the deductive or the inductive approach (Bryman & Bell, 2011) (Wallén, 1996). The deductive approach focuses on the testing of available theory while the inductive approach aims to generate new theory.

This thesis mainly uses the inductive approach. The inductive reasoning comes from the orientation of the research questions and the purpose. The thesis pursues to find what Lean is in building transportation infrastructure, for which limited theory is available. Therefore an inductive approach that starts in the empirical data and develops theory becomes necessary. Since earlier research within Lean production and Lean construction has been conducted there are deductive elements present. As indicated by the research questions, the main focus of the thesis is on applying Lean in a setting not previously explored. Therefore the thesis is mainly inductive since the available theory is remodeled to suit a new context.

Epistemology

The nature of the research can be described in an epistemological sense, which is considering what is regarded as acceptable knowledge. One epistemological position is positivism, which emphasizes that the methods of natural sciences should be used in all research. Generation of a hypothesis and testing it is central to this approach and it regards gathered facts as basis of natural laws (Wallén, 1996). The other major position is the interpretivistic approach where human behavior is to be understood rather than explained (Bryman & Bell, 2011) (Wallén, 1996).

The inductive approach means that there is no theory to test; a positivistic approach is thus unsuitable. Both applying Lean and adapting it correctly requires an understanding of the context, hence supporting an interpretivistic approach. The result of this thesis could be tested through a positivistic approach, but to formulate the results it is pivotal to understand the context. This suggests that an inductive approach is required to generate the theory which then can be tested through a positivistic approach.

Ontology

The ontological consideration regards perspectives on the social world. The two contesting views are objectivism and constructionism. Objectivism regards an organization as external to the persons who are part of it, and that the organization represents the social order. Constructionism on the other hand views the organization as a social construction, it is an interaction between the members and can be assumed to be under a constant evolution (Bryman & Bell, 2011) (Wallén, 1996).

To build the necessary understanding for the interpretivistic position, a constructionist view on the social world is necessary. An objectionistic approach would not consider the individuals linked to the organization. The thesis aims at identifying practical actions that can change the organization. Since the keys to making successful changes are understanding the present situation and using interpersonal skills (Kotter & Schlesinger, 1979), a constructionist stands is suggested.

2.2.2 Research strategy

There exist two forms of research strategies, the quantitative and qualitative strategies. The quantitative strategy is generally oriented towards a deductive approach and follows the norms of positivism. It thus uses quantification of data to verify a hypothesis. The qualitative approach is generally more oriented towards the inductive approach, that is to understand how individuals interpret the world (Bryman & Bell, 2011).

The strategy of this thesis is mostly of a qualitative orientation, since the main approach is inductive. The focus is on understanding how Lean can be applied within a new context. Therefore a qualitative study is suitable. A qualitative approach is also well aligned with the interpretivistic stance on understanding the context (Collis & Hussey, 2009). To build an understanding for how processes work some quantitative data is necessary (Brandon-Jones & Slack, 2008). This thesis is thus of a mixed orientation Leaning towards the qualitative.

2.2.3 Research design

There are many different research designs that can be applied. Most of these are strongly connected to a certain strategy and philosophical orientation (Bryman & Bell, 2011). Some limitations to the possible research design are also imposed by the time and resources available for the research project.

The inductive approach requires a qualitative understanding of the subject. Likewise, the interpretivistic philosophy also focuses on building up large quantities of data for understanding the object of study. The constructionist view will make the organization into one entity of analysis (ibid). This implies that a case study is suitable for creating the necessary understanding of the context. Case studies are often associated with, but not limited to, qualitative research (Merriam, 1988). Since there was limited time available, the research was best done in a case that may generate theory which in the future can be tested in other research designs.

When conducting a case study the selection of the case is very important for the validity and reliability of the findings (Bryman & Bell, 2011). To achieve validity and reliability a representative case must be selected. The construction of roads and intersections are common infrastructure projects, the Swedish Traffic Administration, hereafter STA, alone makes a significant amount of bid requests yearly (Jönsson, et al., 2010). The construction in the case of Bårhultsmotet is therefore representative as it is a fairly common project in transportation infrastructure.

2.2.4 Literature review

The literature review has been a continuous process. Initially it focused on Lean and Lean construction in general. It then moved on to project management to support the understanding of the project. Also the area of organizational theory was examined in order to deepen the understanding.

The existing literature on the subject is limited since there is little previous research. Therefore the background was covered first by reviewing the existing research on Lean production and Lean construction. A basic overview of construction process and techniques was also conducted in order to understand the setting and prerequisites of the construction industry.

During an inductive study, the analysis is an iterative process (Miles & Huberman, 1994). As the research proceeded, additional areas of interest were examined such as project management and communication. Additional literature research was carried out for the purpose of explaining different phenomena that was encountered in the field.

The main source of literature has been books and articles from scientific journals. Using Chalmers Library databases and books along with that of the Library of Gothenburg's University, basic information was gathered. The same process and sources have also been used when researching the other related subjects as both Chalmers Library and the Gothenburg University Library has access to most international journal databases.

2.2.5 Case study

As the approach is mainly qualitative, focus has been on understanding the project. There have been four sources of information in the case study; interviews, conversations, observations and internal documents. The elements of the case study are displayed in Figure 3. The interviews and conversations were done to understand the perspectives of the interviewees and ask questions about observed issues. The observations and internal documents have been used to verify the findings from the interviews as well as identifying new data. The different sources have thus been used for triangulating the findings.

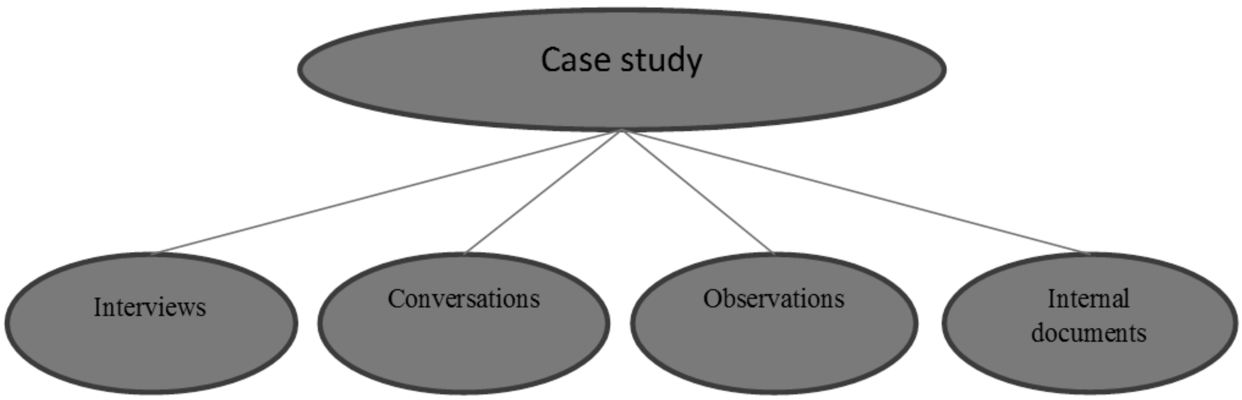


Figure 3 Elements of the case study

Research on the site has been carried out during the daily work of the project. A total of approximately 100 hours has been spent on site. These were spent during two work weeks and an additional follow up week three weeks later. Beside the three data collection weeks, additional time has been spent on site. This was done in the form of an introduction before the start and for evaluating the findings after wards.

Ten interviews have been conducted in the case study. All interviews were done in a semi-structured manner, each lasting approximately one hour. The semi-structured approach was chosen in order not to steer the subjects as their telling can be used to identify new patterns when conducting inductive studies (Bryman & Bell, 2011). Thus the interviews were conducted with only a basic set of questions that the researchers wanted answered, see Appendix A, which allowed for the interviewees to freely elaborate on the subject. The interviews are listed in Table 1 below.

Table 1 List of interviews

Interviewee	Affiliation
Project manager	NCC
Supervisor of Quality, Environment and Occupational safety	NCC
Supervisor Earthworks	NCC
Supervisor Drainage	NCC
Contractor engineer	NCC
Chief of survey	NCC
Surveyor #1	NCC
Surveyor #2	NCC
Project manager, Earthworks	Swedish Transport Administration
Project manager, Concrete	Swedish Transport Administration

In addition to the interviews, shorter conversations about 10 minutes or less was conducted with all employees at the construction site. These have been during the work and have covered the present situation. These have been used as input for interviews as well as observations. There have been 23 conversations noted down.

Interviews and conversations were recorded, and minutes where taken during the interviews. Notes were taken in different colors in order to differentiate between interviewee's explicit wordings, the authors' own thoughts and additional clarifications. Precision in the understanding of words and notes reduce the risk of later interpretations of this data (Miles & Huberman, 1994). All interviews were conducted in pairs. During the interview, one party focused on taking notes while the other was leading the interview.

Observations were conducted on site with the project members aware of the role as researchers and open about the intentions. Otherwise the authors were involved in the daily work and thus participating in some day to day activities. The authors can thus be said to have been researcher-participants, with semi-involvement in order to be fully able to function as researchers (Bryman & Bell, 2011). Some 40 separate events have been noted as observations.

Another aspect of the observations has been participation in the workplace meetings. A total of eight documented meetings has been participated in which covered the groundwork and the overall progress of the project. The meetings were regularly occurring on a scheduled basis for different levels of the project organization and are listed in Table 2 below.

Table 2 Meetings in the case

Meeting type	Purpose	Participants	Frequency
Construction meeting One attendance	Formal negotiations and timetable updates for customer	Project manager (NCC), Construction engineer, Swedish Transport Administration	Monthly
Preparatory construction meeting One attendance	Preparing for construction meeting and checking completion of assigned tasks	Project manager (NCC), Supervisors	Thursday before construction meeting
Weekly meeting roads Two attendances	Reporting progress of construction and update timetable	Project manager (NCC), Supervisors for road construction, Swedish Transport Administration	Every two weeks
Seven week planning Two attendances	Developing the seven week plan for the project	Project manager (NCC), Supervisors	Every two weeks
One week planning One attendance	Developing the construction plan for the coming week	Project manager (NCC), Supervisors for road construction	Weekly
Information meeting Two attendances	Informing construction workers of the work the coming week	Supervisors for road construction, construction workers	Every Friday

The project maintains an intranet website, Projektportalen, for posting and maintaining relevant documentation. The intranet site is available to selected individuals connected to the project. It is mainly used by the management of the project organization and those connected to the project at the headquarters. The authors have had full access to all documentation in this forum.

The quantitative data that has been utilized in the study has mainly been collected from the observations and is thus a primary source. Some secondary data has been gathered from the intranet website. The secondary data has been used to verify findings from the observations and interviews. This dual relationship was used as a verification of both the primary and secondary data. The quantitative data has been used to exemplify and illustrate the context and increase the understanding.

2.2.6 Data analysis

The data analysis of the case have been done in three major steps; daily, weekly and final iterations which are displayed in Figure 4 below. Researching qualitative data, as well as the inductive approach, calls for some analysis to be done in parallel with the data collection (Miles & Huberman, 1994). There are two different ways of building display formats for qualitative data analysis, matrices and networks (ibid). Both kinds of displays has been used in the research at different periods, in the early phase networks where used to identify connections between different observations and events. During the later phase matrices were used to describe and identify key aspects within the analysis.

Data from the interviews, conversations, observations and internal documentations was summarized on a daily basis. These summaries were carried out the same afternoon as the information was gathered in order to remember information and minimizing the risk of coding the data incorrectly. By doing these interim summaries the researchers has been able to more clearly understand and discuss the case (ibid). The coding of data was done with pen and paper using different colors to distinguish citations, observations and reflections noted in conjunction with the interview. Both authors carried out individual reflections to avoid the risk of focusing on the same facts. The initial summaries enabled further insight and identification of areas of future interest (ibid).

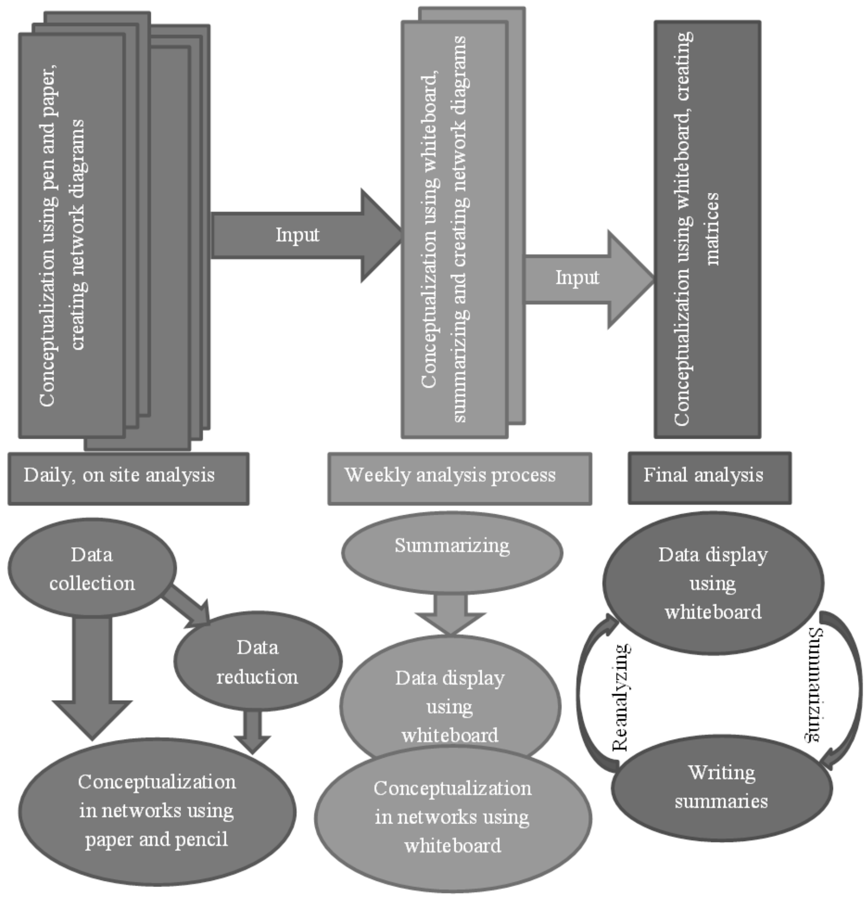


Figure 4 Illustration of analysis process

At the end of each week the data collection was summarized using whiteboards in order to present the data in two dimensions, primarily in networks. The input was the notes from each work day and the different color codes was used to find connections in the data. Findings from the research notes was written on the whiteboard in corresponding color coding as to identify different thoughts. The summarizing was done through discussing and harmonizing the perception of the empirical data. This was done to avoid the risk of misunderstandings and contesting views. The conclusions were noted in computer documents.

After the two weeks of field studies and reflections all the data collected was analyzed with the notes and conclusions drawn earlier. By presenting different aspects on the whiteboard a number of matrices were used to map interdependencies and identify issues. From the matrices and their connections relevant fields of theory was identified and further literature review was conducted on these subjects.

Miles and Huberman (1994) outline the writing of analytical texts as an iterative process. The creation of displays is done by reanalyzing, elaborating et cetera on the existent text, and the writing is done by summarizing and looking for patterns in the in the displays. The analysis has been done by constantly having access to whiteboards in order to elaborate and create new displays. Creating displays and elaborating on the text was done on a daily basis for approximately three weeks, the major part of the analysis and synthesis texts were created in this process. This led to the identification of important issues in the case and the analysis also focused on generating possible and theoretically based suggestions.

2.3 Methodological considerations

It is important to actively reflect on the implications of the method applied (Bryman & Bell, 2011). Reflecting on the method allows for double loop learning by questioning the underlying assumptions (Argyris, 1999). Testing the underlying assumptions of the methodology supports a conscious choice of method. Figure 5illustrates the three areas that should be considered when evaluating the choice of method.

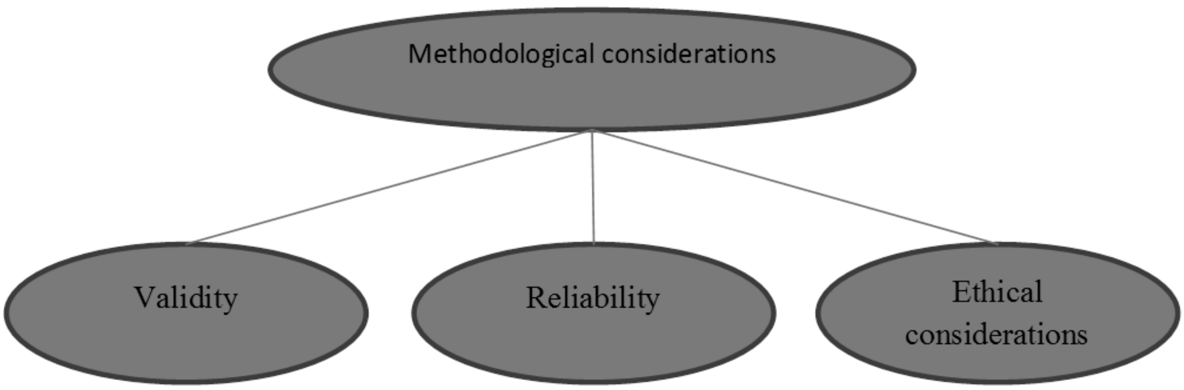


Figure 5 Elements of methodological considerations, after Bryman and Bell (2011)

2.3.1 Validity

The concept of validity is oriented around the quantitative research, but the model of internal and external validity can also be applied to qualitative research (Bryman & Bell, 2011). Bryman and Bell writes that the internal validity, or credibility, relates to how believable the findings are. The external validity, or transferability, concerns to what degree the findings can be applied to other contexts.

Triangulation contributes strongly to the internal validity of the report (Wallén, 1996). By utilizing observations and interviews, as well as secondary data, a triangulation was achieved in this thesis. The use of different methods to gather data strengthen the credibility of the report. The close cooperation with the company in question also enabled the researchers to verify the findings with the individual project members. However, close cooperation might also affect validity by censorship (Bryman & Bell, 2011). This has been countered by from the beginning informing all participants of the public nature of the research and thus no parts have been censored. Therefore the validity of the thesis should be good.

When conducting open research at a case there are some associated problems that might affect the validity. The risk of starting to see the world from the perspective of the workplace, i.e. "going native", could affect the objective stance of the researchers (ibid). However, by continuously alternating between being on site and on other locations to analyze data as well as having discussions with academics, the authors have made conscious efforts to avoid this risk. The consciousness about this risk and actions taken to avoid it should strengthen the validity of the thesis.

Researching on a case might affect the performance of the case due to the fact that there are external persons there (Hersey, et al., 2000). These reactive effects have been mitigated by being present over some periods of time in order to make the project members comfortable with the researchers, hence inhibiting impact on the validity of the findings.

The literature came mainly from scientific articles published in journals. The review necessary for getting published in these kinds of papers should ensure valid theoretical findings. Using different sources to verify the literature prevents unfounded views from being included in the report. Books used in the thesis have had reference lists and the source has been used to verify the statements of the book. The literature review has therefore also been subject to triangulation and can therefore be regarded as valid.

The external validity in qualitative research means transferability and indicates to what extent the findings are applicable in other settings (Bryman & Bell, 2011). The nature of a case study is limited to a single project and the possibility to make general findings could therefore be at risk. However, as the case is what could be considered a representative case for infrastructure projects the findings should therefore be characteristic for the industry. Therefore should also the external validity of this thesis be acceptable.

2.3.2 Reliability

Reliability concerns if the findings of the research can be replicated, which is difficult in qualitative research (Bryman & Bell, 2011). The same social settings will never be present and the environments will thus change. The reliability can therefore be discussed in terms of external and internal. The external reliability concerns the replicability of the study, while the internal reliability concerns to what degree the research team agrees on what they see and hear.

As the case chosen is considered representative for the industry, other projects should express similar characteristics and the external reliability can thus be viewed as high. By identifying a similar project, there are several highway intersection construction projects every year in Sweden; a similar study could generate the same findings. The same preconditions and personnel will not be present but as it is the application of Lean that has been studied there should be good possibilities to replicate the findings in a similar study. The external reliability can therefore be viewed as good.

The internal reliability has been maintained by constant and conscious efforts to align the views by the authors. By conducting interviews with both researchers present and recording the interviews for later use any diverging views could be resolved. By continuously analyzing the data the authors have been able to discuss their views of the case. Also, by discussing with academics and company representatives and getting their agreement should indicate a high internal reliability of the thesis.

2.3.3 Ethical considerations

All research carries ethical implications (Bryman & Bell, 2011). Therefore careful considerations for the persons and company involved have been done in order to minimize any risk for persons or the company involved. According to Bryman and Bell there are different ethical areas that researchers need to consider; harm, informed concent, invasion of privacy and deception.

All personal opinions and all interview notes were handled in a confidential manner. The interviewees were assured that their opinions would not render in any personal implications. The researchers ensured the interviewees that if their opinions could render in any personal harm the researchers would not transfer that information through the organization. No such situations presented themselves during the research but it contributed as a measure to ensure that the interviewees felt secure during the interviews.

Acting as observers at the construction site might instigate feelings of surveillance and distrust. The researchers have therefore taken additional interest in confirming that the individuals that have been included in the study have also given their informed consent, which is one of the key ethical considerations (Bryman & Bell, 2011). A stance of great openness about the research has been taken towards the employees in order to build confidence for the researchers.

The notion of increasing productivity, restructuring and the word Lean might be perceived as threatening to the employees (Anderson-Connolly, et al., 2002). Assuring the employees of the researchers' good intentions by describing the research questions has therefore been important. By clearly communicating that the aim is to reduce unnecessary work which only takes time and energy, the employees might receive a positive attitude towards the study. One way of increasing the satisfaction and motivation of the workers is to clearly show how their efforts contribute to the customers (Rubenowitz, 2004). By allowing for personnel of different hierarchical levels to contribute with their input it is possible to make the employees feel involved and appreciated hence making them more positive regarding the initiative (Beer, et al., 2011).

By clearly stating the researchers’ roles as observers no employee should experience deception. Stating for the employees what aspects are being observed, and for what purpose, reduced the risk of deception.

Since the employees are observed in their working environment there could potentially be a invasion of privacy. If aspects such as their social interaction during breaks and in their locker rooms were to be examined the staff could experience that they were being judged as individuals rather than professionals. By being clear about that the researchers, although sometimes present during breaks and lunch breaks, only are active and observing during the professional elements of the day the perceived invasion of privacy is reduced.

3 Literature review

This chapter presents the theoretical framework of the thesis. The chapter is structured in two parts. The first part explains what is meant with the notion of Lean and its core aspects. The second part is centered on the context of infrastructure construction.

3.1 This is Lean

In order to identify which aspects of Lean to adapt and how to apply them within a specific context, it is first important to establish what is meant by the notion of Lean. This first section explains what the philosophy is focused around, along with a historical context. Furthermore, it presents the principles in detail before describing the central aspect of waste. The section is concluded with a description on the specialized area of Lean construction.

3.1.1 The philosophy of Lean

The center of Lean is to reduce waste and deliver value to the customer (Womack, et al., 1990). This can be expresses as focusing on being both efficient and effective. Depending on which literature that is examined Lean can be viewed as either a philosophy, a strategy or a tool.

This thesis builds on the view of Porter (2002), that strategy is about determining what field(s) to venture in and how to appeal to customers in that market. Efficient operations are therefore not a strategic decision since it does not indicate what is to be done efficiently. To determine effectiveness, a frame of reference is needed. This frame of reference is set in the strategy with the formulation of which field to compete within, along with how to do it successfully. Lean is therefore not viewed as a strategy but instead as a way to fulfill the strategy (Slack & Lewis, 2011).

A tool is a practical step by step technique to achieve a change (Dean & Bowen, 1994). Lean does not provide a way of actively enhancing the efficiency and effectiveness of the company. Lean sets the agenda for addressing those issues with the use of associated tools (Liker, 2004). Although Lean is linked to several tools such as value stream mapping, 5s and so on, these are not Lean per definition. Therefore Lean is not seen as a tool but instead regarded as a beacon in what the tools should be used for.

Although Lean is not a strategy there still is a interlink age between the two. Operations strategy is a link between the overall corporate strategy and the operations of the organization (Slack & Lewis, 2011). One way of describing the connection between the operations strategy and Lean is the efficiency matrix, see Figure 6.

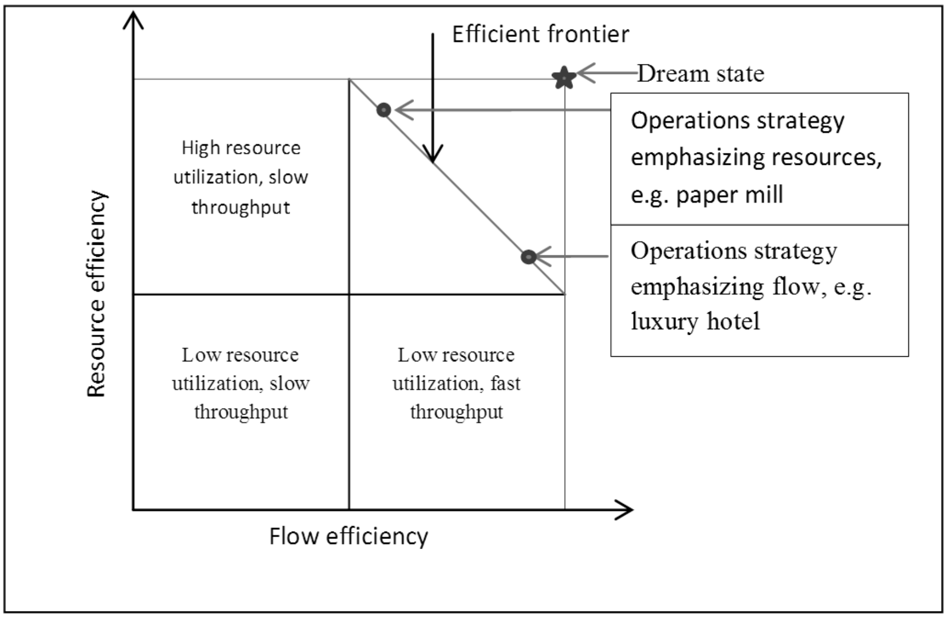


Figure 6 The concept of Lean vs Operations strategy, after Modig & Åhlström (2012)

The role of the operations strategy is to manage the trade-off on the efficient frontier (Slack & Lewis, 2011). If flexibility is desired then lower resource efficiency and higher flow efficiency is preferred, compared with a predominantly cost oriented situation. The role of Lean is to shift the efficiency frontier as far up to the upper right corner as possible by reducing waste and focusing on flow (Modig & Åhlström, 2012). Lean thinking thus acts as an enabler for which strategic directions that can be pursued. Since Lean merely shifts the efficient frontier and not removes it the need for managing trade-offs still remains. To manage trade-offs is the role of strategic decisions in manufacturing (Skinner, 1969).

The authors view Lean as a philosophy that provides input into how to achieve the strategy along with guiding to what end the used tools should be applied.

3.1.2 On the origin of Lean

Striving towards improved quality and productivity is not a new phenomenon, scientific management and Taylor was also working in this direction in the early 20th century (Taneja, et al., 2011). Lean is an extension of this work, by understanding and managing the flow of the product or service and not just the resources used to produce it (Modig & Åhlström, 2012).

The founding of Lean is often attributed to Toyota with the emergence of the Toyota Production System (Holweg, 2007). It contrasted to the, at the time, predominating way of thinking, characterized by standardization and mass production based on the efforts of Fredrick Taylor and Henry Ford. The initiation of Lean was based on the then low productivity within Toyota, inspiring action to reach the standards of the industry leader Ford. It focused first on flow efficiency rather than resource efficiency (Åhlström, 1998). This allowed Toyota to evolve from a troubled company into being one of the most successful car manufacturers.

The label of Lean and its associated use is not credited to Toyota, but to researchers that have studied Toyota. The origin of the word Lean comes from a review of the Toyota Production System, which focused on creating a company that uses fewer resources and therefore being more "Lean" than the western counterparts (Krafcik, 1988). Womack, Jones and Roos present the notion of Lean production in the publication "The machine that changed the world", 1990. In this publication the differences between Lean production and traditional mass production are presented, along with elaborations on the implications of working in either way.

Today Lean production has emerged into several application areas both within manufacturing companies but also into other fields (Weinstock, 2008). Lean now span across several areas, such as Lean services and Lean product development, and are not limited to only production (Cocolicchio, 2012). Construction is a special case of Lean since it has different layout and production compared to either services or traditional manufacturing (Koskela, 1992).

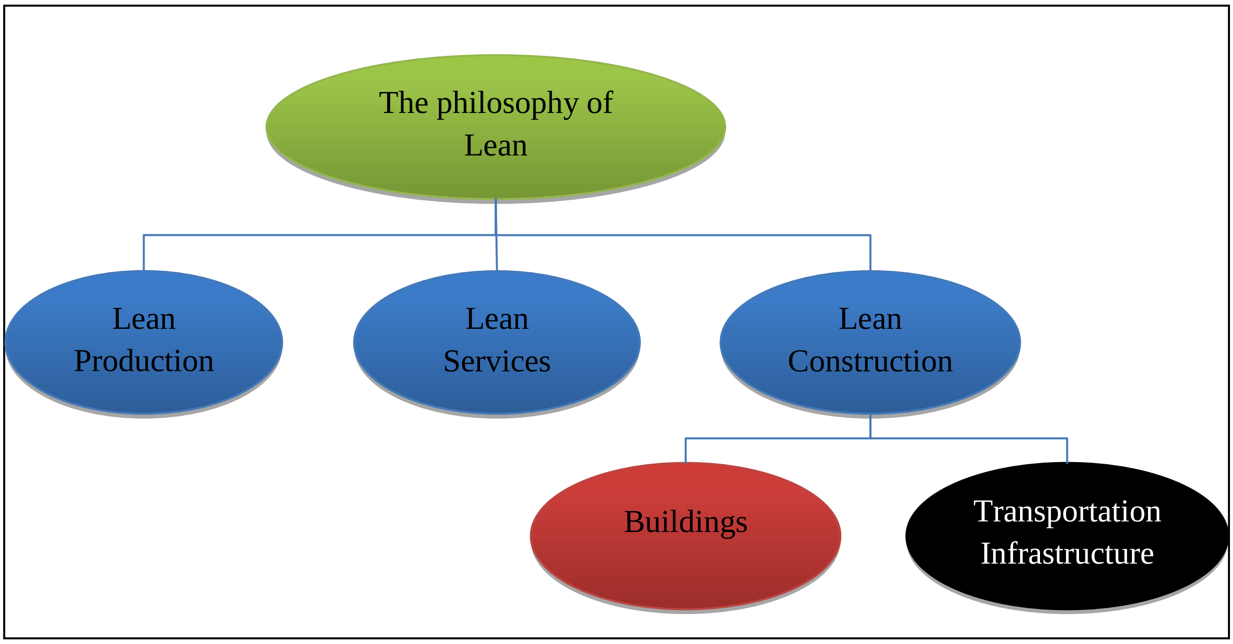


Figure 7 Outline of the fields within Lean as viewed by the authors

The focus of the thesis is on identifying how Lean Construction can be applied and adapted to the unique setting of transportation infrastructure projects.

3.1.3 Lean principles

Numerous combinations of differently formulated principles can be found describing what Lean is, hence making it a complex to review. Even though these are formulated differently, many descriptions can be viewed as a combination or rephrasing of the five principles of Lean as described by Womack and Jones (2003). The principles of Womack and Jones (2003) are presented below. Together they form a conceptual base for how to achieve both efficiency and effectiveness.

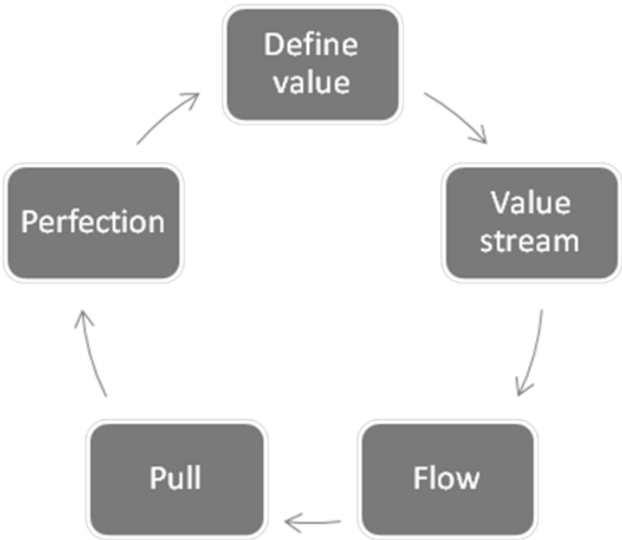


Figure 8 The principles of Lean, Source: Womack & Jones (2003)

Define value

To define value it is required to determine who determines what value is (Bergman & Klefsjö, 2010). Determining which perspective to use does not fulfill the principle. The next action is to identify what customers perceive as value. Traditionally companies have a tendency to get caught up in routines and familiar beliefs, and therefore continue to deliver products that are aiming at the same characteristics as previous products (Morup, 1993). An open mind is required when defining value.

Value can be difficult to establish, everything that does not add value for the customer is waste and should be eliminated (Liker, 2004). The "voice of the customer" must be heard throughout the production to ensure that the production is aligned to the customers need (Bergman & Klefsjö, 2010). In some cases the final customer can be difficult to identify and the wishes difficult to map, then it becomes important to identify the need filled by the operations (Modig & Åhlström, 2012).

The value stream

The second principle of Lean supports the visualization of the value stream of a product. This is the process that the product undergoes from the collection of raw material to the reuse of material (Womack & Jones, 2003).

By illustrating and visualizing the process, a large portion of the activities can be found not contributing with value (ibid). The key to achieving a Lean organization is not only to minimize the waste but also to prevent it (Bicheno, 2008). The importance of looking beyond the organizational borders is highlighted since the entire value chain contributes to the end product, thus rendering in the extension from a Lean corporation into a Lean value chain (Sabri & Shaikh, 2010).

In practice the value stream is often visualized through the use of value stream mapping (Rother & Shook, 2003). The value stream map forms the basis for identifying the problems and benefits associated with the current way of working (Womack, 2006). The benefit of visualizing the value stream is that it enables waste to be identified and removed.

Flow

After determining what is considered to be value as well as the current value stream, the next step is to design the process so that the value is realized in the most efficient and effective way (Bicheno, 2008). According to the third principle of Lean this is done through the use of flow orientation (Womack & Jones, 2003). This action is often compared to making the organization more streamlined with the aim of reducing the throughput time. The focus on each separate product is central to making the flow orientation applicable. Customers are not interested in how much a machine is utilized but rather in that the products are produced (Rother & Shook, 2003).

In practice the flow orientation is achieved through three steps (Womack & Jones, 2003). The first step is to focus on a flow unit and what supports its flow (Modig & Åhlström, 2012). The flow unit can be a product, information or individuals (Ibid). Secondly all traditional organizational structures and barriers must be ignored; these should not control the design of the process instead of the flow unit. Thirdly the specific ways of producing the flow unit needs not to be rigid in order to inhibit changes towards a flow oriented process.

When being processed all flows are subject to some form of constraints that will limit the throughput (Goldratt, 1984). Bottlenecks always exist, and will put a limit on the flow. If focus is on having resource efficiency there will be a buffer before the bottleneck as to ensure that the bottleneck is always working. However, according to Little’s Law the increased number of units will increase the throughput time if the cycle time is kept constant (Hopp & Spearman, 1996). Furthermore, variation increase the throughput time for the same utilization rates as the variation will affect how many units are in queue for the process. Thus, looking at the flow, moving towards 100 % utilization means that throughput times approaches infinity, see Figure 9 (ibid).

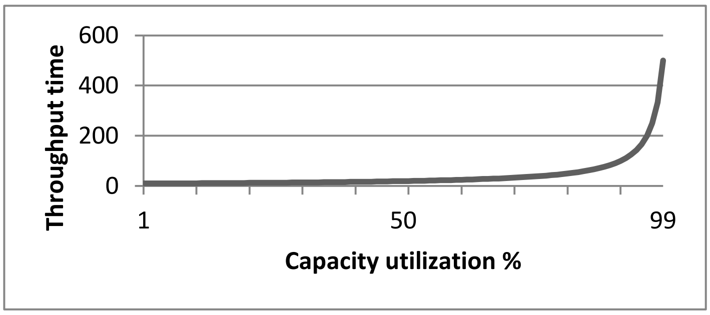


Figure 9 Throughput time as function of capacity utilization

The resource and flow efficiency provide a trade-off between striving for full utilization or a swift flow (Modig & Åhlström, 2012). The optimal state is to have both a high flow and high resource efficiency. However, this is not always possible as variation will introduce a tradeoff between these goals, the efficient frontier which is the current optimal performance (Modig & Åhlström, 2012).

Pull

The fourth principle of Lean is to implement a pull system rather than the traditional push (Womack & Jones, 2003). When using a push process the result can be inventory, which is likely to inhibit the flow. The pull principle can be viewed as an extension of having a flow oriented process. Each activity should be initiated by a signal from the next activity in the value chain. Production is done to meet active customer demands, and not only on estimations of future needs (Jonsson & Mattsson, 2009). To enable this pull system, a swift informational flow is necessary to avoid accumulation of deviations in demand to massive variations (Shahabuddin, 2012), also known as the bullwhip effect (Jonsson & Mattsson, 2009).

The benefits of adopting a pull system are not only to reduce the cost of inventory and extending the flow oriented mindset. The pull enhances the company's capability of adjusting to customers' demands (Liker, 2004). With a pull system it is possible to react on changes in customer demands since production is done based on an expressed demand from the customer. By having a continuous flow, problems in the system will surface instead of being hidden by inventory and buffers thus making them possible to address (Liker, 2004).

A prerequisite for a pull design is to have smaller batch sizes in order to have the flexibility to respond to changes with little or no delay in the production (Hopp & Spearman, 1996). The goal is to reduce the batch seize to one, defects must therefore also be minimized or the flow will be interrupted (Åhlström, 1998). The ultimate goal is to have the entire value chain delivering just-in-time, as there will be no inventories necessary and thus a smooth flow is achieved (Liker, 2004).

Perfection

This fifth and last principle is not as much a practical goal as a mindset (Bergman & Klefsjö, 2010). The goal to continuously improve and enhance the product in order to provide value more effectively and efficiently is commonly expressed as Kaizen (Ibid). The practical implication of this mindset is that the company and its managers should not feel satisfied with the present state of operations. A continuously strive for perfection can be linked to the development of the customer needs. What a customer perceives as value today might be considered basic requirements tomorrow hence driving the need to evolve (Matzler, et al., 1996).

The benefit of adopting the mindset of achieving perfection is that the company and its processes are developed incrementally. This can avoid large, risky process reengineering and instead be made through small continuous changes (Slack, et al., 2010). Small improvements can be initiated by those closest to the process and who has the best understanding of it. This can also increase employee motivation since the staff will feel empowered (Rubenowitz, 2004). However, if some employees experience excessive responsibility and pressure to perform, the opposite reaction can be created (Anderson-Connolly, et al., 2002).

To achieve continuous improvement it is important to involve employees and management (Berger, 1997). Both training and a culture that allows for mistakes are necessary for creating a culture where the improvements take place (Bicheno, 2008). Continuous improvement can only take place where the organizational structure supports these initiatives and reward improvement ideas. Standardization is important to maintain the improvements already made (Berger, 1997).

3.1.4 Waste and how to identify it

Waste is an activity that does not add any value to the customer and can be divided into Type 1 and Type 2 waste; see Figure 10 (Womack & Jones, 2003). Type 1 waste is activities that are presently necessary in order maintain the operations. Type 2 on the other hand is purely unnecessary and can actually destroy value for the stakeholders (Womack & Jones, 2003). There are eight types of waste that are present in the value chain (Bicheno, 2008), see Figure 11.

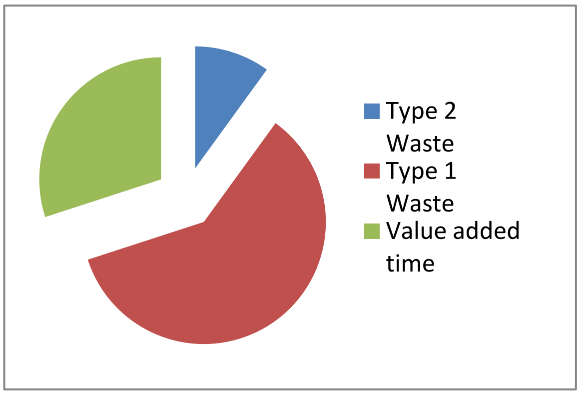


Figure 10 Examples of waste elements in an activity

Overproduction is when an organization is producing too much, to early or just in case (Bicheno, 2008). By moving products, people or information in larger batches, there will be lumpiness in the flow which will impact the flow and resource efficiency negatively (Modig & Åhlström, 2012).

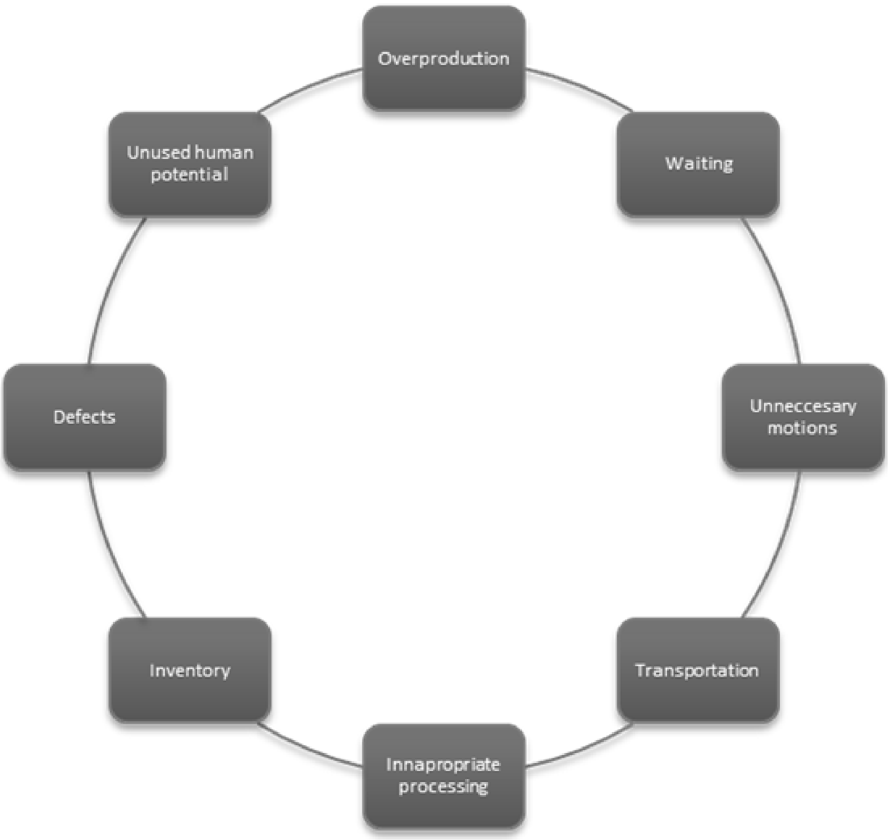


Figure 11 The eight types of waste

Waiting is a waste that is directly related to the flow and to the bottlenecks in a system. If there is a need for waiting this will also create unevenness in the system and disturb the flow. The lead time is dependent on this factor as any bottleneck will define the throughput for the system (Goldratt, 1984).

The unnecessary motions are related to the human workers involved and the layout. Waste at workstations is caused by a non-optimal layout (Bicheno, 2008). By focusing on ergonomics there can be improvements in quality and productivity as the operators will not have to excessively strain themselves when performing an operation.

Transportations are a waste related to the fact that customers are not paying for any transportations besides the transportation of the finished product (Bicheno, 2008). The transports proportionally increase the risk of materials becoming damaged along with adding cost. Transportations should therefore be kept to a minimum without disturbing the flow.

The waste of inappropriate processing is present when using unsuitable equipment for the production or service. Using centralized large equipment can sometimes be necessary in order to provide a large capacity but might at the same time impact the utilization and flow negatively (Bicheno, 2008). Equipment or processes that are unable to meet the quality requirements of the process is also an inappropriate processing.

Inventory is a waste since it prevents rapid discovery of problems, tends to increase lead times and reduces the communication as the inventory buffers any problems in adjoining operations (Jonsson & Mattson, 2011). The inventory has three parts; raw materials, work in progress and finished goods. It is associated with several costs such as additional facilities, tied up capital, additional handling costs and costs for products being damaged in storage (Swartwood, 2003).

Defects are waste in the form of failed production, and carry both short and long term consequences. Scraping, rework and delays are the internal failures, which will incur costs in form of material and tying up production capabilities. External failures like warranties and repairs are also costly and could lead to losing customers. In order to achieve a Lean system the company must aim for defect free products or services (Åhlström, 1998).

The unused human potential is the waste of not capitalizing the ideas and potential of the workers involved in the process (Keyte & Locher, 2004). Basic education for the employees combined with their practical experience of the process can make the operators expert on the process and a useful source of improvements.

Value flow analysis

The value flow can be mapped at three different levels; the big picture, the process value stream and the detailed level (Bicheno, 2008). The big picture is for understanding the system from a strategic point of view and should be led by senior management (Slack & Lewis, 2011). The process value stream is the mapping within the organization and the detailed level is mapping on the individual activities.

The first step in a value stream mapping processes is to identify a product family, a flow object. The product family passes through the same processes, and mapping will thus be simplified and deliver greater benefits when done (Womack, 2006). The product family will also set the boundaries for the system to be studied. It is important to understand both the product and the information flow in order to recognize the workings of the system (Rother & Shook, 2003).

The second step is to determine the current problems in the value stream seen from both the perspective of the organization and the customer (Womack, 2006). The abstraction level for the analysis can then be chosen; either it is inside the company or for the whole supply chain (Petersson & Ahlsén, 2009).

The third step is to follow the value stream, ideally identifying all involved parties and capturing the whole stream (Womack, 2006). Womack suggests starting at the customer end and viewing the processes backwards to the system boundaries. Looking at the different activities is important in order to enable suitable measures to be identified. Throughput time is often the most significant measurement for understanding the flow of the system (Keyte & Locher, 2004) (Womack, 2006).

After mapping of the current state, an analysis can be made on how the system should be working in the future. A new map of the future state can be drawn (Rother & Shook, 2003). This can be done on different timing horizons in order to identify an implementation plan (Keyte & Locher, 2004).

Visual planning methods

Visual control methods are an important element of Lean (Womack & Jones, 2003). Visual methods can also be used to great benefits in planning of projects (Lindlöf & Söderberg, 2011). An improved communication and a shared frame of reference can be obtained by giving more ways of expressing thoughts for the members of the discussion. Prioritization of tasks also becomes easier since the members can get an overview of the whole project. The limit to visual planning is that it cannot bridge geographical gaps but is dependent on all members being present at the discussion (ibid). By visualizing the situation the potential for identifying waste increases (Rother & Shook, 2003), which is a secondary benefit of utilizing visual planning.

3.1.5 Lean construction

The construction industry has traditionally opposed the ideas from Lean production and the Toyota production system, arguing that construction is different (Howell, 1999). Managers within construction are subject to great uncertainties in the projects, like weather, geological conditions et cetera (Howell, 1999) (Salem, et al., 2006). However, due to the focus on individual activities in the project, rather than seeing the value flow there is much waste present in the construction that could be eliminated (Koskela, 1992). The Lean construction philosophy shares many traits with Lean production though with some important differences (Salem, et al., 2006).

The two main features of Lean construction are to focus on the flow and to reduce the waste in order to generate maximum performance at the project level (Ballard & Howell, 1997). This indicates that the goal of Lean construction essentially mirrors the goal of Lean. The differences are instead in what to do in order to reach it, and how it practically can be achieved.

Regarding the flow there are three forms of production that are relevant to the construction industry; transformation view, flow view and value view known as the TFV framework. The transformation view is associated with input and output-as well as achieving a high efficiency. It focuses on the activities conducted. The flow view regards production as a flow of resources with various wastes present. The value generation view is focused on fulfilling the requirements of the customer and that customer requirements are present in all parts of the production (Bertelsen & Koskela, 2002). Through combining the three forms into one value stream that sees the flow, identifies value and acknowledge transformational activities it is possible to improve the processes. Traditionally activities in the construction industry have been regarded as transformation activities and they have been regarded as entirely value adding (ibid).

Last Planner System

One notable approach to planning in Lean construction is the Last Planner System, advocated by the Lean Construction Institute, USA (Maylor, 2010). The Last Planner system promotes that detailed planning should be done by the same employees who carry out the activities. The benefits of this approach is better planning accuracy and improved work flow, thereby reducing cost and duration of projects (Kim & Ballard, 2010).

In the Last Planner System there are different levels of planning. The overall planning should identify important milestones for the project and schedule backwards form these (Kalsaas, 2012). A look-ahead schedule of 4-6 weeks is the next step and details all the activities to be performed. Dependencies that are difficult to spot on the higher levels of planning can be spotted in this process. From the look-ahead schedule a weekly planning is prepared with all activities broken down into half-day units or less. The weekly planning and timing of activities are set by the team of operators to get their input on the duration of activities (Maylor, 2010).

A weekly review is important to control the progress when using the Last Planner System. The review consists of asking whether an activity is complete; therefore it is important that the activities are of roughly equally seized. If any activity is not completed, the reason should be noted down. Dividing the number of activities completed with the number of total activities, giving the Planned Percent Complete Measurement. This indicates how well the planning is working, and by reviewing the causes of incomplete activities the project can be developed (Kalsaas, 2012).

3.2 Context of transportation infrastructure construction

One basic way of describing the construction industry is through describing what type of manufacturing process it is. Two common dimensions to base the categorization on are the volume and variation (Slack, et al., 2010). Construction projects in transportation infrastructure are low in volume, often one single product is the result of the project, but high in variation since not two bridges or roads are exactly alike. This then would typically render in a situation where the work tasks are non repetitive and complex to perform (Ibid). It can also be proposed that the process flow is disrupted by several starts and stops (Ibid). There are however alternative views on the subject. One is to view the project as a sequential chain of activities, hence enabling working towards a smooth and swift flow between the activities (Maylor, 2010).

Infrastructure construction projects are often initiated to fill a societal need rather than individual needs. The value of the product is therefore more abstract since not all aspects of value are clear to define or measure(Bertelsen & Koskela, 2004).Within infrastructure the ones paying, using and ordering are often three different stakeholders (Garrido & Pasquire, 2011). The procurement process is most often initiated by the STA and contracts are awarded in accordance the law of public procurement (Riksrevisionen, 2013).

An additional feature that characterizes the construction industry is the decentralization of decisions to each project manager (Doubois & Gadde, 2002). To a large extent the individual projects can be viewed as separate initiatives, with little coordination and synergies between projects on a corporate level. The individual projects are relatively autonomous with the ability make their own decisions. The decisions are not limited to how to conduct the work level; project managers have often the financial control of the project (Doubois & Gadde, 2002).

3.2.1 Project Management

The construction industry is almost exclusively oriented towards projects. There are seven characteristics associated with projects; mission focused, temporary, change, uniqueness, uncertainty, social construction and integration (Maylor, 2010). Traditionally project management has been focused on the uniqueness of projects (ibid). Uniqueness is associated with a low volume and high variety in the operations (Slack, et al., 2010). Projects can however have some aspects of repetitive elements and the outcome can then be well known which reduce the elements of risk and uncertainty (Maylor, 2010).

There are three main types of projects and they are differentiated on the level of uncertainty present when conducting them (Maylor, 2010). The first type that has the least uncertainty is the “Painting by numbers” type of projects. They are consisting of reoccurring activities with a limited amount of variation. The other two types of projects are characterized by a higher uncertainty. The difference between them is depending on if the organization can be considered an experienced organization in terms of conducting projects. If it can then the project can be regarded as an “As…But” project. The type of activities might be reoccurring but they are done in a new way and it is done in a new setting. The overall project management activities in terms of handling complexity is however more familiar. The third type of projects is known as “First timers” here everything is unique and both the uncertainty and the complexity is significant.

Projects can be said to go through four big phases, sometimes there are phases within a phase depending on seize etc (Maylor, 2010). The 4 D model, displayed in Figure 12, can be expressed as defining what to do, designing how to do it, conducting the actual work and finally developing and improving the way of working (ibid). The design phase, which is analog with traditional planning, in general aims at ensuring a more successful execution of a project in terms of both efficiency and effectiveness (Wenell, 2001).

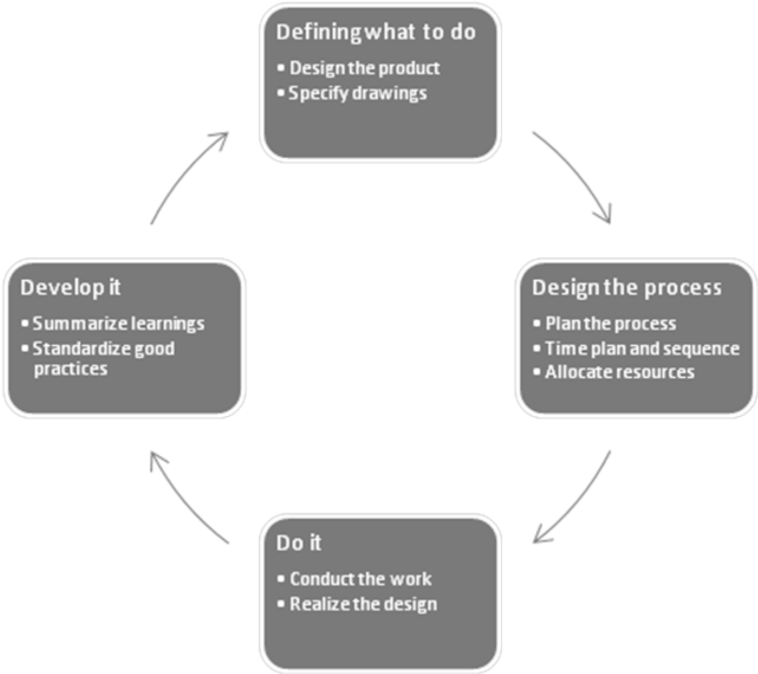


Figure 12 Four D model by Maylor (2010)

It is important to achieve congruency between the different phases so that the definition of what to do is linked with the way f doing it (Maylor, 2010). This enables several benefits such as a closer fit between the operations and the mission thus rendering in lower cost and increased performance (Slack, et al., 2010).

The time it takes to complete different phases in a project is highly dependent on the degree of cross-functional integration (Wheelwright & Clark, 1992). Communicating between and integrating the different functions and departments of an organization improves both quality and reduces the project lead time (ibid). Cross functional integration enables all the different functions to provide input to the project, thus improving quality, and starting parallel work to cut project duration. These parallel workings are known as concurrent engineering. The opposite of cross functional integration is over-the-wall engineering (Maylor, 2010), where the next phase of the project cannot start without completing the preceding step.

3.2.2 Managing complexity and uncertainty

Construction projects are invariably complex and have become progressively more so (Baccarini, 1996). The bigger the project the greater is the need to coordinate the different tasks (Maylor, 2010). Often the individuals are not even part of the same organization thus there is contrasting goals and views, (Doubois & Gadde, 2002).

In contrast with many traditional manufacturing industries, the construction industry also has a large degree of uncertainty present during the project (Ray & Raju, 2009). This uncertainty is derived from several factors such as environmental changes and insufficient informational exchange between individuals (Doubois & Gadde, 2002) (Ray & Raju, 2009).

Uncertainty can be described in two ways. Either as the difference between the information that is needed to complete the task and the information known (Galbraith, 1974). The other definition is that uncertain things are those that cannot accurately be known or predicted (Granli, 2009). The first definition can be expressed as perceived uncertainty while the other is genuine uncertainty. The complexity can be viewed as perceived uncertainty if not all dependencies and interrelationships are identified.

Managing uncertainty is depending on the informational flow within the organization, the greater uncertainty the greater need for informational exchange (Galbraith, 1974). To some degree the uncertainty can be handled through bureaucratization but at some point the exceptions from the procedures become to extensive, hence overloading the hierarchy. There are then two general ways of managing the informational exchange; either to reduce the need for it or increase the capability to process information (ibid). The ways to manage uncertainty is illustrated in the Figure 13 below.

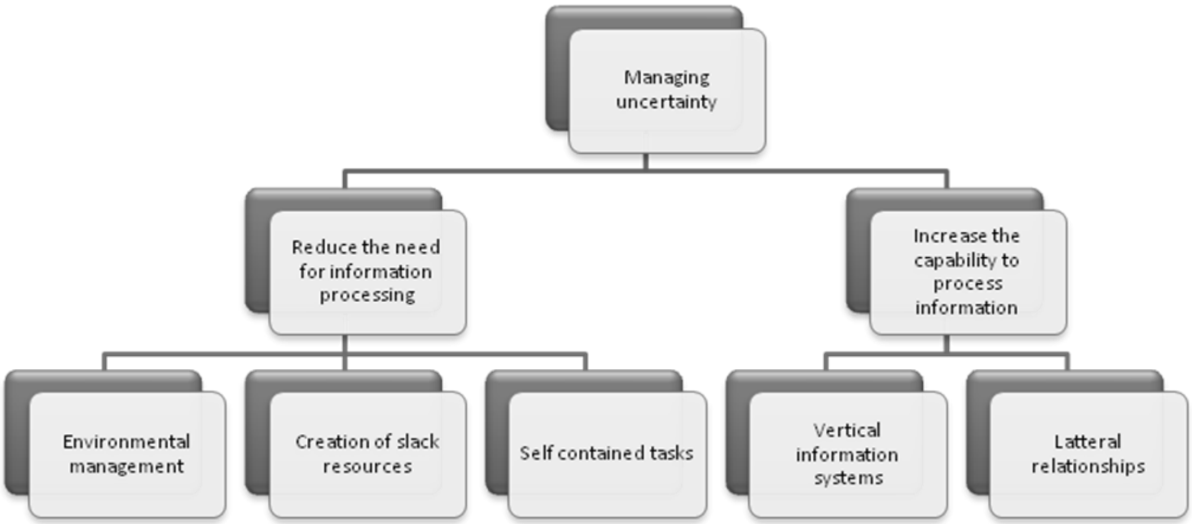


Figure 13 Organization strategies to handle uncertainty, after Galbraith 1974

In practice several strategies can be perused at once in order to combine their strengths. The mixes of strategies are to be based in managing the uncertainty at the lowest cost in the specific context (Galbraith, 1974). If no conscious decisions are made then slack resources will be added hence increasing the waste embedded within the organization.

Uncertainty is very high in the beginning of projects, and up to 80 % of the costs for projects are set in the design phase (Chou, 2009) (Verganti, 1997). Trying to anticipate every possible issue the project has to handle can be too much of an effort. Likewise, the lack of proactivate management can derail a project (Maylor, 2010). Verganti (1997) describes that in the beginning of projects detailed designs are seldom necessary, planning for very uncertain activities will only waste time. Instead interfaces should be designed in planning, for instance by modular design so that the uncertain parts does not influence the overall progress of the project (Verganti, 1997). This then allow for the uncertain activities to be changed without impacting other activities hence it is a way of plan for an increased flexibility.

The mix of complexity and the uncertainty implies different organizational structures (Mintzberg, 1980). An increased complexity requires an increased bureaucratization to handle the interdependencies while an increased uncertainty implies a more decentralized organization (Marmgren & Ragnarsson, 2001). Mintzberg proposes five basic coordination mechanisms to handle different levels of complexity and uncertainty which are illustrated in Figure 14.

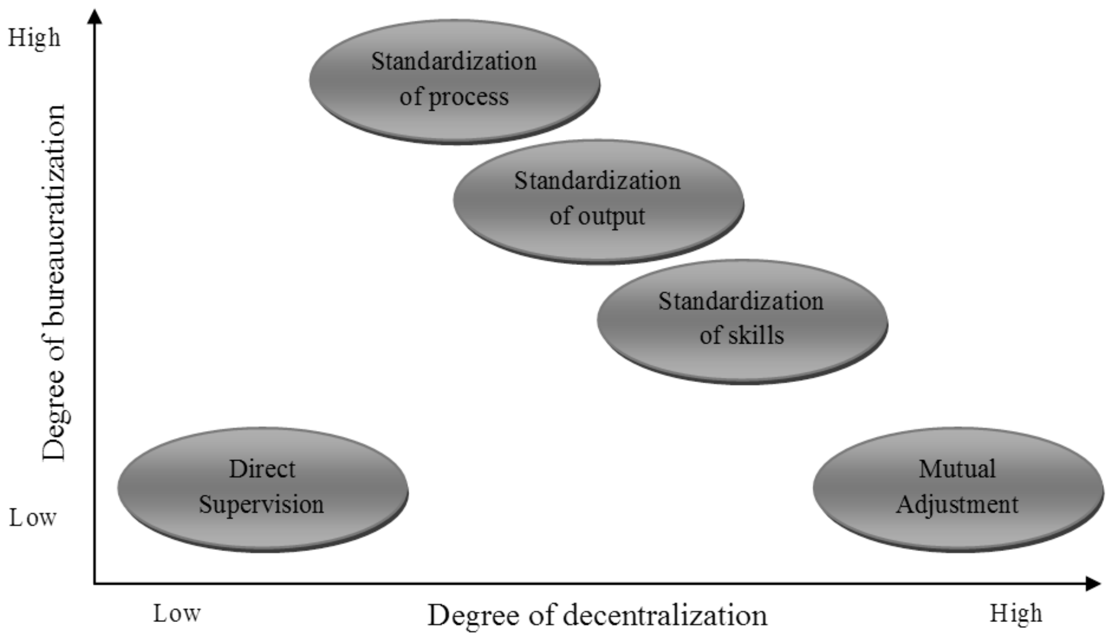


Figure 14 Coordination mechanisms as described by Mintzberg (1980)

Direct supervision is linked with high uncertainty and a strong centralization based on a strong leader, typically found in start-up firms of companies in crisis. The mutual adjustments deals with high uncertainty environments typically highly sophisticated organizations based on highly educated and specialized employees. Standardization of work processes are suitable in low uncertainty environments but can handle high complexity, it is typically found in mass-production industries. Standardization of outputs allows for greater flexibility hence enabling an increased capacity to handle uncertainty. The standardization of skills is based on complex work tasks that require significant training and education, often found in professional organizations such as law firms or hospitals.

4 Case description

This chapter presents the company, the project details, the project initiation, the project management and the ongoing processes.

4.1 The Nordic Construction Company, NCC

NCC AB, Nordic Construction Company, is the second largest construction company in the Scandinavian region. The main business is based in Sweden and subsidiaries operate throughout the Scandinavian countries and the Baltic region. The annual turnover is approximately SEK 57 billion with about 18 000 personnel.

The company is divided into business areas formed around the types of construction performed. NCC construction is responsible for both building and non-building construction projects and these are further divided into geographical areas and a special unit, NCC Infra, for larger infrastructure projects as displayed in Figure 15 NCC infra is further divided into three units and the construction project belongs to region west based in Gothenburg.

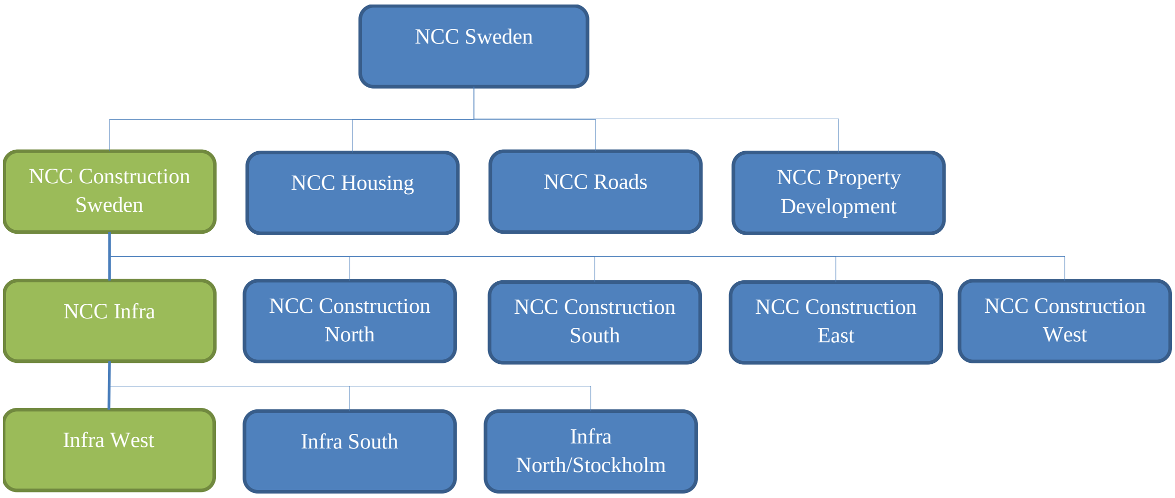


Figure 15 Organization of NCC Sweden, green displays belonging of case unit

The main customer for NCC Infra West is the STA who procures and maintains most of the infrastructure in Sweden, both railways and roads. The municipalities have some share of the markets for small and urban roads and railways. Private parties only provide a fraction of the market.

4.2 Project background

The case project studied in this thesis has been the construction of the highway intersection between roads 40 and 549, Bårhults-motet. The construction site is located between Landvetter and Gothenburg in the west of Sweden. The project was initiated by one of the forerunning agencies to the STA in 2009. The duration of the project is planned to be approximately 16 months. The new intersection is intended to ease passage between the highway of E20 running northeast towards Stockholm and highway 40 running eastwards to Borås, see Figure 16. This will enable easier access between these two main highways without passing the city center of Gothenburg, where congestion pricing has been instituted as of January 1st 2013.

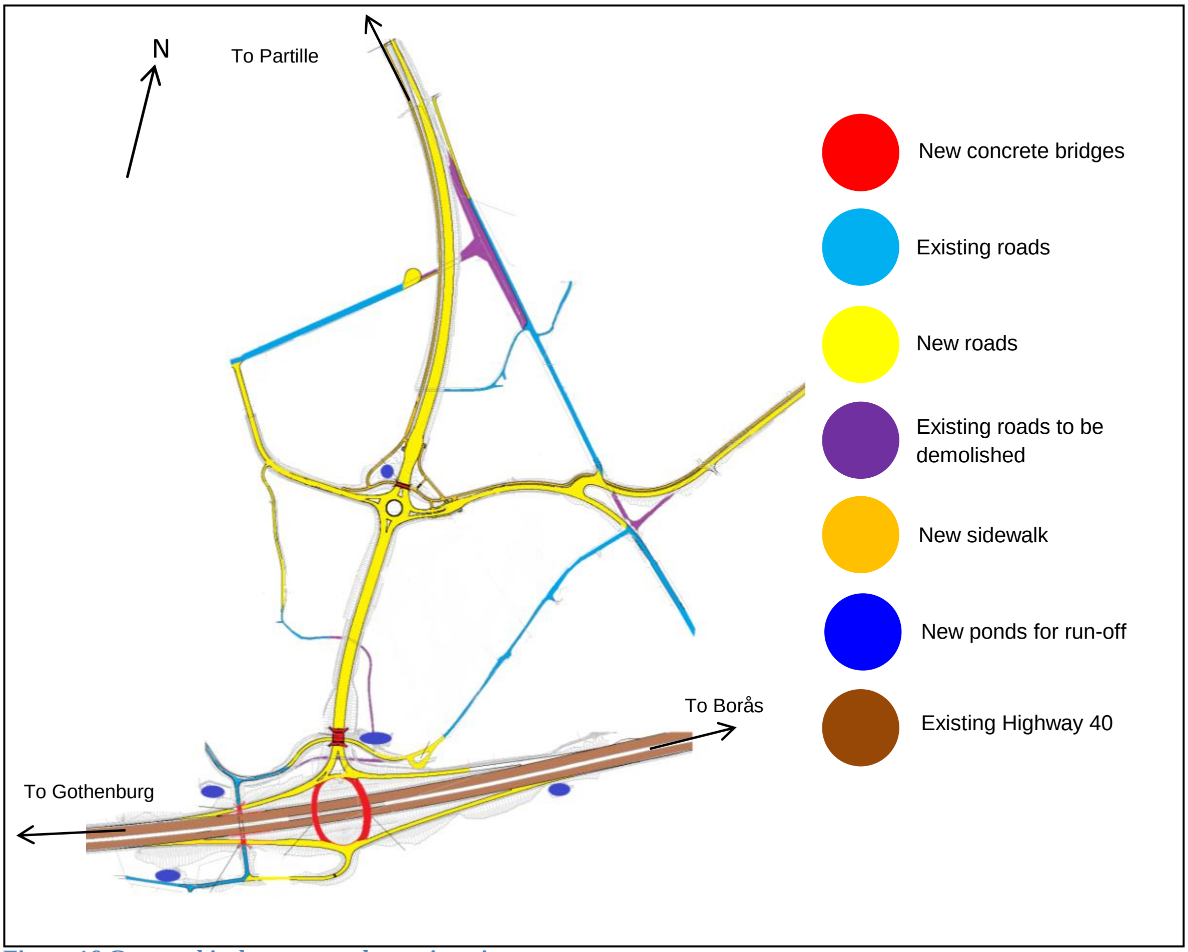


Figure 16 Geographical map over the project site

The project is under the oversight of the STA that assigns different parts of the project to contractors. Initially the STA designated the general area for the new intersection and a public procurement procedure followed to assign a designer of the project. The design consisting of a layout and blueprints was delivered to and controlled by the STA. The blueprints were after approval used for a second call for bids that was sent out to construction contractors. The call for bids specifies the required quality of the product using the blueprints and sets the timetable for the production. In accordance with the regulations for public procurement the offer conforming to quality and the time schedule at the lowest cost was then selected and the contract was awarded to NCC with a budget cost of 128 MSEK.

Härryda municipality has designated the areas next to the new intersection as industrial zones and they are due for development after the completion of the project. The Swedish Postal Service has a major terminal neighboring the construction which has been threatened by closure due to lack of sufficient infrastructural support. Härryda municipality has funded the construction as part of an agreement to keep the terminal operating. The municipality is also planning for new industrial zones attached to the new intersection. The funding is in form of loans to be repaid when funds become available for the original construction date that was planned in the late 2010s.

4.3 Project initiation

From NCC's side the project was initiated by the call for bid by the Traffic Administration. The bid for the contract was calculated and prepared at the NCC Infra west headquarters. The headquarters drafted a preliminary production plan along with a budget for the project. This planning was presented to the Traffic Administration as part of the bid. After the contract was awarded a short startup meeting was held with the project organization. Here the reasoning and assumptions made in the calculation phase were presented. The construction activities were initiated almost instantly after the start-up meeting was held.

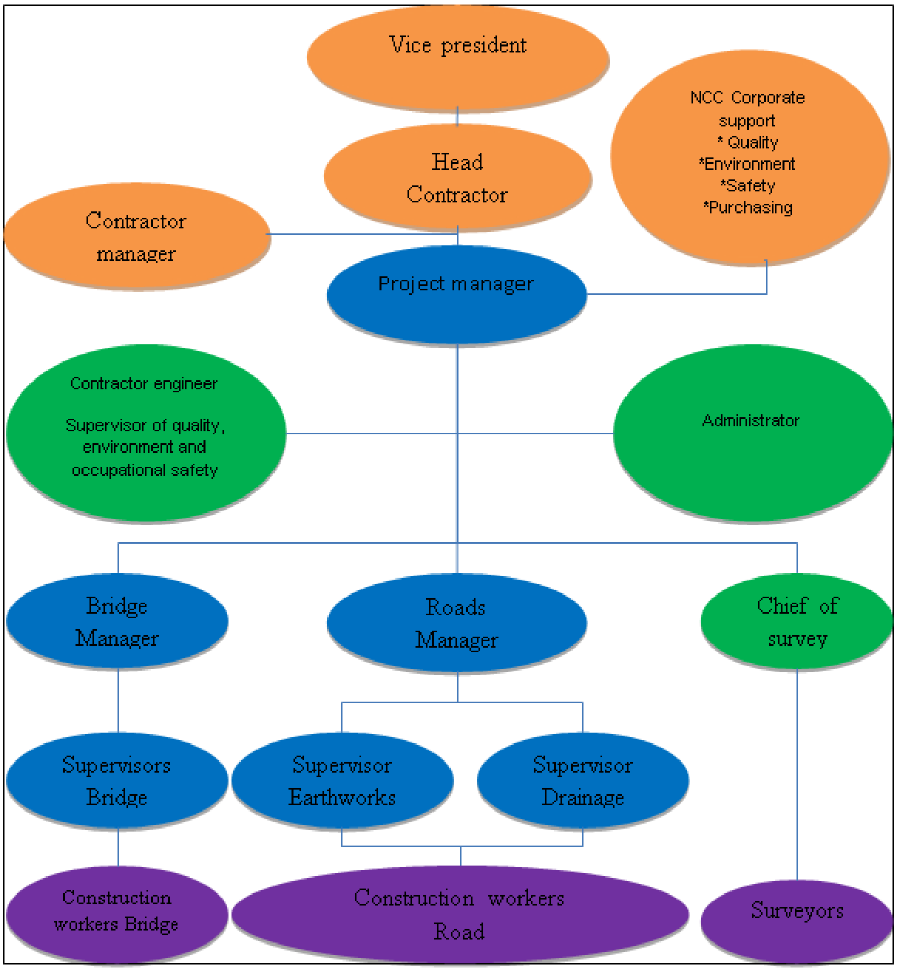


Figure 17 Organization chart for project

Blue indicates senior positions in the project. Orange is NCC management connected to the project not located on site. Green are the supporting roles for the project manager. Purple are employees and subcontractors.

The core team of the project organization is formed by in-house white collar employees. The team is not a permanent entity and individuals can be assigned to different projects. From interviews it is indicated that the individuals do establish relationships among themselves. The appointed project manager has a large influence on who is selected and tend to establish more long term teams. Besides the white collar employees from NCC about 35 blue collar sub-contractors are employed throughout the project.

Some parts of the project organization have been working together over the course of several projects, in some instances well over a decade. This includes not only the management but also several of the construction workers, machine operators and subcontractors. Interviews indicate a strong preference for persons that someone has worked with previously, even if this means disregarding demands set by the customer.

Construction began at August 2012 after an initial delay of a few months due to an appeal of the procurement process. However, the timetable has not changed and the project must still be completed at the designated date of November 28th, 2013. The basics timetable is shown in Figure 18; the detailed project plan can be viewed in Figure 18.

Task	**Timeframe**					
Year	2012		2013			
Quarter	Q3	Q4	Q1	Q2	Q3	Q4
Clearing area						
Excavation						
Rock blasting and grinding						
Refilling						
Pavement						
Finish						
Drains						
Ponds for run-off						
Bridges						

Figure 18 Simplified production schedule

The design blueprints are the basis of the construction project and it constitutes the detailed design. The blueprints are handed over to NCC at the initiation of the project by the STA. The blueprints in turn are designed by a third party.

On-site the STA maintains a presence to ensure the quality of the project. The bid from the contractor includes only the work that is specified in the blueprints and any changes or additional work will have to be paid for by the STA, commonly referred to as ÄTA. This is settled in a negotiation process between the contractor and the onsite personnel of the STA.

The blueprints themselves are used to create a computer model of the construction. The computer model is created by the chief of survey. All machines utilize the model and navigate the construction after the built in computer in the machines. The model indicates exactly how the construction should be done. During the project, several changes were made to the design due to unexpected changes in the on-site conditions, changed demands or other reasons.

4.4 Project management

The project management is constituted both by planning for the activities that are to be conducted and for adjusting the plans according to changes.

4.4.1 Planning

The time plan for the project is constructed and revised in three types of iterations. After the contract was awarded a general production plan was created by headquarters. It is broken down in regular intervals with the development of seven week plans that govern the long term management of the project. The general production plan was not revised.

All production plans are based on the different activities that are to take place, for example excavation, refilling etc., it is represented as a work breakdown structure (Maylor, 2010). Construction is divided into geographical units in order to more accurately indicate how far the work has progressed. The duration of the activities is estimated in the long term planning (general production plan and seven week plan) from earlier experience. In the short term planning (two week plans) it was observed that the project management communicates with trusted operators to get estimations on the time required for completion. Accumulated changes in the project are detected in the follow up phase through the use of cost and time controls.

It is in the long term planning that the types of machines used are determined. In this case a conscious choice was made towards smaller and more flexible machines.

Interviews indicate that the plans are not held to be absolute. In case of stops and disruptions by for instance weather the supervisors mostly prepares an alternate plan to employ machines and operators. Conversations identify this as the primary function of the supervisors and thereby keep the equipment utilized. Interviews with the management also states that the operators are actively seeking out new tasks in case of prolonged disruptions. Observations showed the management also added extra time to the activities, about 10 %, in order to preserve the integrity of the planning and make sure that the tasks could be finished.

The planning is focused on adjusting the sequence of activities. Sequencing the activities is primary based on identifying technical dependencies, for example the soil needs to be excavated prior to the refilling with crushed rock. Observations indicated that there was a secondary focus on also taking the flow dependencies into account when the seven week plans were formulated. The planning to include the flow was however mainly based on experience and on individual efforts. Interviews with the project manager indicated that the flow was the primary concern for the project management. The planning also has to take into account that the activities share a common resource pool. The leveling of resources and their utilization was however mainly the responsibility of the supervisors.

4.4.2 Communication

Meetings take place on several different levels of the project, see Table 3. The meetings have different purposes and recurrence. Observations indicated that many unofficial meetings take place in the break room between the supervisors and project manager. Also, several unofficial meetings were held with the traffic administration which had the onsite office next-door. Interviews indicate that this kind of communication between the project and traffic administration is highly unusual. The interviews and observations indicated that there often is an animosity between the project organization and traffic administration.

Table 3 Meetings in the project

Meeting type	Purpose	Participants	Frequency
Construction meeting	Formal negotiations and timetable updates for customer	Project manager (NCC), Construction engineer, Swedish Transport Administration	Monthly
Preparatory construction meeting	Preparing for construction meeting and checking completion of assigned tasks	Project manager (NCC), Supervisors	Thursday before construction meeting
Weekly meeting roads	Reporting progress of construction and update timetable	Project manager (NCC), Supervisors for road construction, Swedish Transport Administration	Every two weeks
Seven week planning	Developing the seven week plan for the project	Project manager (NCC), Supervisors	Every two weeks
One week planning	Developing the construction plan for the coming week	Project manager (NCC), Supervisors for road construction	Weekly
Information meeting	Informing construction workers of the work the coming week	Supervisors for road construction, construction workers	Every Friday

Informal meetings take place as well. Planning is not limited to the allocated meetings but done continuously by cooperation between the supervisors and the project manager. The meetings are used to fix the plan and for communicating it to the involved parties. Trusted operators are visited and asked for their input on how to proceed with the plan. The surveyors also frequently discuss the progress on site with operators when surveying the terrain.

The work descriptions and geological models were not delivered on a scheduled basic. Instead they were provided when a need for them was discovered; employees sometimes requested these ahead of schedule directly from the supervisors. This was done either through the surveyors when they asked the professional workers on how they progress or from the supervisors when they estimated the duration of the activity. The work descriptions were mainly provided when requested by the STA or when tasks that were, perceived by the management, above the knowledge level of the professional workers were identified.

It was observed that much of the communication was done with a terminology that required experience in construction. Also, when discussing the planning the attendees required to be well informed of the project and up to date with the current question discussed. The problems discussed and solutions presented also displayed a high tendency towards resource utilization and a more efficient execution.

4.5 Ongoing processes

The earthwork processes during the case period consisted of five different chains of activities. The chains of activities have been studied as processes based on conducting a value stream mapping based on the excavated material as the flow unit. Capacity utilization is determined as percent non-waiting time when working, excluding planned stoppages such as breaks. Flow efficiency is calculated as a percentage of the time the resource, earth or rock, is being transformed. This is from initial excavation until delivered to the final destination i.e. subject to value adding time (Modig & Åhlström, 2012). Since the STA pays for each part of the project it means that all transports of material are value adding time and has been treated as such.

4.5.1 Excavation of soil

On the north side of highway 40 the activity consisted of moving the soil in order to initiate the construction of the north-south road linking highway 40 and E20 together. elow presents a map over activities in order to transform the input into the desired output at the desired location.

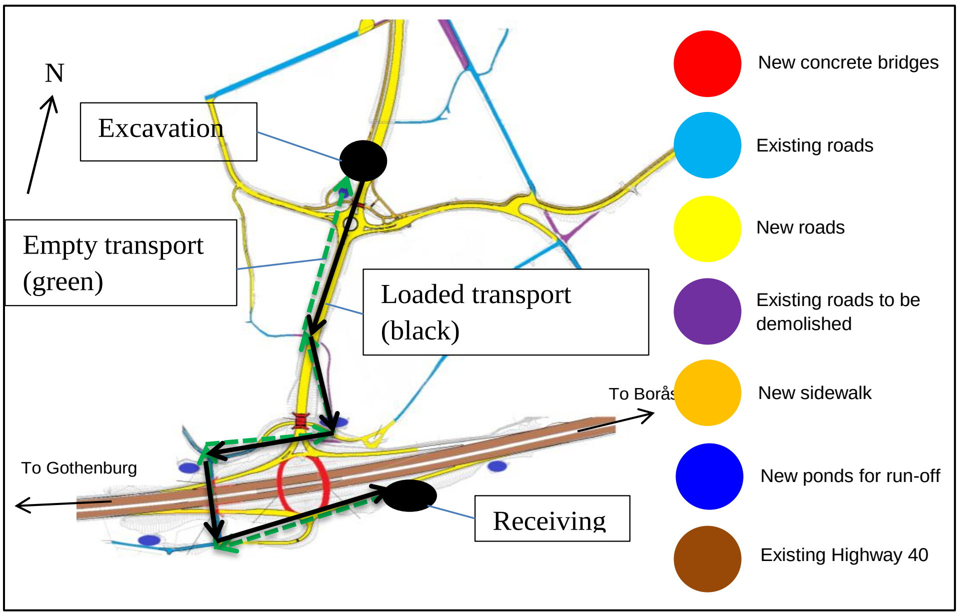


Figure 19 Geographical display of soil excavation

The process employed two excavators and three articulated haulers and the process is displayed in Figure 20. The excavator cannot load unless the articulated haulers constantly pull supply from the excavation. There was no inventory and almost zero waiting times for the excavator were nonexistent. Small waiting times could still be value adding as the experienced driver can position the machine for optimal loading adjustments. For the articulated haulers, running back to the loading zone and small waiting time for entering loading position counted for approximately 33% and 8 % of the cycle time respectively. Due to technical parameters it is not suitable to transport rock and soil with the same articulated hauler. The value stream mapping is visualized in Figure 20.

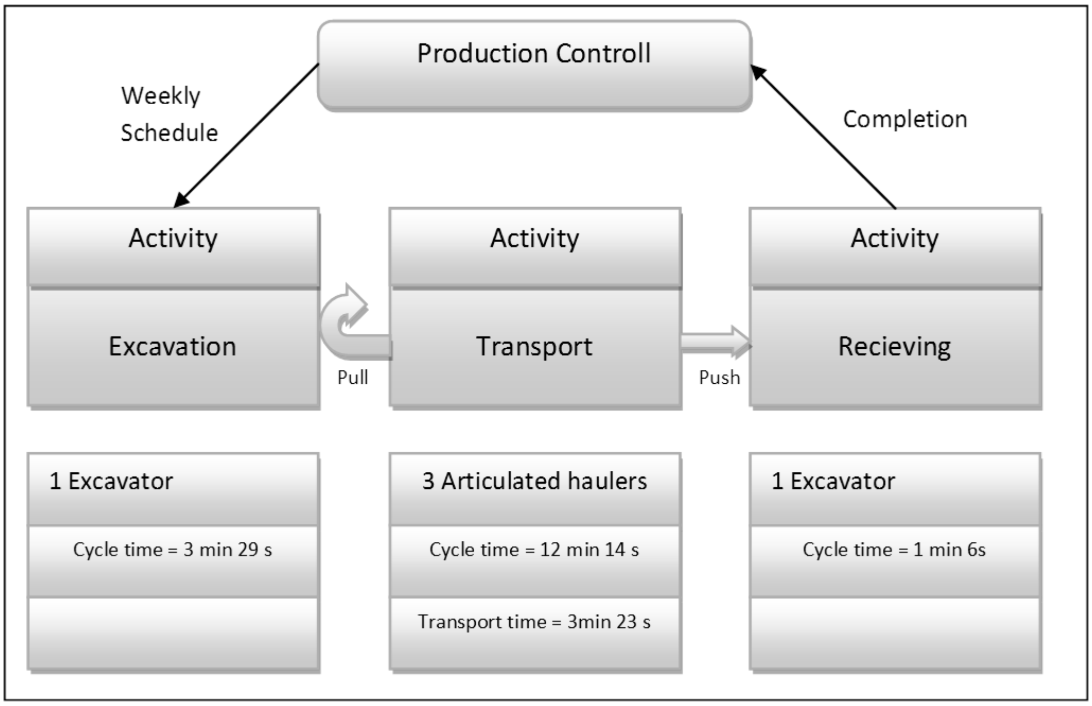


Figure 20 Value stream map over soil excavation

The throughput of the excavation process can be plotted in the resource and flow efficiency designed by Modig and Åhlström (2012). The capacity utilization is very high for all involved equipment and the different machines are used around 90 % of the available time. Also, the throughput is subject to value adding time throughout the entire process and the ratio of value adding time versus total time approaches 100%.

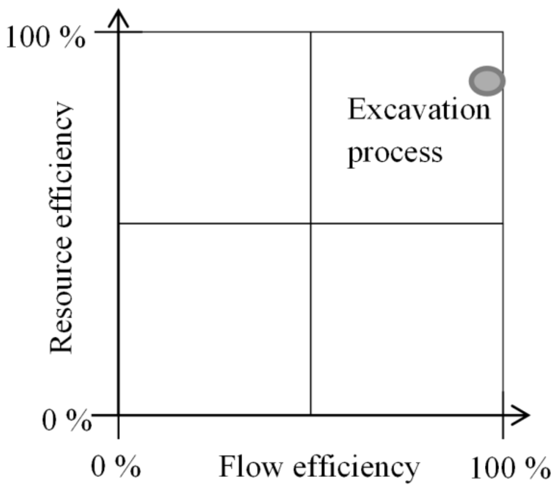


Figure 21 The excavation process put into the efficiency matrix by Modig and Åhlström (2012)

The process is subject to a number of factors that induce variation. Weather can make the roads more difficult to travel and thus increase transportation times. Other transports and transfer of articulated haulers to other processes also affected. The breakdown of equipment also disturbed the process. Disturbances occur on weekly basis and are mostly corrected without involvement of project management.

4.5.2 Rock blasting and filling manufacture

On the north side of Highway 40 was the process of transforming rocks into gravel conducted, Figure 22. The gravel was to be used in the construction of the roadbeds later in the project. In this case the rocks used for the transformation into gravel were taken from areas that were to be removed in order to allow for the road to have a smoother topographical profile. This places technical demands on the sequence since it required that the rock was grinded into gravel prior to initiating the building of the road.

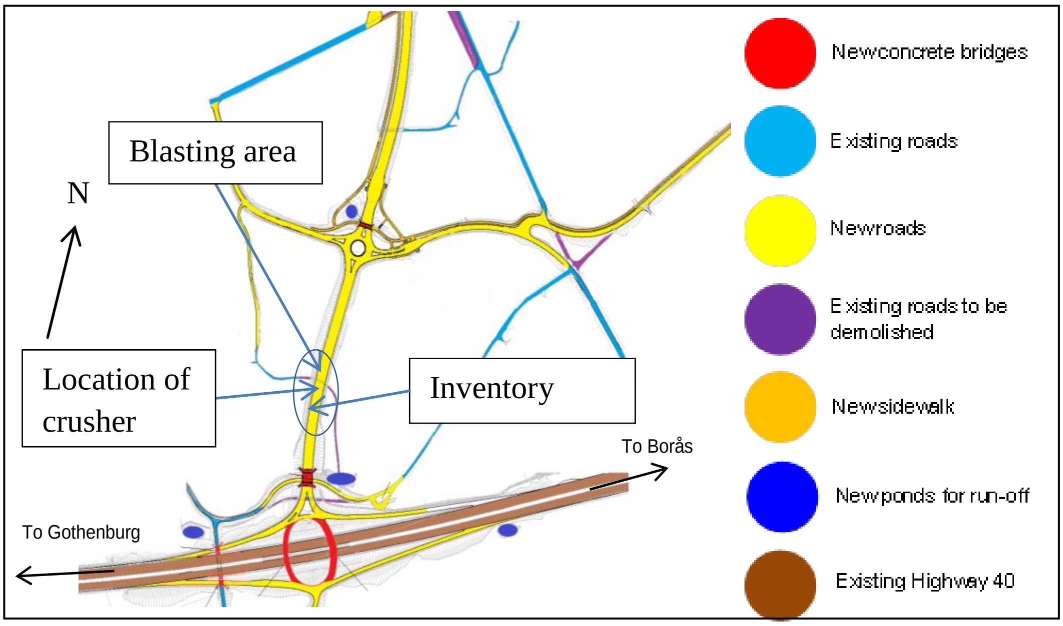


Figure 22 Geographical map of rock crushing

The process requires two excavators, one crusher and a wheel loader along with drilling and blasting. The process along with the machinery is provided by a subcontractor and this subcontractor sets its own work hours. The initial surveying and blasting are manual processes that require only minor equipment. After the blasting a specially fitted excavator picks large remaining stones into smaller ones that then can be lifted into the crusher by another excavator. The crusher limits the throughput rate and the excavators fill the machine at a near constant rate. The product is placed into inventory by the wheel loader. There was no articulated haulers nor intended destination assigned during the process. A value stream map over the process can be viewed in Figure 23.

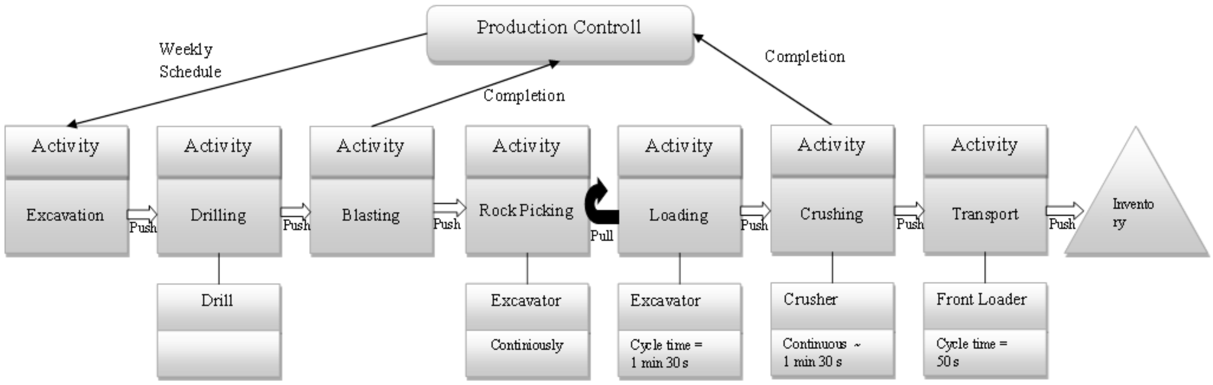


Figure 23 Value stream map over transformation of rock into gravel

The capacity utilization is determined at about 90 percent of the time; the major stop is due to blasting which requires evacuation due to security concerns. The flow quota is about 1 percent as rock will wait to be put into the crusher for about a day. The waiting in inventory is weeks before utilization. Both the resource and flow efficiency is illustrated in Figure 24.

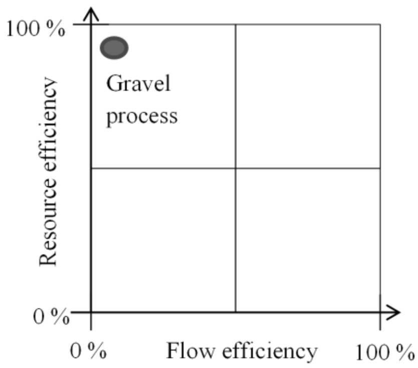


Figure 24 The gravel process put into the efficiency matrix by Modig and Åhlström (2012)

There are some variations elements present in this process. Blasting requires both the public highway and all other work in the vicinity to be shutdown. This makes it important to adjust the blasting times so that it interferes as little as possible.

4.5.3 Rock excavation

Blasting, excavation of rock and construction of a ramp was done south of highway 40, map in Figure 25. The rocks are used as input in the construction of the ramp but must also be removed in order to make room for the end of the ramp.

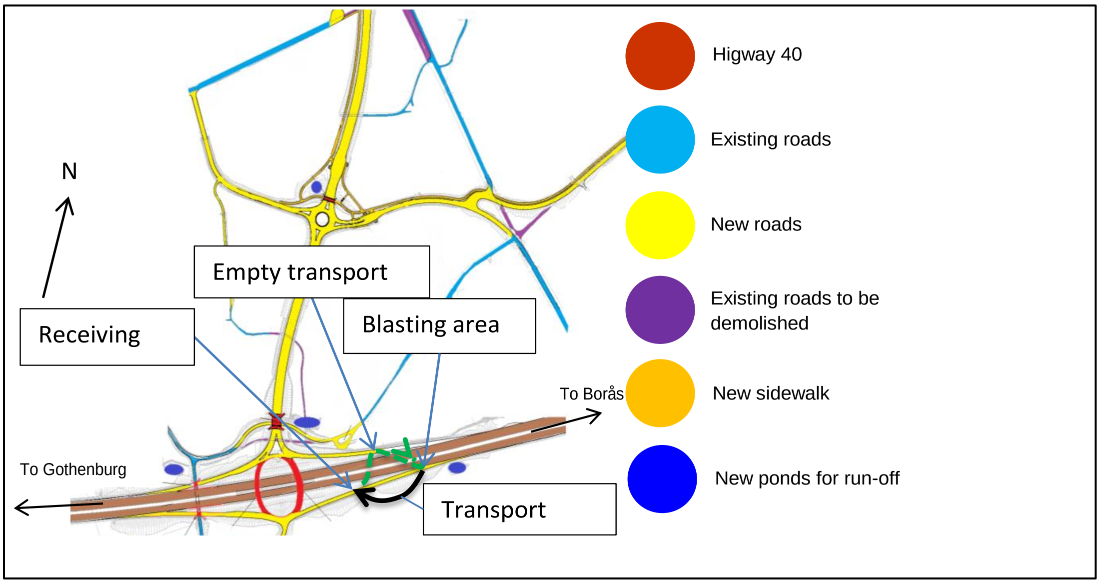


Figure 25 Geographical location rock excavation

The process utilizes two excavators, an articulated hauler and a bulldozer and shares blasting and drilling resources with the gravel process. Large rocks were separated and picked in order to enable the excavator to load the rocks onto an articulated hauler. The hauler then transported the rocks a few hundred meters to the ramp and the bulldozer pushed them into place.

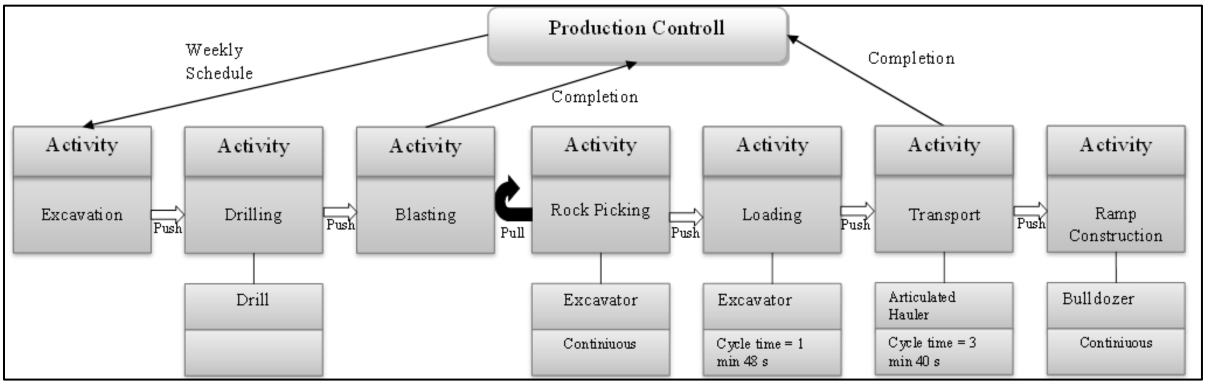


Figure 26 Value stream map for rock excavation

The short transport stretch made the transport time for the articulated short. This reduced the time the bulldozer had to wait until the articulated hauler returned thus being occupied at a near 100 % utilization. The excavator was forced to wait for the articulated hauler and had a utilization of about 65 %. The picking was done continuously at a the blast site where the rocks had a mean waiting time of about half a day which made the flow time about 5 %. The resource and flow efficiency are illustrated in Figure 27.

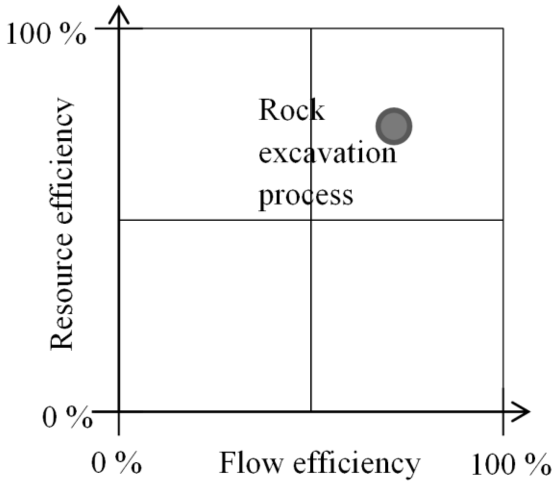


Figure 27 The rock excavation process put into the efficiency matrix by Modig and Åhlström (2012)

There were also some variations imposed on the process. Blasting calls for evacuation and traffic from other processes induced some variation in transport times.

4.5.4 Pond

On the south side of Highway 40 one of five ponds for runoff was excavated, see Figure 28. The ponds are possible to establish at almost any point in the project but the STA prefers to have them established early. The ponds are constructed out of environmental concern since they Lean urban runoff from the road.

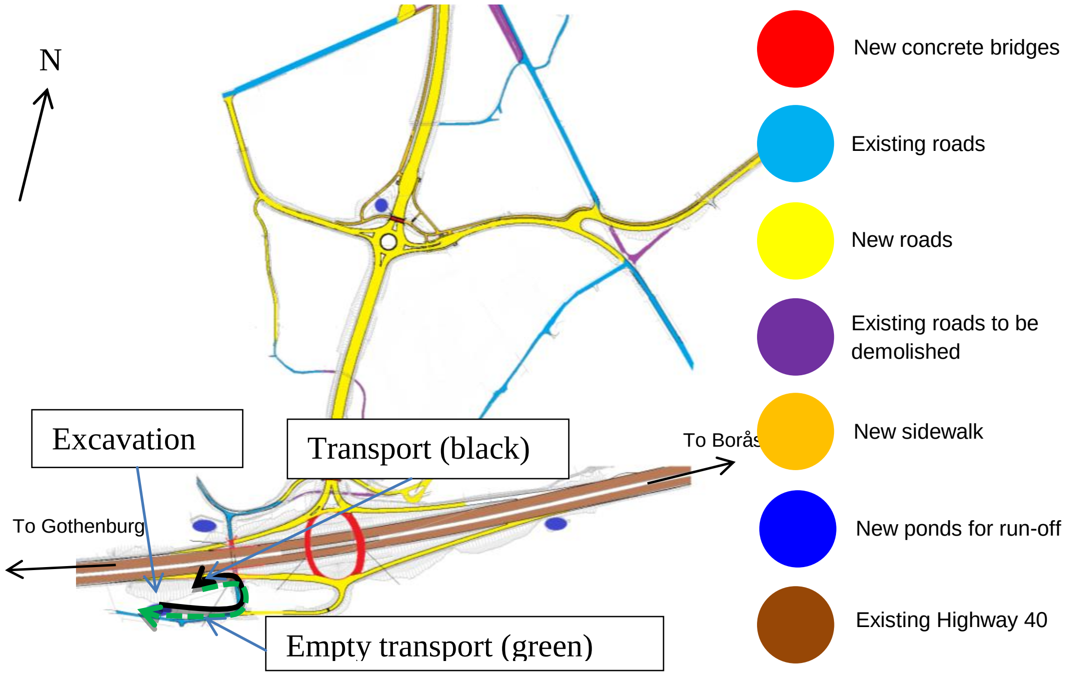


Figure 28 Map of pond excavation

The process employed an excavator and an articulated hauler. Both machines maintained a capacity utilization of about 90 %. The articulated hauler only moved a few hundred meters while the excavator had to spend the time maneuvering and adjusting to the small area of the pond. Combined with a short distance to travel and more detailed excavation the unproductive time is kept at a minimum as the excavator process the detailed edges as the articulated hauler dispatch soil and then loads the main load when able to. The flow was at 98 % as the material is transported directly to the destination. The value flow is illustrated in Figure 29 while the resource and flow efficiency is presented in Figure 30.

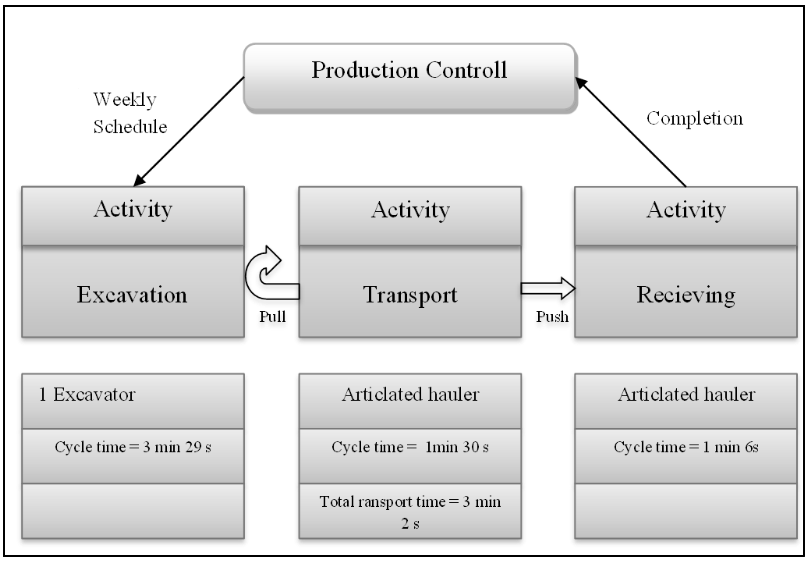


Figure 29 Value stream map over pond excavation process

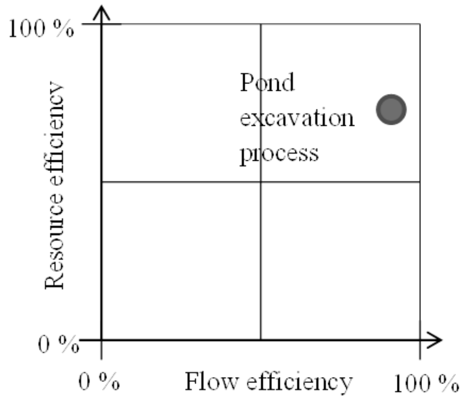


Figure 30 The pond process put into the efficiency matrix by Modig and Åhlström (2012)

Variation came from the unexpected discovery of rock in the excavation area. According to the details provided by the traffic administration the area should only have consisted of soil which turned out to be inaccurate.

4.5.5 Drains

North of highway 40 and adjacent to the excavation of soil the preparation of drains took place, see Figure 31. The drains are established to lead urban runoff into designated ponds. The output volume of the excavated soil is low along with a low need for material supply in relation to other activities.

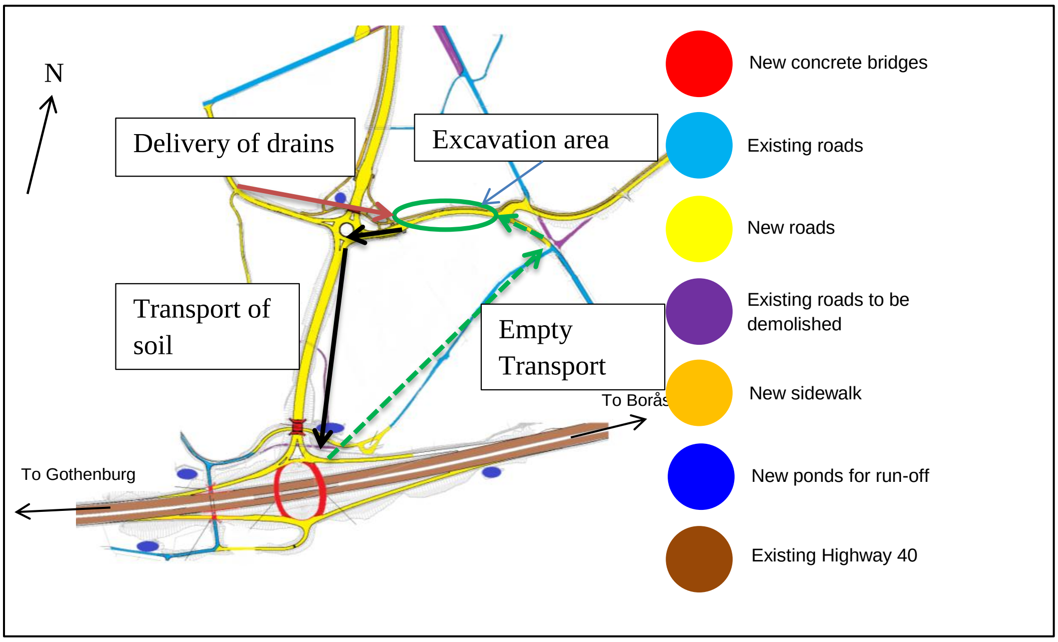


Figure 31 Map over construction of drains

The service vehicle placed drains in the excavated ditch. Surveyors were called out to measure the location of the drains before covering. This more extensive chain of activities is illustrated in Figure 32.

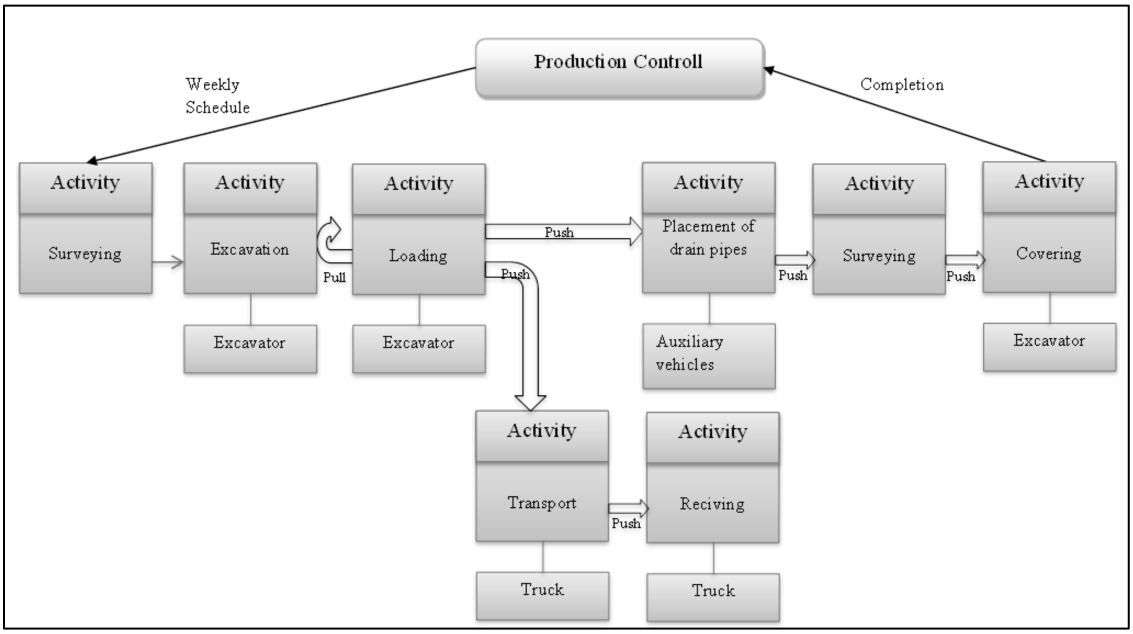


Figure 32 Value stream map over drains

To the process an excavator and a truck along with a service vehicle was assigned. The excavator created a ditch to place the drains and the soil was loaded onto a truck. The excavator is dependent on the transport to load up the soil but can do more detailed excavation while awaiting the transport to return and thus the utilization was about 90 percent. The excavator placed about 30 % of the output into an inventory waiting for the truck and this reduced the flow to 70 %. The flow and resource efficiency are illustrated in Figure 33.

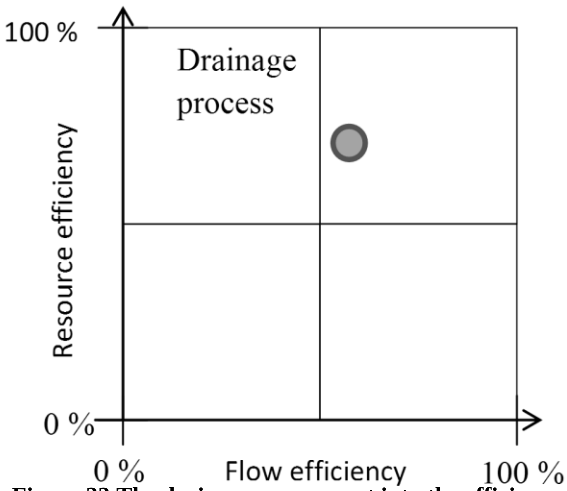


Figure 33 The drainage process put into the efficiency matrix by Modig and Åhlström (2012)

This process contained several direct issues of variation. Working along the transportation roads variation was induced by other traffic. After the drains were placed these needed more visits from surveyors as it is required to map the placed drains before covering. This process also displays a high sensitivity towards changes in the weather and is highly dependent on the exact terrain. Uncertainty is also present as it cover large stretches of roads were the ground conditions sometimes are poorly scanned.

5 Analysis

In this chapter the case is examined and different phenomena explained. It is based on breaking down the processes and evaluating their performance. The chapter also aims at presenting why the processes are the way they are. Furthermore the implications of the current way of conducting the project are discussed.

5.1 The flow and resource efficiency of the processes

From the empirical data it is revealed that the studied processes have both a high flow and high resource efficiency, although with one evident exception. All processes are plotted in the efficiency matrix in Figure 34. The process differ somewhat but they are generally in the upper right corner which is the desired state (Modig & Åhlström, 2012). The key is embedded within identifying the factors that enables a high flow and resource efficiency.

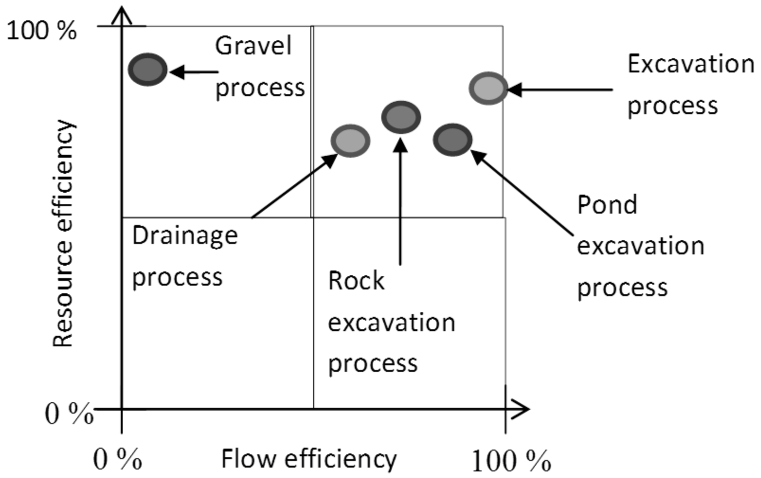


Figure 34 Combined picture of ongoing processes

5.2 Achieving high resource and flow efficiency

Two main factors that determine the flow and resource efficiency emerged namely arranging the sequence and to adjust to uncertainty. They emerged through identifying what significantly lowered either, or both, the resource and flow efficiency. In the following sections they are presented more in detail.

5.2.1 Arranging the sequence

One influential factor that governs the amount of waste is the sequence in which the activities and processes are conducted. There is a technical dimension that determines the sequence. A large part of the activities are required to be conducted in a specific order, for example the excavation is required to be conducted prior to rock filling and so on. These dependencies are stabile and known at the initiation of the project. They can therefore be planned in detail, (Maylor, 2010), and taken into consideration already at the calculation stage.

Several of the activities, such as the rock and soil excavation, produced significant volumes of output that was needed to be transported and utilized in order to uphold high flow efficiency (Modig & Åhlström, 2012). The difference between arranging a suitable or unsuitable sequence is illustrated by comparing the soil excavation and the transformation of rock into gravel. The flow efficiency is significantly higher in the soil excavation. This also implies that there is no need to load the excavated material again which is associated with substantially higher costs. Other activities required significant input of material in order to be conducted, such as the construction of the ramps. Delays in the input of materials would significantly impact the resource efficiency (Ibid). This implies a complexity in terms of input output dependencies. By taking the dependencies into account it is also possible to adapt the machines used for each activity throughout the process thus avoiding inappropriate processing.

The amounts of input or output material are determined by the blueprints and the geological models used. Thus it is possible to plan and take the dependencies into account in the initial phases of the project (Maylor, 2010). The smaller volumes such as the ones created through the drain processes and the construction of the pond display a larger relative variation and thus they need to be changed more frequently during the project. The possible combination of destinations to match need for input and produced output also increases and the costs of not matching are reduced in absolute terms. This implies that there is a lesser need to plan in detail and more benefits to be drawn by allowing for operative plans (Ibid).

One additional dependency that impacts the sequence was the shared pool of resources and the limited capability to adjust the capacity. To achieve high resource utilization it is important to match the tasks to be performed with the available capacity. This implies that the sequence of activities must be adjusted to the available capacity.

5.2.2 Adjust to uncertainty

From the empirical data variation emerges as one influential factor on both the flow and resource efficiency. Uncertainty induces variation which lowers the efficient frontier in the efficiency matrix thus lowering both the flow and resource efficiency (Modig & Åhlström, 2012).The particular type of project that was studied consisted of elements previously done but combined together in a new configuration and in a new setting. This type of project is referred to as “As… But…” projects, characterized by significant uncertainty (Maylor, 2010). To uphold a high flow and resource efficiency it is therefore pivotal to remove the uncertainty, handle it when it arises or to render it harmless (Bergman & Klefsjö, 2010).

The variation that can be removed is perceived uncertainty and it is removed through increased informational processing (Galbraith, 1974). One examples of such variation is the amount of traffic on the transport roads. The soil excavation was disturbed by additional traffic from concrete carrying trucks that prolonged the transport time hence reducing the resource and flow efficiency. This source of variation requires a more centralized approach were a greater overview is achieved to identify the interconnections between processes. Other clear examples on how to reduce the source of variation is to include more information about the on-site conditions when designing the processes and activities (Ibid).

In practice much of the variation is rendered harmless due to having flexible and competent workers and machines. From interviews it was evident that there was conscious efforts made to use machines and operators that could operate in a wide set of conditions. This enabled for the activities and processes to carry on despite uncertain elements. Larger and more specialized equipment might have the possibility of increasing the capacity while the more flexible resources can have better resource efficiency and flow efficiency. By foreseeing possible sources of uncertainty such as the temperature it is possible to adjust to the conditions. One example of this was how the concrete constructions could be fitted with wiring for controlling the temperature. By doing so the possibility to continue the process still existed.

Some of the variation is genuine uncertainty (Granli, 2009) which cannot be removed through more extensive planning. Instead it needs to be handled when it arises. Examples of this type of uncertainty are the weather conditions. This impacted the possible transport roads, the feasibility of constructing drains and so on. The genuine uncertainty instead has to be handled when it arises.

5.3 Project management to support resource and flow efficiency

The key areas within project management are to handle the complexity, in terms of arranging a suitable sequence of activities and to handle uncertainty (Maylor, 2010). It is therefore a key activity in order to secure a high flow and resource efficiency.

Project management is a wide and abstract area and in order for the activities conducted to be analyzed and understood it is beneficial to use conceptual models. The project management activities conducted during the studied project is therefore related to the 4D model presented by (ibid). Within each category the activities are analyzed with a focus on explaining their characteristics.

With the reasoning presented above it can be argued that project management is not consisting of one activity but instead that it is built up through several activities that are combined. In combination with the empirical data five main categories of activities emerge. They are illustrated along with a description of their purpose and the questions raised in Table 4. The individual categories are further discussed under individual headlines in this chapter.

Table 4 Different categories of activities in the project, their purpose and practical examples

Category	Purpose	Examples of activities conducted
Define the project	Specify the outcome of the project along with the design	Conducted outside of NCC by The Swedish transport administration and a constructer
Designing the project -Strategic level	Design the process *Identify dependencies *Manage the flow	The overall time plan The seven week plan Construction meetings
Designing the project -Operational level	Design the process *Handle uncertainty *Resource efficiency	Two week plan Weekly meetings Coordinate changes in the plans and in the execution
Doing the project	Transform the physical project site	Conducting the activities, for example soil excavation Adjust to changed conditions both for the "own" activity but also "others"
Develop the project	Develop both the activities and the project management	Reviews Work descriptions Individual learning curves

5.3.1 Defining the project

The definition of the project is mainly done by the STA in collaboration with the constructer when they specify the blueprints. At the time of the procurement process the parameters time and quality are already set. The public procurement process awards the contract to whoever offers to deliver the stated quality to the lowest price at a set delivery date. Quality can be described in many different ways and Bergman and Klefsjö (2010) describes quality as the ability to meet or preferable exceed the customer's expectations. This indicates that the quality is defined by having a close fit between the original drawings and the end product. Figure 35 illustrates how the satisfaction of the STA varies depending on the fulfillment of the three basic project parameters, Time, Cost and Quality.

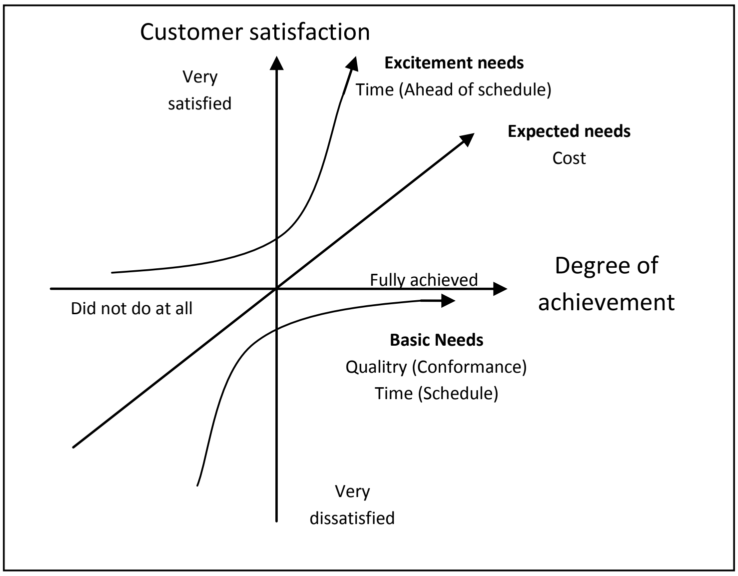


Figure 35 Kano analysis of project dimension, after (Matzler, et al., 1996)

The rational strategic decision in such a situation is to opt for a low price strategy (Porter, 2002). This holds large implications on the type of relationship that is established between the STA and the assigned contractor. The contractor aims at providing the required quality at the lowest possible cost without delays. The incentives for long term relationships and collaborations are low and a transactional relationship is established.

In terms of defining the product, the outcome of the project, the type of relationship also holds implications. The transactional relationship limits the amount of interaction which determines the possibility of altering the design to suit the manufacturing and the specific characteristics of NCC (Dwyer, et al., 1987). A silo culture emerges where the STA first defines the project then allows for a contractor engineering firm (Konstruktören) to specify the design until a contractor is appointed with the actual construction of the project. Every part can thus be said to be a small project of its own (Maylor, 2010). This imposes the risk of sub-optimization and that the overall project performance become secondary (ibid). The lack of cross-functional work also imposes the risk of a silo culture (Wheelwright & Clark, 1992).

A closer cooperation between the involved parties would enable a closer fit between the definition of the project and the process of realizing it. This lowers the total cost of the project, (Paulson, 1976), through avoiding waste. The current way of working stands in stark contrast to the cross-functional team configuration that is desirable when operating in a complex and uncertain environment (Wheelwright & Clark, 1992). According to Paulson (1976) there is a lot to be earned by a greater push in the initial phase of the overall project in order to limit costly changes later. As much as 80 % of the costs are specified in the initial design and definition of the project (Wheelwright & Clark, 1992).

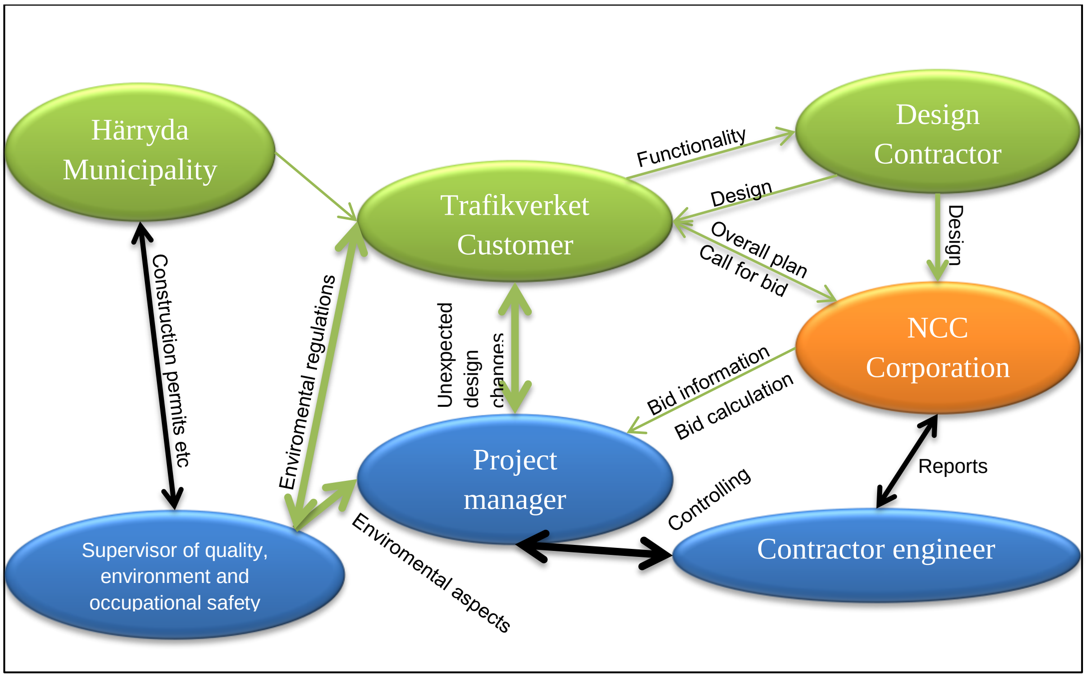


Figure 36 Communications regarding the design, Green indicate design communication, black is administration

The technical dependencies are also determined, to a large extent, by the definition of the project. They can be considered as determining the frameworks within which the sequence can be adjusted to support both flow and resource efficiency. This then large impacts the amount of waste present in the project.

Changes are often originated after the project has started. This then inhibits a detailed plan since variation and disturbances are introduced to the system. The resource and flow efficiency can thus be impacted negatively (Modig & Åhlström, 2012).

It is also the case that the ones calculating the bid are not the ones involved in conducting the project. To enable a good fit between the intended way of conducting the work and the actual work conducted the ones calculating the bid must interact with the ones conducting the work. It is also against the assumptions in the calculation that ÄTA can be used for the contractor to minimize the risk. If then these necessary changes can be covered by ÄTA they pose no risk to the contractor. By utilizing planned flexibility it is possible to be anticipative and reduce the impact of uncertainty (Verganti, 1999). They can then be regarded as self contained tasks, which lower the uncertainty and allows for increased flow and resource efficiency (Galbraith, 1974). This does however require knowledge about the on-site conditions and insight into the construction processes along with securing that the initial plan is carried on into the execution of the project.

5.3.2 Designing the project

The planning and design of the process takes place at different levels and with different focus areas. This can be understood when reflecting over the difference between seven week plans and two week plans. In the more long term seven week plan the focus is on finding a suitable sequence through managing the complexity of the project in terms of visualizing interconnections between activities and processes. The weekly plan on the other hand deals with leveling the resource utilization.

Therefore the design of the process in reality consists of two main types of activities namely short and long term planning. The figure below can act as an illustration of the two types along with describing the questions raised at each level.

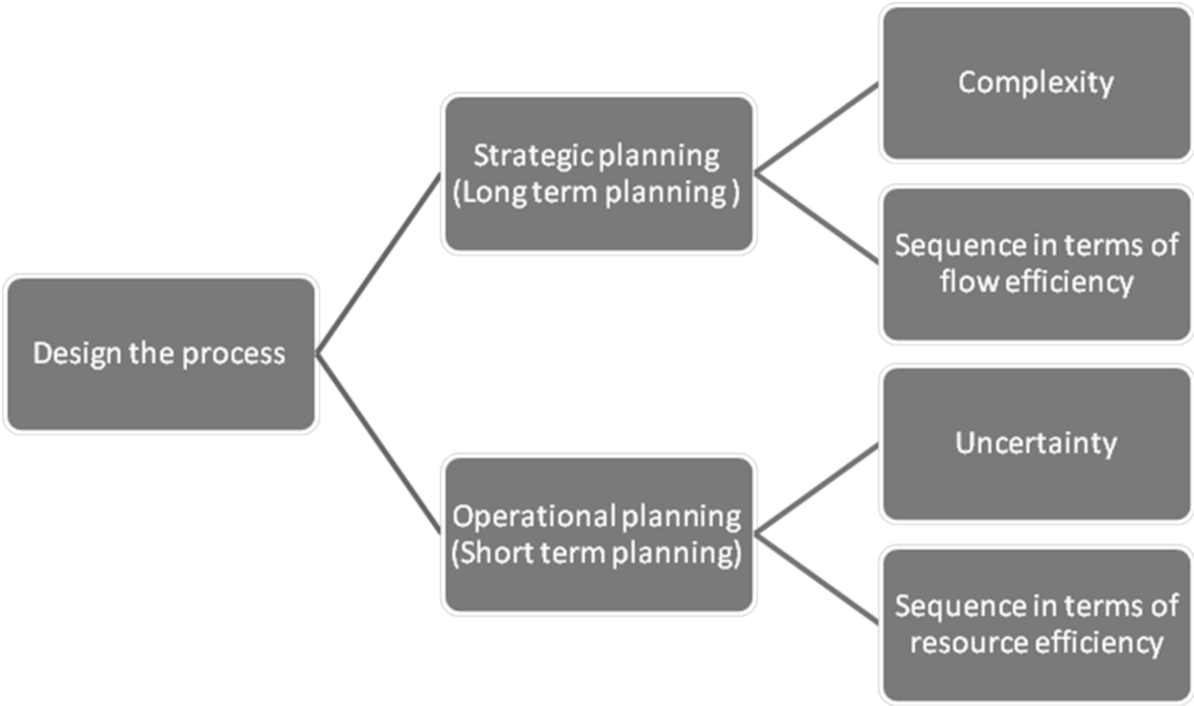


Figure 37 The different types of planning

Both the strategic and operational planning are described and analyzed more in details below.

Strategic planning

Strategic planning deals with managing the complexity of the project. This is done in terms of visualizing dependencies and planning a sequence. It is here the flow on the project site is planned. The possibility to transport the material directly from the excavation site to a place where it is needed is determined here. It thus significantly impacts the amount of waste and the time the activities will take.

To support the strategic planning several meetings take place. The ones formally linked with the strategic planning are the seven week planning sessions along with the project start up and initial time plan. The long term view of the project is also discussed during the construction meetings with the STA. This implies that it involves individuals with different competence and experience thus displaying a potential for cross-functionality. This increases the capability to handle the complexity (Wheelwright & Clark, 1992), and to take more aspects into account when designing the sequence (Maylor, 2010). One example of the benefits of the cross-functionality is how the project manager bases where to transport the excavated material on the calculations done by the chief of survey.

In reality the work is revolving around the project manager while the supervisors and the chief of survey are also included to a lesser extent. They coordinate the project to a large extent through direct supervision (Mintzberg, 1980). They are not included in the calculation phase nor are the assumptions made in the calculation communicated to the project organization. This increases the perceived uncertainty since less information is processed (Galbraith, 1974).

In addition to the formal communication additional information is gathered through including the seasoned and trusted professional workers when assessing the feasibility or to estimate the duration of specific activities. This allow for more bottom-up communication which reduces the perceived uncertainty (Galbraith, 1974). The professional workers are however included not when they have significant input but instead through initiatives from the supervisors and the project manager. This indicates that the genuine uncertainty is not handled only the already anticipated perceived uncertainty.

It is important to allow for flexibility since the STA also can present articulated demands on the sequencing of the activities as the project progresses. By allowing for them to be involved to a larger extent of the planning or by allowing for NCC to take on more responsibility for the design it is possible to foresee the changes, (Wheelwright & Clark, 1992), or to be anticipative on what to change (Verganti, 1999).The work with the strategic planning can be visualized in accordance with Figure 38.

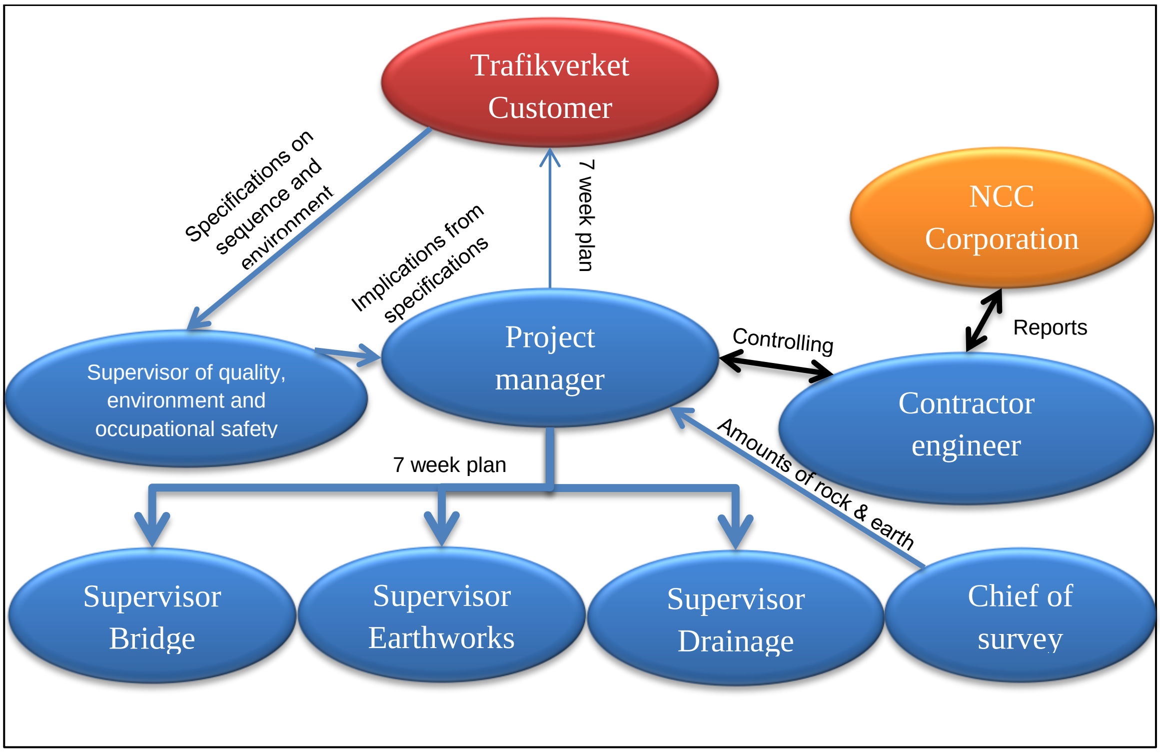


Figure 38 Information regarding strategic planning. Blue is strategic planning, black is administration

From observations during the meetings it is concluded that the focus is on planning each activity individually and not on visualizing the dependencies between them. The technical dependencies are managed through experience but the input output dependencies lack formal support. They are handled individually and discussions are with a high level of abstraction. This requires that all participants in the meeting have the same understanding and experience of the project and the activities (Snowden, 2002). Due to the high abstraction level and the focus on activities dependencies are sometimes missed or not communicated clearly.

Operational planning

In practice much of the work referring to making the operational plan is confined to the supervisors. Based on the seven week plan they construct the two week plan that is used to operatively guide the work. This work is based around the weekly meetings that include the supervisors of drainage and earth works and sometimes even the project manager. The resulting two week plan is then communicated to the professional workers and the machine operators in a top-down manor during the weekly information meeting each Friday.

One prominent activity within this category is to balance the capacity with the chores. There are a number of strategies for assigning the operative capacity (Slack & Lewis, 2011). To reduce waste, and its associated costs, it is important to adjust so that the capacity is suitable to support the flow efficiency, no more no less (Liker, 2004). The capacity can be adjusted in smaller steps with the use of smaller and more flexible machines hence allowing for a finer match between the capacity and the resource utilization (Slack & Lewis, 2011) (Adams, 2006). The decision made by the project manager to use multi-purposed machines also greatly enhanced the flexibility in terms of capacity.

In the case of varying amounts of work, like seasonal variation, a company can choose to either try to follow the demand or use a level capacity strategy (Jonsson & Mattsson, 2009). Adopting a chase strategy would mean changing the number of contractors, thus dissolving the relationships (Dwyer, et al., 1987). To support the collaboration between the professional workers and the project management it is important to develop more long term relationships and trust. In practice the number of workers were rather stabile, each worker were contracted

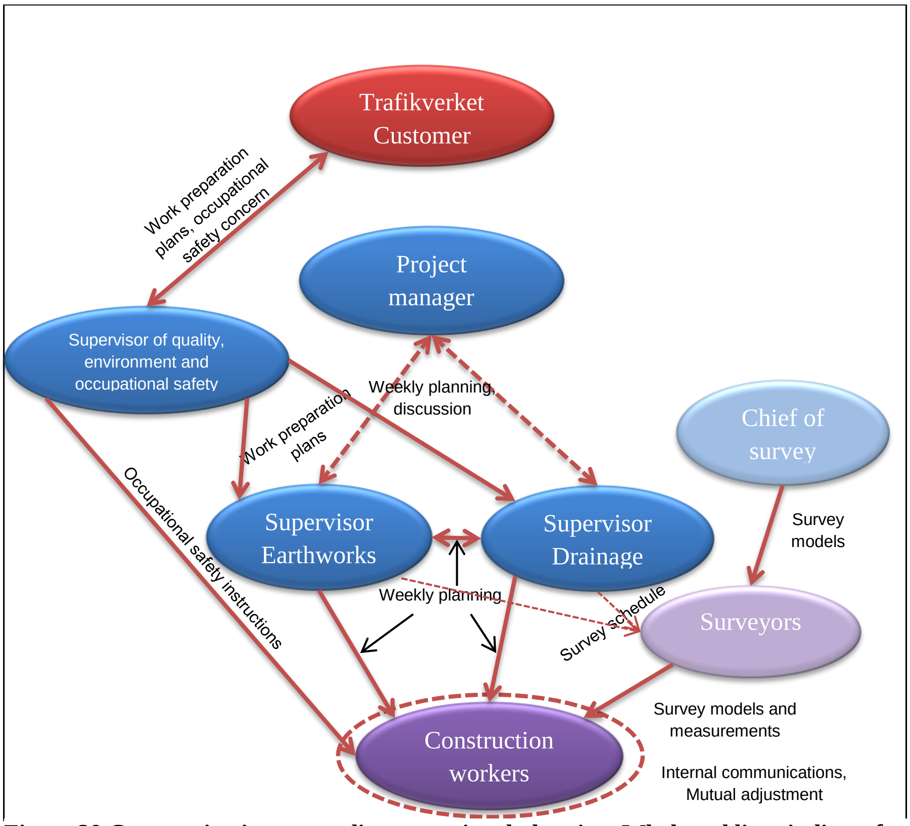


Figure 39 Communications regarding operational planning. Whole red lines indicate formal communication, dotted informal

for an uninterrupted period of time. This then focuses on maintaining long term relationships with the professional workers. The challenge when arranging the sequence within the operational planning is to plan the amount of activities so that they add up to match the more stabile capacity.

Another key activity is to handle the uncertainty. Much of the uncertainty can be handled through the use of seasoned workers who can solve the situation through experience. They then use mutual adjustments to coordinate the work according to the changes as long as the complexity is not too prominent (Mintzberg, 1980). Some aspects however need formal approval such as changing the drainage dimension and other such aspects since the STA might have specified demands. This then require an increased bottom-up vertical informational flow so that the supervisors can handle the aspect when it arises.

The durations set for the planned activities are also linked to the uncertainty. Due to the uncertainty additional buffers are added to every task which is slack resources. Parkinson's Law dictates that the activities will fill the time slot available and not be done earlier even if so is possible (Parkinson, 1957). The perceived uncertainty can be reduced by including the ones with the most knowledge about the task in the planning thus allowing for the buffers to be removed.

The communication regarding the minor adjustments due to uncertainty is conducted either through a link between the supervisors and the professional workers or with a surveyor acting as a middle man. The figure below can act as an illustration on how the operative planning is conducted in terms of both resource efficiency and handling uncertainty.

By allowing for the construction workers who have the most extensive knowledge regarding how to conduct the activities it is possible to get more accurate plans and forecasts. The type of machines that is suitable can for instance depend on the humidity in the ground which thereby makes the choice of machine exposed to uncertainty. The transportation routes can be depending on the temperature, if it is below zero degrees Celsius it could be possible to drive across areas that are not available in warmer temperatures. By allowing for the professional workers and machine operators to handle much of the uncertainty their potential can be utilized.

5.3.3 Doing the project it

The intended outcome of this category is the actual transformation on the physical site from the original state into the end result (Maylor, 2010). This is also where the plan mergers with reality hence making it important to overcome and bridge the small differences that exist between the drawings and plans and the actual characteristics on-site.

As input to this level a weekly meeting is held were the supervisors and also the project manager has a briefing on the activities to be conducted the following week along with informing the professional workers and the machine operators of their planned chores. These meetings were held in a top-down approach which limits the amount of feedback the professional workers can provide. This lowers the vertical informational flow hence reducing the potential to handle uncertainty (Galbraith, 1974). It also reduces the motivation of the professional workers as their autonomy and impact on their own work is lowered (Rubenowitz, 2004).

The work tasks that were divided among the professional workers on those meetings had a defined duration, determined by the supervisors. This imposes a risk for procrastination since there is a deadline set for when the task is to be completed. It is common to initiate the task as late as possible so that it can be completed at time (Parkinson, 1957). The problem is when unexpected events impose delays then the original buffers are used prior to the initiation.

The professional workers also get input on how to conduct the activities from both the supervisors and the surveyors. Due to the uncertainty regarding when tasks can be initiated or finalized there is a great need to be flexible in order to avoid waste (Slack, et al., 2010). The geological models that the surveyors provide are for instance provided on short term predictions. This allow for the surveyors to prepare the models that are to be used within a short period of time. The surveyors still are required to themselves examine what activities that are about to be initiated rather than that the professional workers request models when they are needed. The same reasoning can be applied to how the supervisors provide work descriptions. They are provided when the supervisors perceive a need for more thorough descriptions, i.e. technical challenging tasks. The work descriptions are not explicitly based on the experience level of the professional workers but instead the perception of their competence.

In practice the uncertainty, both perceived and genuine, is to a large extent dealt with through lateral relationships among the professional workers and machine operators. They adjust to each other and adapt to the situation if one activity in the process is disturbed through uncertainty. This can be exemplified through how several activities were served by the same truck. It was done so to balance the capacity with the demand for transportation in order to increase the resource utilization without disrupting the flow efficiency. In order to simultaneously handle the uncertainty and variation in the output of the output creating activities the truck was called upon when needed (Slack, et al., 2010). This is largely done through mutual adjustments, such as body language (eye contact, gestures and so on) or through telephones and two-way radio contact. This is one way of lowering the need for managerial attention while still adjusting to uncertainty (Mintzberg, 1980).

When situations arise that the professional workers cannot solve through the use of their own experience they need to consult the supervisors. This is either done through direct contact, face to face or phones, or with the assistance of a middle man in form or the surveyor. The informational flow can be illustrated with the figure below.

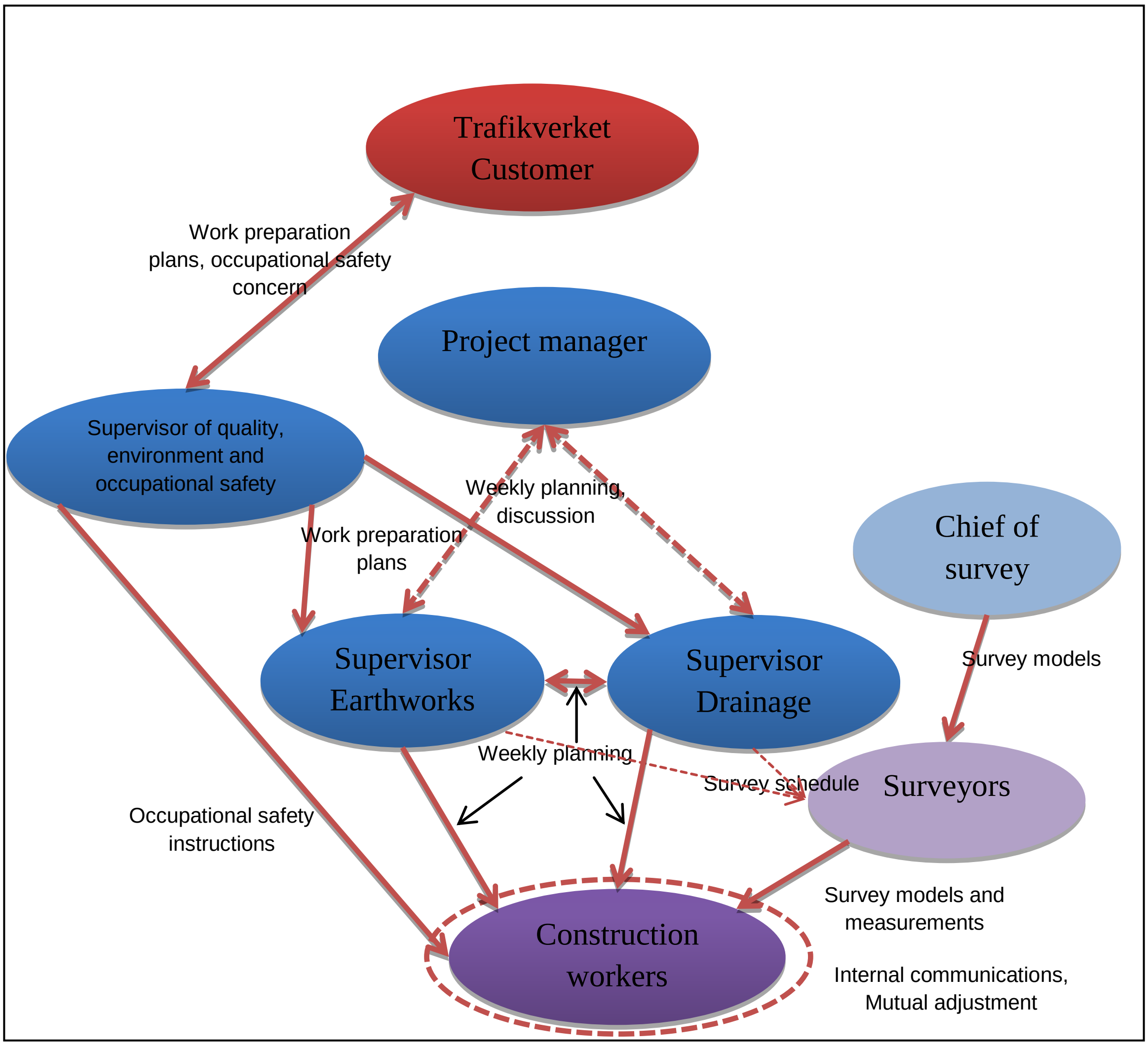


Figure 40 Communications in operational level is mainly among construction workers Whole red lines indicate formal communication, dotted informal

Since quality is defined as conformance to specifications, due to the design of the procurement process, it is when the work is conducted that the ability to conform to the blueprints comes into play. The professional workers might dig in the wrong place or in the wrong way if they are not experienced or have the proper support in terms of for instance GPS coordinates (GeoROG) or proper surveying work that provide the basic virtual models or visual guiding indicators. It is important that the chore is conducted right from start since the cost of rework is high. This is due to that the product is locked in once the work is initiated. By not allowing for the workers to themselves review their work their potential is not fully utilized.

The efficiency of the work is also set in this category through the way of conducting the work. The way in which it is to be conducted is specified in AMA. The efficiency is large determined by the experience level of the workers due to learning curves (Granstrand, 2010). Seasoned workers have developed their way of working and removed unnecessary elements such as additional movements.

5.3.4 Developing the project

During the period the project was studied there were limited amounts of activities conducted in order to develop the way of working. The focus on developing the way of working was through individual learning's based on gaining new experience. In order for these to gain a wider applicability and to enable double loop learning they need to be externalized and communicated (Nonaka, 1994). This would enable for a cross project learning were projects can develop based on all experiences gained and not only the individual experience of the participants.

The strong project orientation and teams can hinder the knowledge transfer that needs to take place within the organization in order to achieve large scale improvements (ibid). The nature of much of the work implies the need of expert knowledge within the craft renders in a somewhat professional organization which often holds a resistance to change and alternations (Brock, et al., 1999). To counter the resistance it is beneficial to use peers to spread the knowledge and to allow for the individuals to take part in the formulation of new routines (Kotter, 1996).

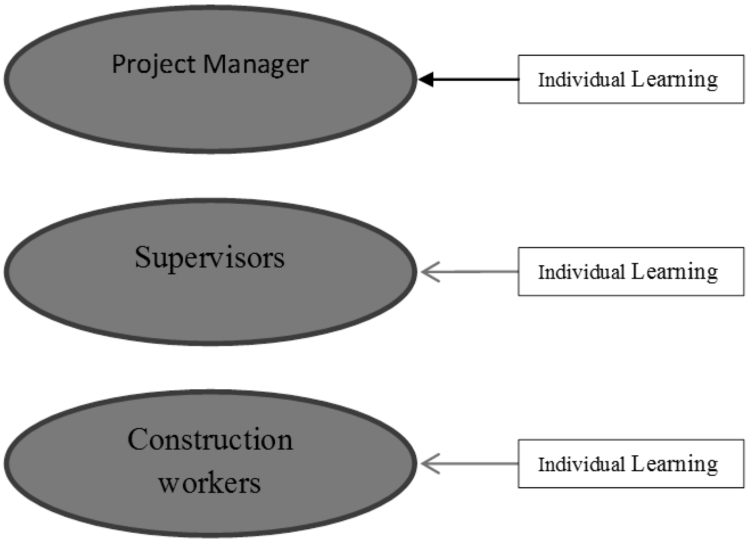


Figure 41 Learning on different levels in the project

The control and monitoring made by the contractor engineer can be expressed as one way of developing the project. By reviewing the outcome against the planed result a platform for questioning the actions is created which is a requirement for double loop learning (Argyris, 1999). The data collected for monitoring and controlling was however on a more aggregated level hence hindering the identification of aspects in need of improvement.

The planning and monitoring tools that were provided by NCC corporate can also contribute to the development. The tools support standardized ways of working which can be compared with wedges that enables the project to find a equilibrium at a more developed level (Bergman & Klefsjö, 2010). The lack of more extensive routines in place can be attributed to the lack of incentives for improvements. Due to the transactional relationship with the STA there is little motivation to improve in terms of allowing for more concurrent designs or cooperation.

Also the provided work descriptions are a way of striving towards perfection. Today the work descriptions are based around having experienced workers who have the skills and experience required to conduct the work. This renders in a strong dependency on individuals and their knowledge on how to conduct the work. If the workers are less experienced more excessive and detailed work descriptions would need to be compiled thus illustrating a trade-off between having experienced workers with lesser managerial activities and un-experienced workers with more managerial activities. Additional support in detecting deviations would also need to be implemented, such as visual aid or additional control of own or others work to detect the mistakes that previously were identified through experience. One way to counter the dependency on individuals is through initiating work descriptions based on standardization of processes and outputs (Mintzberg, 1980).

6 Synthesis

The chapter of the report is devoted to answering the research questions. They are discussed in three sections, one for each research question. The answers are formulated through comparing the analyzed empirical data, the context of the transportation infrastructure industry and the theoretical framework. The chapter is concluded with an evaluation of the proposed improvement suggestions.

6.1 What Lean principles are applicable

In the analysis the activities were conceptualized into five categories; Defining, Strategic Planning, Operational planning, Doing and Developing. By comparing the desired outcome of the categories with the principles of Lean it is possible to identify that all five principles are applicable to the specific context. In the sections below the reasoning to why they are applicable along with possible differences are presented.

6.1.1 Define value

The intended outcome of the Define category is to design a product that fulfills the societal need. In order to define the product satisfactorily it is important to clarify what the intended outcome is. The outcome of the project should correlate with the customer requirements in order to achieve customer satisfaction (Bergman & Klefsjö, 2010). Therefore a clear definition of what is regarded as value is of importance.

To make changes in the project without impacting the effectiveness of the work requires knowledge about the desired outcome. The changes must be made with knowledge about what the value of the task is (Slack & Lewis, 2011). Several changes were made both within the operational planning and within the do category, due to the inherent uncertainty. Therefore it is important that the definition of value is heard and expressed all the way through the project organization.

Traditional definitions of value are based on attributes directly linked with the physical product, which can be measured (Womack & Jones, 2003). Within construction value includes more abstract aspects such as societal needs (Bertelsen & Koskela, 2004). The interviews indicated that not only functionality but also the visual appeal of the finished product was of importance. The current practice to define value has been focused around the transformational process were the activities on-site are in focus, (Bertelsen & Koskela, 2002), and not with the starting point in the customer. Therefore there is a need to adapt the way in which value is defined within construction to further include the customer.

Linked to the difficulty of defining value is the conundrum of defining the customer. Within traditional manufacturing industry the customer often is the one ordering, using and paying for the product, which is often not the case within construction (Garrido & Pasquire, 2011). From the empirical data several stakeholders, for instance The STA and Härryda municipality, were identified who all impacted the definition of value.

This complexity with both the definition of the customer and the attributes renders in a need to be more holistic and broad in the interpretation of value.

6.1.2 Visualize the flow

The strategic planning is mainly focused on addressing the complexity of the project. Defining the dependencies and thus the sequences, both technical but also in terms of input-output relations, are key activities. By visualizing how the material, people and information flow within the project it is possible to identify the dependencies between activities (Rother & Shook, 2003).

The aim of the activities in the operational planning is to ensure that the day to day activities run smoothly. Interviews and observations indicated that there is a struggle towards identifying and removing unnecessary activities and actions. To enable the waste to be identified and subsequently removed the process first need to be visualized (ibid).

Based on the reasoning above the principle of visualizing the flow can be of aid in designing the process. Within both traditional manufacturing along with house construction the supplier integration and just-in-time deliveries constitute prominent features (Jonsson & Mattson, 2011). The flow is however somewhat different within earth works in comparison. To minimize transportations the excavated material is gathered and can be used on-site therefore the flow is ideally confined within the construction site. The project organization is both the consumer and producer of material thus representing a larger share of the value chain.

6.1.3 Manage the flow

One key area within the strategic planning was the importance of avoiding inventory of soil and crushed rock. There was an active strive towards achieving a flow efficiency within the studied processes. When managing the construction the flow view is to be used in order to eliminate waste and increase the speed of the project (Bertelsen & Koskela, 2002).This is in essence the principle of managing the flow and streamlining it to reduce the throughput time and inventories (Modig & Åhlström, 2012).

The studied activities depended on other activities for either input material or for handling the output produced. This illustrates that the activities were part of a process that was characterized by a flow of material. Therefore the duration of the project were determined by the flow of the material, since any delays in the flow would impede the initiation of a downstream activity (Goldratt, 1984). Much of the efforts within the operational planning were spent on removing sources of variation. Within the Do category active efforts were also made to reduce variation, such as using mutual adjustments to avoid inventory or waiting.

The flow therefore is managed on different levels within the project. The sequence in terms of enabling the material to flow without additional loading is set in the strategic planning. The material flow is also managed in the operational planning where resources are appointed and the sources of variation are removed. Finally the flow is managed through mutual adjustments made by the professional workers as they handle the uncertainty when it arises in the activities. Within for example the Toyota Production System the flow is managed mainly centralized through the operational planning and strategic decisions (Liker, 2004).

6.1.4 Pull

The interviews made it clear that one of the main issues within the strategic planning was the allocation of excavated material. It was a prioritized activity to ensure that prior to excavating soil or crushed rock there was a designated recipient activity. In combination with avoiding additional loading and inventory, the process was to first identify a need for soil or gravel. This is also extended to the Do category where the professional workers use mutual adjustments to request material when needed. In practice this implies attempts to initiate a pull system (Womack & Jones, 2003).

A form of pull can be adapted into the planning as well as the process. When an operator is about to finish a task the planning for what to do next should be initiated (Ballard & Howell, 1995). One example was that not all geological models could be done prior to the initiation of the project. Instead they were provided when they were needed. This illustrates that the principle of a pull system is applicable to enable the flexibility required to handle the uncertainty present. By allowing for the tasks to be initiated when their output is needed it is possible to avoid waste and support the elimination of buffers within the planning.

The principle of applying a pull system can be initiated both in the traditional material flow but also in the planning of the project. It can be argued that the pull system and its possible initiation is governed by the sequence of the activities since it determines the playfield in which the blue collar workers then can adjust within. When conducting the planning it is therefore important to take into consideration how to allow for a pull system to be established. Furthermore it is not only the direct flow of material that is possible to arrange in a pull system. Also the initiation of the activities as such can be supported by adhering to a pull system. Due to the uncertainty when estimating the duration of the activities it is important to pull the initiation of the activities that interlink with each other. Since the activities, as argued previously, are linked together by dependencies it is important that the initiation of activities is based on a need for them to be initiated. It is not suitable to, for example, initiate an excavation of soil prior to the need of soil emerges within another activity.

6.1.5 Perfection

As the traffic administration calls for bids for several of similar projects yearly there clearly is a potential for developing the way of conducting those projects. The project organization also is not as temporary as suggested by Maylor (2010), due to that the backbone of the project organization continue to work together. Therefore the type of project can be altered from an "As…But…" type of project into a "Painting by numbers" type. This leads to a reduced uncertainty and risk as the outcome is familiar. This illustrates that standardization and learning's can be drawn.

The traditional way of regarding perfection in terms of how the activities in the Do category are developed is naturally applicable. It currently is a focus within the project organization on developing routines and standards to support a more efficient execution of the activities. This can be complemented with efforts in the same line of thought but instead within the project management practices. This shows that perfection can be applied throughout the project and is not confined only to the Do category.

6.2 What are the success factors

The next step after establishing that all five principles are applicable is to identify which aspects are essential in order to become Lean. To conclude which factors that are essential the root causes to identify why, or why, not the principles are applied.

6.2.1 Define value

To enable a holistic and broad definition of value it is important to include several perspectives and competences (Morup, 1993). The ones that have the most knowledge about the onsite conditions are excluded. The problem is that there are no common forums where the ones defining the product and the value and the ones with detailed knowledge can meet and harmonize. This in turn originates from the silo culture that exists with an over the wall engineering approach (Sohlenius, 1992) (Wheelwright & Clark, 1992), due to the transactional relationship with the STA. All actors in the process focus on their own contribution rather than having the end result in mind.

This reasoning can also be extended to include the departments within NCC. The ones calculating the bid and the ones included in the project organization work in a similar silo way with a low degree of integration.

Therefore the success factor when defining value is to achieve cross-functionality.

6.2.2 Visualize the flow

The flow is visualized through identifying dependencies between activities (Rother & Shook, 2003). These efforts are hampered by the fact that not all dependencies are identified and that all identified dependencies are not clearly communicated.

The difficulties with communicating the dependencies are not due to a lack of a suitable forum to discuss the aspect in. Rather it is linked with the high abstraction level of the communication. The dependencies are not clearly stated nor are they visualized but instead they are implied when referring to each activity.

The high abstraction level is not a problem per se but instead it becomes problematic when individuals that are included in the process have different knowledge of the situation (Snowden, 2002). The ones that have been addressing the issues of inter-dependencies for some time can interact on a higher abstraction level. The problem therefore is the lack of a common zone of acceptable abstraction level in the discussion forum.

The lack of a common abstraction level can be attributed to a focus on activities rather than processes. By planning for activities each one seems to be isolated but in reality it is part of a process (Maylor, 2010). The success factor for visualizing the flow therefore is to combine activities into processes.

6.2.3 Manage the flow

The work sequence largely determines the flow and it is based on planning accordingly to the discovered dependencies. Therefore a prerequisite to managing the flow first is to visualize the flow. The flow is then managed on different levels in order to cope with both the uncertainty and the complexity. The complexity is expressed as dependencies in terms of technical, input output and resource dependencies.

The aspects that have a large complexity but low genuine uncertainty are to be handled centrally already in the calculation phase. To enable this it is important to have a rich communication both top-down and bottom-up. This allow for the decisions to be communicated down to the ones conducting them in practice and to allow for the decisions to be based on facts from the construction site.

The aspects with low complexity but with high genuine uncertainty on the other hand need to be handled in a decentralized manor as the project progresses. This is done through mutual adjustments. To be able and apply mutual adjustments it is important that also the responsibility and ability to take decisions is decentralized (Marmgren & Ragnarsson, 2001).

The aspects that display both a high complexity and a high genuine uncertainty needs to be taken centralized in the project organization to allow for both an overview and detailed knowledge about the situation (Wheelwright & Clark, 1992). It requires both top-down and bottom-up information. The key to succeed therefore is embedded within enabling meeting forums that supports both a top-down and bottom-up communication within the project.

To succeed with managing the flow it is therefore important to differ between the decision making levels and that the levels are supported by a vertical information flow.

6.2.4 Pull

To enable a pull system within the material flow the activities conducted must be possible to combine through input output dependencies. This requires that the complexity is handled. The success factor therefore is to combine activities into processes and then allow for that information to be communicated through the organization through cross functionality. The possibility of allowing for the material to flow is determined by how well adjusted the concurrently ongoing activities are planned. This does not warrant that the material will flow as smoothly as it is possible but it sets the frame for how well it can flow. Therefore due to complexity it is important to combine activities into processes to allow for the material to flow.

The planning is currently conducted in a push way where activities are assigned a certain amount of time to be completed in. By applying pull the buffers could be added in the end rather than between all activities (Maylor, 2010). This builds on identifying the dependencies and to plan in accordance hence requiring that activities are combined into processes. The uncertainty inherent within the project renders in variation within the duration of the activities. To allow for the variation to be handled successfully it is important that the changes in one activity are taken into consideration when other activities, within that process, are to be initiated. Another aspect that comes into play is that there are no natural forums for the workers to request information on what to do next or give feedback on their progress. They instead have to initiate contact with the supervisors. To succeed it is therefore important to allow for the ones with the most knowledge about the conditions to take part in the planning and that they can adjust to how the other activities progresses.

6.2.5 Perfection

The perfection in terms of developing the entire project and to establish routines that span across projects requires a coordination and information sharing on a central level. To achieve this cross-functionality is of importance and the establishment of lateral relationships that support information sharing cross projects.

The perfection is also achieved within the project. One key part of that is the efficiency. The efficiency can be derived back to a lack of knowledge in how to conduct the work in a more efficient way. The way of learning a more efficient way is either through experience or through more thorough work descriptions to follow.

Perfection is also linked with avoiding defects or flaws. These can then be based on either faulty information on how to conduct the work or on conducting the work in a faulty way. Regardless of which the reality is that the professional workers do not detect the difference in what they do and what the product design orders. This depends on not providing the workers with the suitable tools to detect anomalies or by having established routines that prevent a mistake in one activity or work chore to be carried forward to the next.

It can also be beneficial to implement a support for avoiding mistakes to take place. It can be viewed as an extension of the work description. It complements the direct description on what to do since it aid in detecting if the work is not done correctly. This can relate to the standardization of outputs and processes that act as ways of reducing the need of managerial attention (Mintzberg, 1980). The current way is based on utilizing standardization of skills which is suitable in highly uncertain environments (ibid). Even though the project have a high uncertainty a large portion of the activities and processes are repetitive and less uncertain thus opening up for other coordination mechanisms (ibid). The standardizations of outcomes is a work description on a higher level of abstraction, it can be compared with describing what to do rather than how to do it. They both give the professional workers the possibility to avoid defects and enable an efficient way of working.

To succeed with achieving perfection it is therefore important to support cross-functionality and to use not only standardization of skills but also standardization of outputs and processes.

6.2.6 The success factors

In order to support the application of Lean some success factors can be deduced.

The first important factor is to enable a cross functional and also cross company collaboration in order to overcome a silo culture. This would improve the definition of value, allow for the flow to be visualized along with managing the same and enabling a pull system. It would also facilitate attempts towards perfection since the entire project can be improved. This could generate a more complete focus on improvements in contrast with only improving each part individually.

The second success factor is to combine activities into processes. This would enable the flow to be visualized, managed and support the initiation of a pull system.

A third important factor is to differentiate between what can be handled centralized with little need for handling uncertainty, what can be handled decentralized with little need for handling complexity and what needs to be handled centralized with respect to high uncertainty. This would enable the flow to be managed along with supporting a pull system.

The fourth success factor is to provide a match between the experience and knowledge level of the professional workers and the provided work description in relation to the task at hand. They should be based on standardization of skills, output or processes depending on the uncertainty present. This supports perfection in terms of both allowing for better quality through avoiding defects and improving the efficiency.

The success factors are to:

- Achieve cross functional and cross company work
- Combine activities into processes,
- Differentiate between required decision making capabilities
- Differentiate between the provided work descriptions

6.3 What actions support the application of Lean

To enable that the success factors are meet in the project a desired future state is developed. Suggested improvements are discussed based on realizing each success factor.

6.3.1 Achieving cross functionality

One way of ensuring a more developed collaboration within NCC is to use partnering contracts. This would ensure that a larger part of the definition is done internally, which creates a platform for closer cooperation within the organization. This form of contract already is in place both within other geographical areas but foremost within other division of the company, such as the construction of houses. Partnering contracts does, however, require cross-functionality to be in place (Riksrevisionen, 2013), which illustrate that it has to be complemented by other solutions.

One way to support the collaboration between projects and functions within an organization is to implement a project management office (Maylor, 2010). The project management office has five major roles; monitoring and control, development of project management capabilities and methodologies, multi project management, strategic management and organizational learning (ibid).

Today the contractor engineers fill one of the project management office roles through their monitoring and control function. To combat the risk of ad hoc solutions in the projects, that often contribute to poor and uneven performance, the project management office needs to cover more areas (Engle, 2005). Since organizations that have a project management office perform better (Dai & Wells, 2004) the role of the contractor engineers would be suitable to expand.

By assigning the contractor engineer, or engineers, immediately at the bid calculation the contractor engineer can work to integrate and structure the whole project (Engle, 2005).

Contractor engineers can act as an integrating force between the ones calculating and the project organization, thus supporting cross functional work. They can represent the project organization in the bid phase and respectively represent the support functions within the project organization.

The development of project management capabilities and methodologies is also a relevant factor to include. By training the contractor engineer to use different tools and methods they can move beyond the traditional role of administrative support. From the training with planning tools the contractor engineers can help the project manager with revising the plan when so is needed during the project. Through communicating the reasoning from the calculation phase they can also assist the project manager in the initial phase of the project with coming up to speed. The contractor engineer can thus become a change agent and implement new tools and work processes (Maylor, 2010).

The multi project management and strategic management currently exist at NCC headquarters. However, by including the contractor engineers into this process it is possible to achieve a closer fit between the company strategy and the operations. This allow for a closer fit between the projects undertaken and bid on and the strengths of the company (Skinner, 1969). This would also enable the organization to communicate in the same manner (Dai & Wells, 2004) and thus minimize the gap between management and the project organization. They can overcome several of the barriers that hinder collaboration between different functions such as different terminology, experience and so on (Griffin & Hauser, 1996), and thus increase the cross functional work.

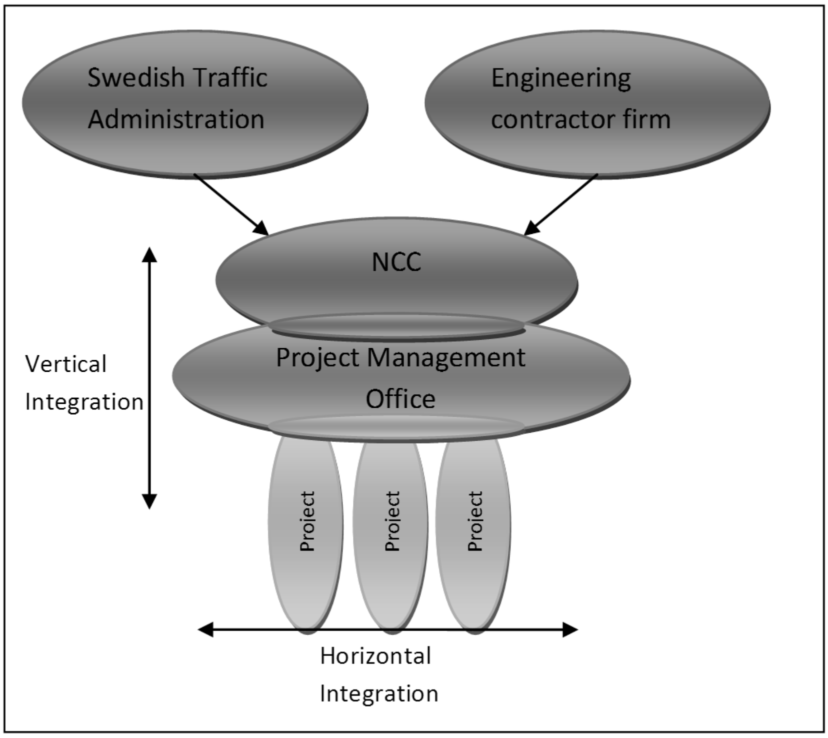


Figure 42 Functions of Project Management Office

Another key aspect is the organizational learning from the projects (Maylor, 2010). The group of contractor engineers can form an own network to exchange experience and cultivate the organizational knowledge in form of databases and groups. The project management office can thus assume the role of developing it in Maylor's (2010) model. This input will then be possible to utilize in future projects. By spreading the experiences in a forum of peers they are able to discuss on a common level of abstraction (Snowden, 2002), hence increasing the possibility for it to be accepted and used.

6.3.2 Combining activities into processes

From the empirical data it can be argued that the idea of designing processes are present in terms of defining input output relationships. The problem is that it is not done in a structured way. The key therefore is to enable a way in which dependencies are identified through a supporting routine and also to establish a way in which a rich communication is initiated.

In order to identify the dependencies it is important to enable a forum where individuals with different competence and knowledge can gather and discuss on even terms. One way of doing so is to map the flow of material so that input output relations can be revealed (Rother & Shook, 2003). By also building the informational exchange on the visual representation of the flow it is possible to lower the abstraction level of the discussion. The visual representation can thus act as an enabler for informational exchange. By visualizing the material flow enables for individuals to take part in the discussion thus the need of additional information is lessened (Lindlöf, 2011).

A visual representation also creates a platform for double loop learning in terms of reflecting on why the output of one activity is intended to be the input of another (Argyris, 1999). The visualization can be an extension of the work break down structure that currently is in use. It can allow for an increased flow and resource utilization. This would then target the type 1 waste through redesigning the system and chain of activities (Womack & Jones, 2003). Visualization and formation of processes at different levels are displayed in Figure 43.

In practice the use of visual planning can differ between situations. A suggested improvement would therefore be to base the strategic planning on a visual flow map that connects activities over spatial distances into work processes. It should be based on

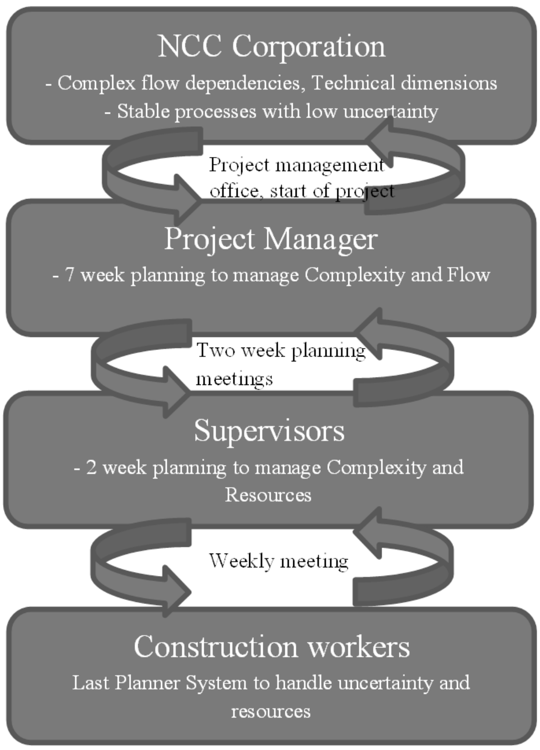


Figure 43 Visual planning opportunities in project

input output relationships. The more stabile and larger flows of material can be visualized and planned for at the initial stages of the project since they are mainly complex and not uncertain. They can be discussed during the calculation and bid phase and subsequently spread through the use of the contractor engineers via the project management office. A large scale map over the construction site can be used to illustrate the large flow of materials.

The aspects that have higher uncertainty but still display complexity need to be handled centralized at the project level as the project progresses. The current seven week planning can be a suitable forum to visualize the flows of materials. There the supervisors and the chief of survey are contributing with knowledge on the onsite condition and the project manager can see the big picture. A more detailed map over the entire site can be used to illustrate how the material is to flow within the construction site.

The aspects that are less complex do not have to be visualized to the same extent. It can still be beneficial to illustrate the flow of individuals and machines so that the activity can be conducted smoothly without disturbances and unnecessary variation (Rother & Shook, 2003). The lower degree of complexity implies that the planning can be done more decentralized. The visual planning of the lesser complex activities can be done in the two week planning meetings between the supervisors and also extent into the weekly Friday meetings where the professional workers are able to air their opinion and contribute with input. By utilizing a map that display for instance the transportation roads it is possible to visualize potential problems linked to shared resources.

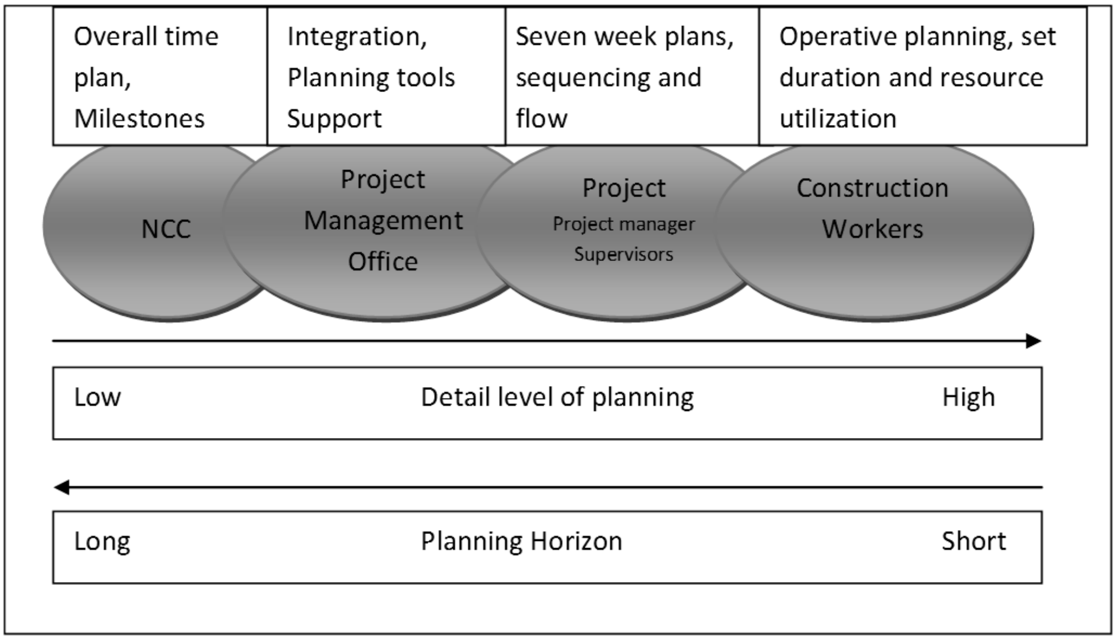
6.3.3 Differentiate between required decision making capabilities

The decisions that are to be taken centralized in the calculation phase require cross-functionality. This cross-functionality can be achieved through the earlier discussed project management office. They can act as an integrative force between NCC corporate and the project organization. For further details on how that is achieved in practice see Achieving cross functionality.

The current way of making decisions in the project resembles the way desired for handling complex and uncertain aspects. Therefore there are no structural changes needed but instead they can be supported by additional tools and input information. One tool earlier discussed that could be of great aid is the visual planning. It ensures a richer discussion that process more information. For further details on how it can be applied see the section on strategic planning in the section Combining activities into processes.

The surveyors can be an integrating link with information to and from those meetings. This is done through both providing the professional workers with an information on a context on the flow of material but also to communicate the uncertain aspects upwards. This can ensure that the uncertainty regarding the complex decisions are communicated and that the workers are provided with the context and ability to make changes without interfering with the flow.

One way of decentralizing the decisions is to implement Last Planner System which increases the possibility to more exactly match the available resources and time with the activities that is to be conducted, (Ballard, 2000). Within this system the key difference is that the professional workers are appointed with the responsibility to match the work that should be done with the work that at the time being can be done in order to avoid over or underutilized resources. By including the professional workers in the operational planning through the



weekly meetings and not only as today where there is a top down informative manner.

The input to the Last Planner System can be the current seven week plan. There the sequence but not duration of the activities is specified. This would enable for the processes to be defined based on complexity while the execution to be based on handling uncertainty. To allow for a lesser administrative task among the professional workers it is suggested that the seven week plan is further broken down into a weekly plan. There activities should be described in units that are up to about half a day in duration in order to allow for a more accurate planning. This in essence resembles the current two week plan but with the exception of not stating who does what and the duration of the activity. The actual application of the Last Planner System can be done on the weekly meetings. Here the two week plan can be presented for the professional worker and they can take over in determining who does what. The weekly meeting also represents a prominent possibility of stimulating bottom-up communication as input for the centralized decisions. These face to face meetings enable a richer informational exchange to take place hence allowing for an increased flow of information (Wheelwright & Clark, 1992). The follow up on how the work progresses, in terms of the planned percent complete, can then done in the break room through a visual

Figure 44 Differentiation of decision making capabilities

representation. This then allow for all to see how the work progresses and adjust their own work to avoid waste.

6.3.4 Differentiate between the provided work descriptions

The standardization of processes can be applied to the activities that are low in uncertainty. There currently is a development of the ways of conducting the task but it is built on that the professional worker learn and imitates what others do well. It could have been interesting to expand this knowledge sharing but it is crippled through not having the individuals under one organizational roof. It can thus be a competitive disadvantage for the competent workers to educate others. The aspects that clearly can be expanded to include standardization of processes are the technically demanding tasks along with the tasks with strict demands such as environmental restrictions. By using the Last Planner system it is possible to conclude if the technical knowledge is present among the workers or if additional support from the supervisors is needed. As input to the weekly meetings the contractor engineer with focus on Quality, Environment and Occupational safety can provide descriptions on how to conduct the tasks with restrictions in terms of quality, environmental or safety dimensions.

Standardization of outputs is based on that the outcome of the activity is specified in advance. This can be done by for example the geological models or by the use of BIM. By arranging a visual representation of how the end result will look like it is possible to provide the workers with additional information that support the detection of deviations. This information can either be displayed in the break rooms or provided in connection to the weekly meetings that form the base for the Last Planner System.

Standardization of skills is already in place due to the professional nature of the work. By comparing the demands of the project with the competence of the available workers it is possible to achieve a fit. The problem is to move away from a heavy reliance on the individuals. To provide detailed descriptions on how to conduct a task is associated with a low motivation (Rubenowitz, 2004). A middle route can then be to focus on providing standardized outputs that still allow for the workers to define the process but lowers the dependency on the individuals for detecting flaws. Standardization and experience is displayed in Figure 45.

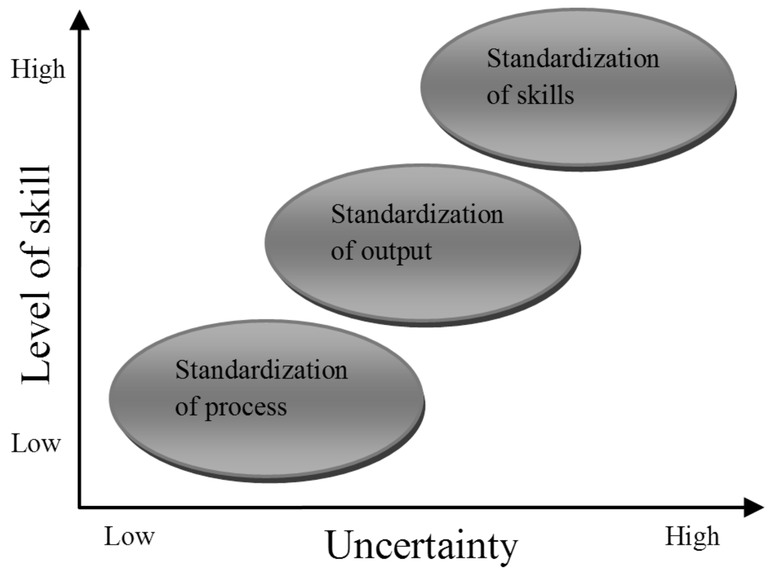


Figure 45 Standardization and degree of uncertainty with coordination mechanisms from Mintzberg (1980)

6.4 The intended future state

The actions that are to be made to improve the current state is to:

- Construct on Partnering contracts
- Institute a Project Management Office
- Use Visual planning methods
- Institute Last Planner System
- Differentiated work descriptions

How they will impact the current state and form a future one is illustrated through presenting the future state in terms of the five main categories of activities identified in the analysis. Figure 47 displays a future where the definition of value is done more holistically. It includes representatives from both NCC corporate and the project organization thus allowing for a closer integration. The role of the STA is to specify the functionality of the outcome of the project.

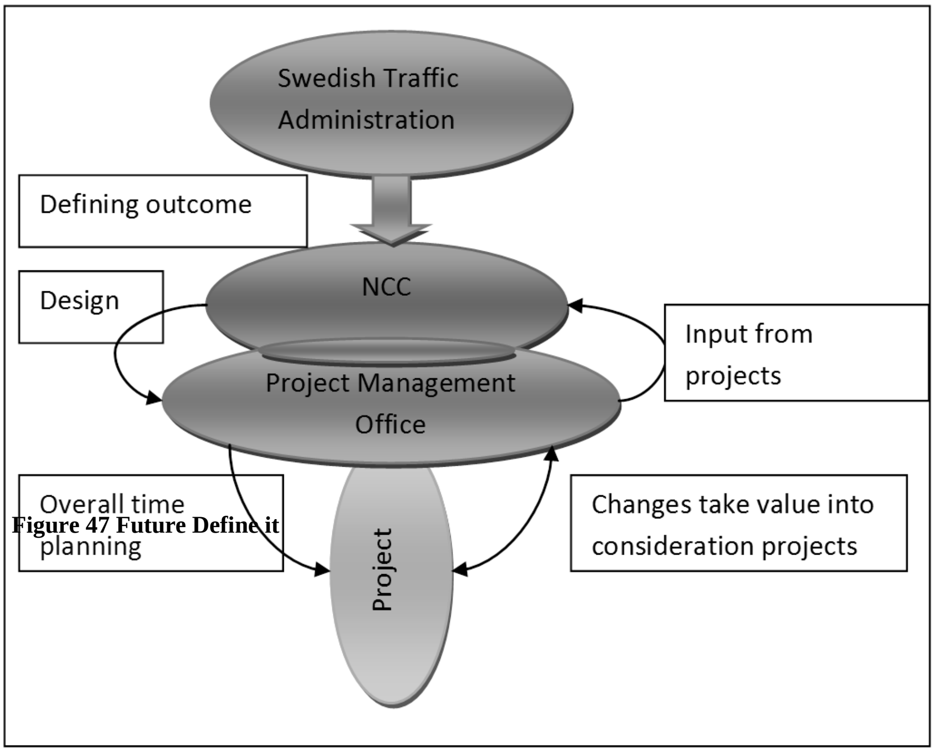


Figure 47 Future Define it

Figure 46 Future Doing the project

Figure 48 below indicates that the planning and design of the process is to be done on several levels in order to handle the uncertainty. The assumptions made in the initial phases and the overall complexity are communicated and integrated throughout the project. The strategic and operational planning is based on visual planning methods that support the management of the flow and a pull system. The initiation of the Last Planner System supports the handling of the

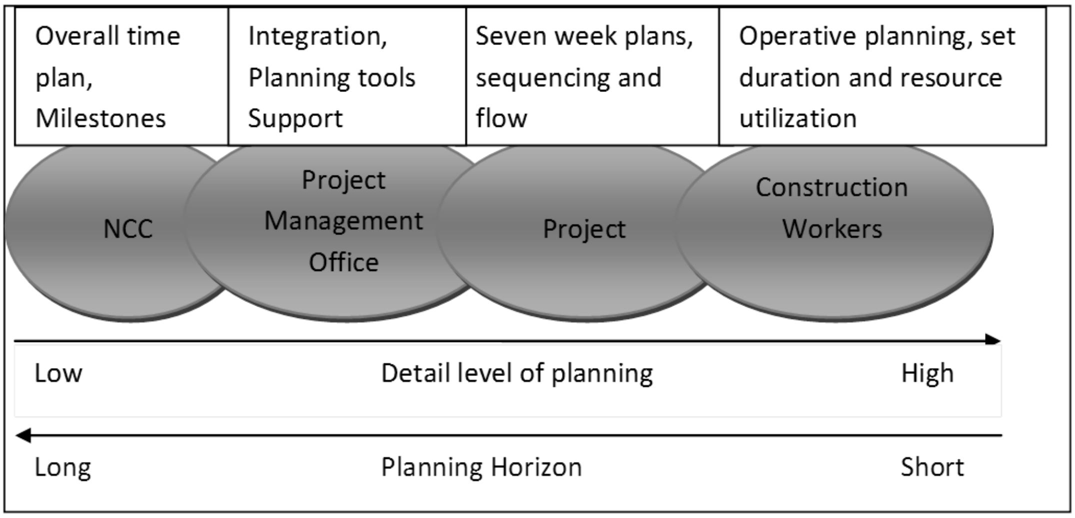


Figure 48 Future Designing the project

uncertainty and reduces the waste.

Figure 46 indicates that the Do phase is characterized by a two way communication between the professional workers and the project organization. The Last Planner System supports the autonomy of the workers and allow for an improved handling of the uncertainty. The provided work descriptions based on standardization of processes, outputs and skills reduces the risk of defects and supports a more efficient way of working.

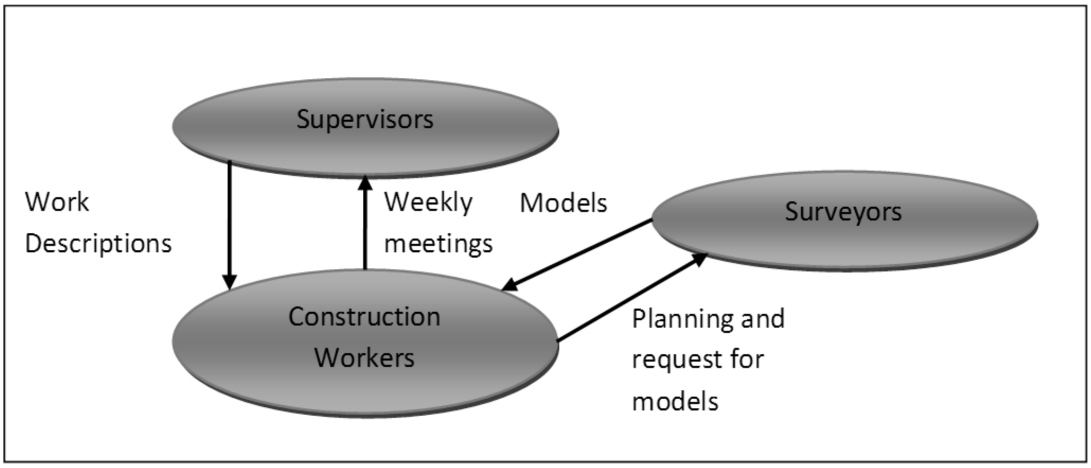


Figure 49 suggests that both individual and organizational learning takes place. The project management office supports both the cross-project learning's and the intra-project learning's through aiding with the use of tools and practices. The Last Planner System provides routines for more detailed follow up and monitoring which supports the double loop learning.

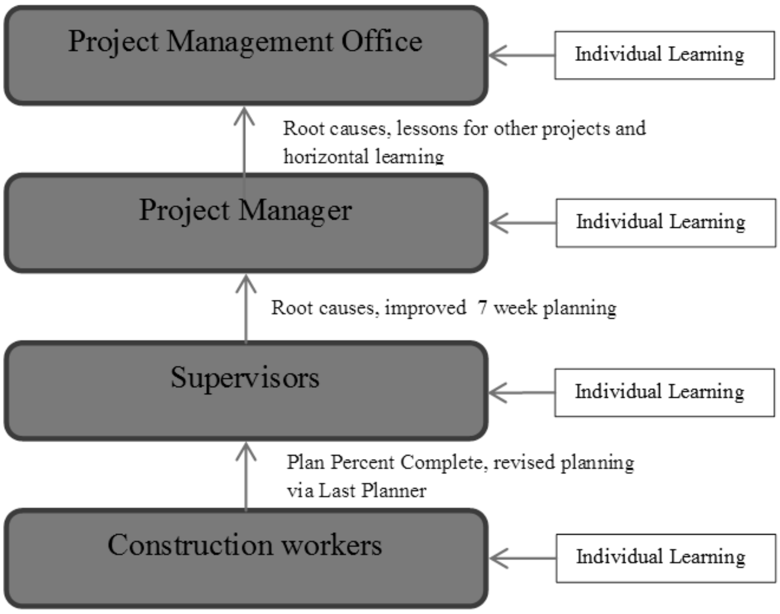


Figure 49 Future Developing the project

6.5 Evaluation of the improvement suggestions

The different actions that are recommended for NCC have some different impacts. The impacts can be traced in the three dimensions for which projects are managed after, time cost and quality (Maylor, 2010). Cost benefits are estimated from data collected in the project, see Appendix C.

6.5.1 Partnering contracts

According to Josephson and Saukkoriipi (2005) as much as 35 % of the construction costs can be waste. This thesis indicates that much of the waste is set in the early phases of defining the project and designing it. Therefore the increased communication and integration in a general contract could reduce much waste encountered later in projects (Walker, 2007). The improved communication and thus implementation of concurrent engineering can generate cost savings in manufacturing for up to 30 % (Creese & Moore, 1990). Applying the same order of benefits for the case studied would indicate that the benefit of using partnering would reduce cost for the project with around SEK 25 million. This while increasing quality and reducing total the time with up to 50 % (Creese & Moore, 1990) (Walker, 2007).

Much of the savings in a partnered approach would probably come in the early phases of the project. Initially a lot of resources would be saved by going through only one procurement process instead of two .Preparations for the project could also start earlier in the project organization as part of an concurrent engineering and thus increase speed. This thesis argues that the degree of type 1 wastes and thus the design could also be better suit the "Do" phase of the project. This enables a platform for standardization of a set of repetitive activities possible to combine in multiple ways. This enables both flexibility and cost advantages, (Sanchez & Mahoney, 1996).

The benefits of such a procurement process are probably far ahead into the future. Presently, neither the contractors such as NCC nor the STA possess the necessary competences for a partnered procurement (Riksrevisionen, 2013).The companies do not presently have the ability to design projects and the traffic administration is directed to interfere in the designs (ibid). A major change in the competence structure is therefore needed before these benefits could be reached. Given the culture of resistance (Kululanga, et al., 1999) and the large scale of the transformation, the benefits are probably difficult and time-consuming to reach.

There is a trend towards an increased ratio of partnering contracts within the construction industry at large but also within infrastructure (Riksrevisionen, 2013). It indicates that it is possible to do and also that it is desirable due to the positive trend. Therefore the problem and hinder is not a resistance against the procurement form as such but rather its implications. In order for partnering contracts to yield benefits it is important that the right competence is present both within the contractor but also within the STA. Currently the STA has much competence within how to actually build infrastructure and how to lead the projects, which is exemplified through that the representative onsite was an old project manager. Within partnering contracts their role is shifted towards identifying societal needs and to express them as functional demands. NCC on the other hand has to increase their involvement within the design phase and the translation of functional demands into technical parameters.

It is this transformation of knowledge and competence that is troublesome. Often there is a significant academic education behind the competence hence making it hard to obtain and change. The learning anxiety is significant hence making the task of motivating the involved individuals a hardship (Coutu, 2002). The key is to impose a strong sense of urgency towards the necessity to change the current way of working (Coutu, 2002) (Kotter, 1996). This can be hard in a time of large profits and increased turnovers and can therefore require significant top management attention and commitment, which is one of the key aspects in all big changes (Beer & Eisenstat, 2000).

The difficulty of the change indicates that the benefits would be realized over night but instead the change needs to be viewed as a long term investment. It is most probable that the first projects conducted actually display lower profit rates than the traditional projects. In the long run however the benefits will outweigh the cons through learning curves (Granstrand, 2010), where an increased collaboration and a better fit between the design and the processes will provide significant competitive advantages. The decision to increase the partnering contracts is strategic to its nature and those decisions and investments often span for several years. The benefits therefore are not realized within the current or perhaps not even the coming year but within a five year period it is probable to see positive results.

6.5.2 Project management office

Achieving cross-functional integration yields several benefits that are necessary to achieve success in partnering contracts. The PMO role can serve as an implementation channel for strategic decisions. The function can also perform several of the administration roles and knowledge of tools that are required for successful planning (Pemsel & Wiewiora, 2013). The initial planning is central to the success in project, and requires a basic level of planning tools (Dvira, et al., 2003). The integration and support in this phase can thus enable a higher success rate and reduced risk in the project.

Project within construction has a higher success rate than other industries (Zwikael, 2009). The key performance that must be improved is the planning in different aspects such as cost estimation etc (ibid). By using the project management office the "Do" phase of the project could probably start smoother. This due to that the integration enables some concurrent engineering in the project. The reduced uncertainty in the project would be the major cost benefit of the integrating position. By reducing the time needed for the project manager to do initial planning cost savings in the beginning of the project would probably reduce the cost of at SEK 160 000. Furthermore could probably the uncertainty be reduced and thus the type 1 waste in the project. Avoiding inventories in the beginning of projects would decrease machine cost as the handling of the inventories can be eliminated. Looking at the initial phase of the project interviews indicated that it takes a few months to get up to speed and the costs associated are between SEK 750 000 to 1.5 million. The improved planning could in the case yield benefits of cost savings of horizontal learning between projects, thus standardizing on high performance levels.

There are several dimensions of benefits to implementing a project management office. Not only would the direct cost probably be reduced but the critical aspect of perfection can be introduced. As the PMO can carry experience and knowledge and transfer this in the function (Pemsel & Wiewiora, 2013) the success rate for other projects can be. This can be the source of continuous improvements in the projects and thus increase performance in all the aspects cost, time and performance. The PMO can also serve as a potential recruitment pool for new project managers (Maylor, 2010). The benefits outside the case are difficult to determine but could be substantial. A suggested assumption would be a five percent saving thus saving SEK 6.9 million.

There currently is a seed of a project management office present within the organization. This indicates that the change is less radical but instead it is an incremental development. This has a significant impact on the feasibility (Slack, et al., 2010). The contract engineers are currently acting as some sort of project management office, the change that is needed is to further develop their role.

One change that is needed is to view the project not as an entirely own entity but instead as one part within the larger perspective that is NCC´s overall profitability. This requires that the current functional barrier that exists between the ones calculating the bid and the project organization is overcome. The barrier can be based on for example different use of vocabulary or a different educational background (Griffin & Hauser, 1996). These barriers can often be overcome through active efforts such as job rotation and reorganizations (ibid). It therefore is possible to initiate a project management office that supports the horizontal and vertical collaboration; it will however take time and resources.

Also within this area it is expected to be a short term dip in the productivity due to the changing work routine. The reorganization and the change of work tasks often can take substantial amount of time (Kotter, 1996). The required change of attitude towards an increased collaboration and a more holistic take on the entire project may require even more time.

6.5.3 Visual planning methods

The use of visual planning methods can yield major benefits to the project. Enabling a clearer communication will eliminate miscommunications and increase involvement in the planning. This can help overcome the difficulties of high abstraction levels in the meetings.

Visual planning can yield major cost benefits. Improving communication will make the work run smoother and probably avoiding costs in this case for up to SEK 700 000 in forms of improved flow. The major benefit is however to avoid any inventories. By adding inventories in the transportation the cost of the same process almost doubles. This could probably reduce the cost in the project for about as much as SEK 3 million. Since inventories are stated to be very common in projects improvements in this area can thus yield major cost reductions.

To implement the use of visual flow maps is a rather uncomplicated task. The knowledge is at place within both the calculation and the project organization. The suitable forums are there within the project organization. The only problem that needs to be overcome is the missing sense of urgency for the way of working. The project manager and the supervisors were hesitative towards that such a simple tool could render in any significant benefits. This lack of urgency can be countered through highlighting the costs of not visualizing the flow in terms of missed dependencies and the additional work and time it takes. Furthermore the belief in the tool can be increased through pilot projects, (Kotter, 1996), and workshops that can act as illustrative examples of the benefits (Bergman & Klefsjö, 2010).

The benefits can be yielded as soon as the managers start to adjust to the dependencies that are identified through the visual flow maps. This indicates that benefits could be realized literally tomorrow. The most significant benefits are however present in the early phases of the project which make the tool most applicable and useful at the start of the next project. Naturally there is a learning curve for the tool but it was evident from the case studied that the way of thinking already was put to use a visual map only aid the process therefore the learning curve is already initiated.

6.5.4 Last Planner System

By implementing Last Planner System the cost will decrease and efficiency increase (Fernandez-Solis, et al., 2013). In the case of the project many activities are given slack resources, an extra day or two, about 10 %, just to be sure that the activity is complete (Galbraith, 1974). According to Parkinson’s Law, any activity will expand to fill the entire time allocated (Maylor, 2010) and thus add waste. By instead allowing the operators to do more planning would invite to better time estimation and thus eliminate the need for slack resources. The prospect of saving 5-10 % on the side activities could yield benefits in the scale of SEK 6.9 million.

To enable a Last Planner System where responsibility is delegated downwards in the project organization the behavior of the project manager must change. Currently a tendency towards centering all responsibility to the project manager prevails. Interviews on site suggested that the pendulum is shifting in that direction where more decisions would be decentralized. Thus the change of behavior is possible.

The Last Planner System is based on having motivated and driven workers that individually strive to achieve progress. By allowing for the workers to take responsibility and plan their own work they might also become more motivated, (Rubenowitz, 2004), hence responding positively to the challenge. From the conversations with the professional workers it emerged that the workers that were lazy and aimed at conducting as little work as possible were dismissed from the construction site. It was viewed as not the managers fault but instead the individual that did not pull his own weight. To decentralize the responsibility it is also required to have trust. This trust need to be earned. The semi-stabile project organizations were managers and professional workers have been working together for a longer period of time show that trust is in most cases already established. This indicates that the workers are up for the challenge and that a system of a more decentralized operative planning can be rolled out.

The benefits of adopting last planner can be obtained almost instantly since buffers are reduced directly. The benefits of reducing the project manager's workload can also be done rather swift since some activities can be delegated downwards. The initial benefits of adopting a last planner system can therefore be realized rather swiftly but the full benefits require some learning to occur first.

6.5.5 Differentiated work descriptions

Making work descriptions for the standardized tasks, through standardization of processes, would make quality defects less common. The costs of quality defects are associated with the cost of redoing work. Minor deviations occur frequently and, although not all matters, avoiding these can reduce the overall costs. Through improved the standardization of work processes and by providing standardization of outputs it can be estimated that half the faults could have been avoided, thus saving some SEK 325 000. This goes in line with studies of the amounts and causes of defects in construction (Josephsson & Hammarlund, 1999).

The possibility to differ between different types of work descriptions is good. In fact it is currently done through using standardization of skills and processes. The aspect that is in need of change is to initiate standardization of outputs. This is currently done in a sporadic way through describing the work not in terms of how it is to be conducted but instead in what it should result in. The aspect that needs to be developed is to ensure that there is a more extensive support for following the standardized outputs. It is the way to make sure that the end result complies with the pre-defined outcome that is lacking. This is currently done in small scale through the aid of visual aids such as indicators of direction and width of the excavation.

The required change is not substantial since it is not a question of adopting entirely new ways of working but instead it is a way of ensuring that the way of working is stabilized at a higher level to avoid dips in efficiency and effectiveness. It is however required that the descriptions are being followed and that they are perceived as aids and not restrains.

The change can be conducted even during the current project and tendencies towards providing visual inspection aids so that the result can be controlled against the standard were being initiated to counter some defects. The impact is instant and reduces the amount of defect since they can be detected earlier or even fully avoided. There is naturally room for incremental improvements to investigate which aids are most effective but that is linked with the principle of perfection to always improve.

6.6 Ranking the improvement suggestion

The actions are evaluated on their potential benefit, the feasibility of conducting it and the time until benefits are realized. The categories have been graded with a scale from 1-10 where ten always have represented a positive outcome, meaning that the potential is vast, it is easily conducted and achieved quickly.

Action	Potential benefit	Feasibility	Time	Sum	Rank
Partnering contract	10	3	2	15	5
Project Management Office	8	5	5	18	4
Visual Planning methods	6	10	10	26	1
Last Planner System	8	6	6	20	2
Differentiated work descriptions	2	8	10	20	2

Table 5 Evaluation of improvement suggestions

Based on the table above it is possible to conclude that the initiation of visual planning methods should be of focus for NCC. It should initially be complemented by attempts to initiate a Last Planner System and differentiated work descriptions. Due to that the partnering contracts are so far ahead in time they do not yield any direct benefits but their potential is staggering thus supporting the initiation of lobbying towards changed procurement processes and a change in competence to prepare for the long term profitability. The same reasoning can be applied towards the Project Management Office since it also is a long term commitment that is a precondition for other types of improvements it can be vise to enable for the initiation.

7 Conclusions

In this chapter of the thesis the answer to the research questions are presented along with an elaboration on the most significant findings. How general the findings are and possible future research on the subject is discussed under Implications for future research. Last, the managerial implications are presented.

7.1 What Lean principles are applicable

It is evident that all five principles of Lean are applicable to a large scale infrastructural construction project.

To define value is pivotal in order for the product to be designed to fulfill the customer demands. The difference in comparison to traditional manufacturing industry is the difficulty of defining who the customer is along with the abstract product demands. To handle the differences an increased need to be holistic and broad arises.

Visualization of the flow is essential for allowing the complexity and dependencies to be clarified which is necessary for designing the process. The visualization of the flow indicates that it is mainly confined within the project site and not in or out of it. Within the construction of buildings the material flow to the site from suppliers is often significant. Within transportation infrastructure projects some internal activities act as suppliers, hence adding to the complexity in terms of dependencies.

Managing the flow is central to the profitability of infrastructure construction projects. The high uncertainty and complexity present within the project indicates that the flow needs to be managed not only initially in the project but also consistently throughout the project. To handle the complexity an overview is required hence supporting a centralized management while the predominantly uncertain aspects requires a more decentralized way of working. To handle both the uncertain and complex aspects it is required to have a large informational flow connecting the ones in a more central place in the hierarchy with the ones closer to the activities.

To adopt a pull system is applicable in both the planning and in the material flow. Enabling pull system within the material flow it is important to also allow for a pull system within the planning. It is through ensuring that the activities conducted simultaneously can be matched in terms of input-output dependencies that a pull system within the material flow can be initiated.

The last principle, perfection, is also applicable due to the reoccurring elements within and between the projects. Standardizations can be made both within the project management practices along with the activities. The inherent level of uncertainty does however somewhat impact the possibility to standardize. To address the uncertainty it is therefore advised to implement ways of standardizing that allows for greater flexibility and variation.

7.2 What are the success factors

In order for the principles to be applied several success factors were identified. They are illustrated in the list below:

- Achieve cross functional and cross company work
- Combine activities into processes
- Differentiate between required decision making capabilities
- Differentiate between the provided work descriptions

In order for value to be defined more holistically it is important to apply a cross functional and cross company mentality where different actors collaborate to capture more dimensions.

To visualize the flow it is important not to view each activity separately but instead to see how activities are combined into processes. This also set the base for the subsequent managing of the flow and the initiation of a pull system. The managing of the flow needs to take place on different levels. The complexity and uncertainty present determines the suitable level for managing the flow. It is therefore important that the project have the capability to take decisions on different levels to address both the complexity and the uncertainty.

A pull system is largely based on designing a suitable process out of the included activities so that the flow can be arranged accordingly. Within planning the uncertainty present require a more decentralized approach where the professional workers through mutual adjustments requests information and material. This indicates that the possibility for initiating a pull system is based on arranging a suitable sequence and enable input output relationships to be taken into account when combining activities into processes. The practical application is then based on allowing for the blue collar workers to adjust to the variation induced by the uncertainty.

The perfection is based on formulating and upholding standards and routines that warrant a high effectiveness and efficiency. The degree of uncertainty impacts the abstraction level of the standards ranging from standardization of processes, outputs and skills.

7.3 What actions support the application of Lean

The principles of Lean can be applied in practice through the use of the following actions:

- Construct on partnering contracts
- Institute a Project management office for the initial and strategic planning
- Use visual planning in the initial, strategic and operational planning
- Institute Last Planner System for the detailed planning
- Differentiated work descriptions

A more broad definition of value can be through the use of partnering contracts in combination with a project management office. This unifies the project organization with the calculation and design phases and enable cross functional workings.

Visual flow maps can be used to support the visualization of the flow. Together with the unifying function of the project management office that communicates the result of the visualizations so that all involved parties have the same understanding of the situation.

The flow is managed through the use of the visual flow maps through identifying the problems. The institution of a project management office also imply that the onsite conditions and the process demands are communicated and included more clearly in the initial and strategic planning. The Last Planner System allows for the uncertainty to be handled by the ones with the most knowledge about the on-site conditions thus avoiding disturbances in the flow.

A pull system can be supported by the project management office and the visual planning since the frame for the material flow is set in the initial and strategic planning. By taking more aspects into account it can be done to allow for a pull system. The pull system, within planning, benefits from using the surveyors and the weekly meetings as a forum for adjusting the plan to the changing circumstances. This is also supported through the Last Planner System that enables the workers to request a new task and adjust to each other.

Perfection is supported through the differentiated work descriptions that act as standards. By basing the work descriptions on both the uncertainty present and the skill level of the worker it is possible to achieve routines and thus increase the efficiency. The work descriptions can be applied both within the processes and the overall project management principles. The project management office also supports the diffusion of ideas horizontally within NCC at large along with vertically through implementing tools and practices with the projects.

7.4 Implications for future research

The implication of the first research question, that the five principles of Lean are applicable is a general finding. In transportation infrastructure construction the principles of Lean do apply and benefits are yielded, however in some slightly different manners than in traditional Lean construction. The way in which they are adapted is based on characteristics that are reoccurring in all transportation infrastructure projects containing ground works. There are many projects that share characteristics with the case, given the number of procurements in Sweden per year. Although this case was carried out in Sweden, the principles of Lean probably apply in all infrastructure projects of this form. The construction itself will probably not differ by much, even if regulations and culture are highly different in other countries and cultures, and thus the principles could be applied in other contexts.

The principles of Lean have some further aspects that could be researched. To further identify and test the difference between Lean Transportation Infrastructure and Lean Construction in buildings more research is needed. One possibility is that infrastructure is less mature due to being mainly driven by government procurement while Lean Construction often has a more direct customer involvement. Conducting a comparative study between building and infrastructure projects could be used to verify the difference. A longitudinal study of the notion Lean Construction could identify the evolvement of Lean Construction and identify if there could be similar patterns for the infrastructure to learn from.

The second research question has some less general findings. The success factors identified are probably limited to projects with a similar degree of uncertainty and complexity. Small, uncomplicated projects do not require the coordination mechanisms identified. Similarly, projects with very low uncertainty will probably not require the actions and involvement of the workers to the same degree in order to be successful. However, given the size and inherent uncertainty of most infrastructure projects the success factors are probably applicable for many infrastructure projects since they are focused on the enablers of high flow and resource efficiency.

Further research is required to verify the impact of the success factors identified. By conduction comparative studies on a set of infrastructure projects a statistical connection could be established. Identifying how the projects perform compared to the level of performance in the success factors could confirm the success factors and establish the benefit of these. Significant work would be required to establish suitable measures for conduction such as study and it requires long time in order to follow a large number of projects and their performance.

The third research question carries limited potential for general findings. The actions identified are specific for the context of this project and some actions are probably limited to the situation of the case. However, some findings are more on the level of the organization and as there is a number of similar construction companies there are probably some actions that would be applicable in them as well. The use of the success factor to identify different areas of improvement is probably also of a more general nature than the specific actions themselves. Therefore the way of identifying actions is more general than the actions themselves.

Future research on the applications of the principles and success factors could probably yield major benefits for the industry and support the general findings. By conducting action research the benefits of implementing the actions could be established. A successful implementation would indicate the validity of the success factors. A longitudinal study during the lifetime of a project would probably also enable to find when different actions can deliver most benefits for the company.

Significant research in the area of Lean transportation infrastructure still remains. This thesis finds that there is a difference between Lean construction and Lean transportation infrastructure, while there are also some similarities. The nature of this relationship is a matter of future research. Also, research must be conducted in order to confirm the theories presented in the conclusions of this thesis.

7.5 Managerial implications

The thesis started as a venture into unknown territory in terms of identifying the applicability of Lean principles when conducting transportation infrastructure projects along with how to adapt the principles to the specific context. It is suggested that an enhanced application of the principles of Lean can render in significant competitive advantages. The most significant differences towards traditional Lean manufacturing and also Lean construction are that; Value requires a holistic approach, the flow of material is based not to but within the construction site, and the flow needs to be managed throughout the project. This increases the complexity and the impact of uncertainty since changes can start a chain reaction.

The application of the principles of Lean depends on that the identified success factors are in place. This implies that the focus of the companies should be put on securing that they are in place prior to aiming for applying Lean principles.

7.5.1 The practical implications

Currently the principles of Lean are occasionally applied within the studied context. The problem is that they are only occasionally applied. There is a need for changes to enable the normative way of working to be based on the principles of Lean.

One key implication is to increase the collaboration between projects to support the establishment of standardized ways of working. By doing so the projects can be continuously improved and a common standard can be established supporting that the principles of Lean are applied in all projects. The key to achieving competitive advantages is not only confined within allowing for an improved performance within the best projects but also to standardize all the other projects to be at par with the currently best one.

Currently the predominant way of thinking within the industry is that the resources should be fully utilized. One key change is to instead focusing on that the flow should be as smooth and swift as possible and then to adjust the resources to support the flow. This implies the need for smaller and more flexible resources rather than high capacity specialized equipment, even if it still can be valid under some circumstances.

The decisions are currently centralized around a strong project manager which can be beneficial during some conditions. In order to apply the principles of Lean it is important that the decisions are taken centralized in the initiation of the project to handle the complexity, centralized in the project organization to handle the uncertainty and complexity and decentralized to adjust for the uncertainty. This imply that the project organization have to change the current way of managing the project. The assumptions and reasoning from the bid and calculation phase need to be carried on to the execution and the day to day decisions in the operative aspects need to be taken in proximity to the activities and actions.

Furthermore the role of the professional workers and machine operators is currently often limited to conducting a pre-described work task. If the principles of Lean is to be applied they must be accredited a more prominent role in terms of planning for the work (both in terms of how and when) along with providing more information upwards in the project organization in a bottom up way. This indicates that they are to be given more autonomy which renders in a need for more long term relations with the sub-contractors and a deepened collaboration.

7.5.2 Hinders towards applying the principles of Lean

Even though the required changes are possible to describe and identify they are not so easily done in practice. Change is never easy and changes in behavior and way of reasoning are especially hard.

The current procurement process and type of construction contract hinders the transaction to a more holistic approach with more cross-functionality. It supports a silo culture and has firmly established a competence base along with a role definition for the different actors. The competence within the different organizations implies that there is a desire to maintain the status quo.

The shifted focus towards managing the flow rather than upholding the resource utilization is also somewhat troublesome. The mindset that prevails today is that the key towards profitability is to enable the machines to work as much as possible. In order for a change to be realized the importance of allowing for a swift and even flow must be communicated and also accepted among the ones designing the processes.

Furthermore the current power distribution with a strong project manager that is both decoupled from the central management and in charge of all aspects of the project hinders the transition towards applying Lean principles. The power structures are always hard to change since individuals tend to look at their own interest and aim at maintaining or enhancing their own power and influence.

The culture that characterizes the construction industry also hinders the application of Lean principles. The mindset of the employees needs to be altered to support the sense of urgency to adopt the principles of Lean. This is at the very core of enabling any change thus it is utterly important to attend.

It is therefore possible to conclude that the potential of applying Lean is vast but that significant hinders remain. These hinders are both practical in terms of the procurement and contract situation and the strong project organization and more abstract in terms of mindsets and cultures. In order to successfully apply the principles it is therefore important to address both types of issues with equal attention and not only focus on the tangible aspects.

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Appendix A - Interview guide

Kan du beskriva din roll i projektet? Vilka är dina arbetsuppgifter?

Vilka personer har du kontakt med i projektet? Rörande vilka frågor?

Vilken roll har du i planeringen av projektet?

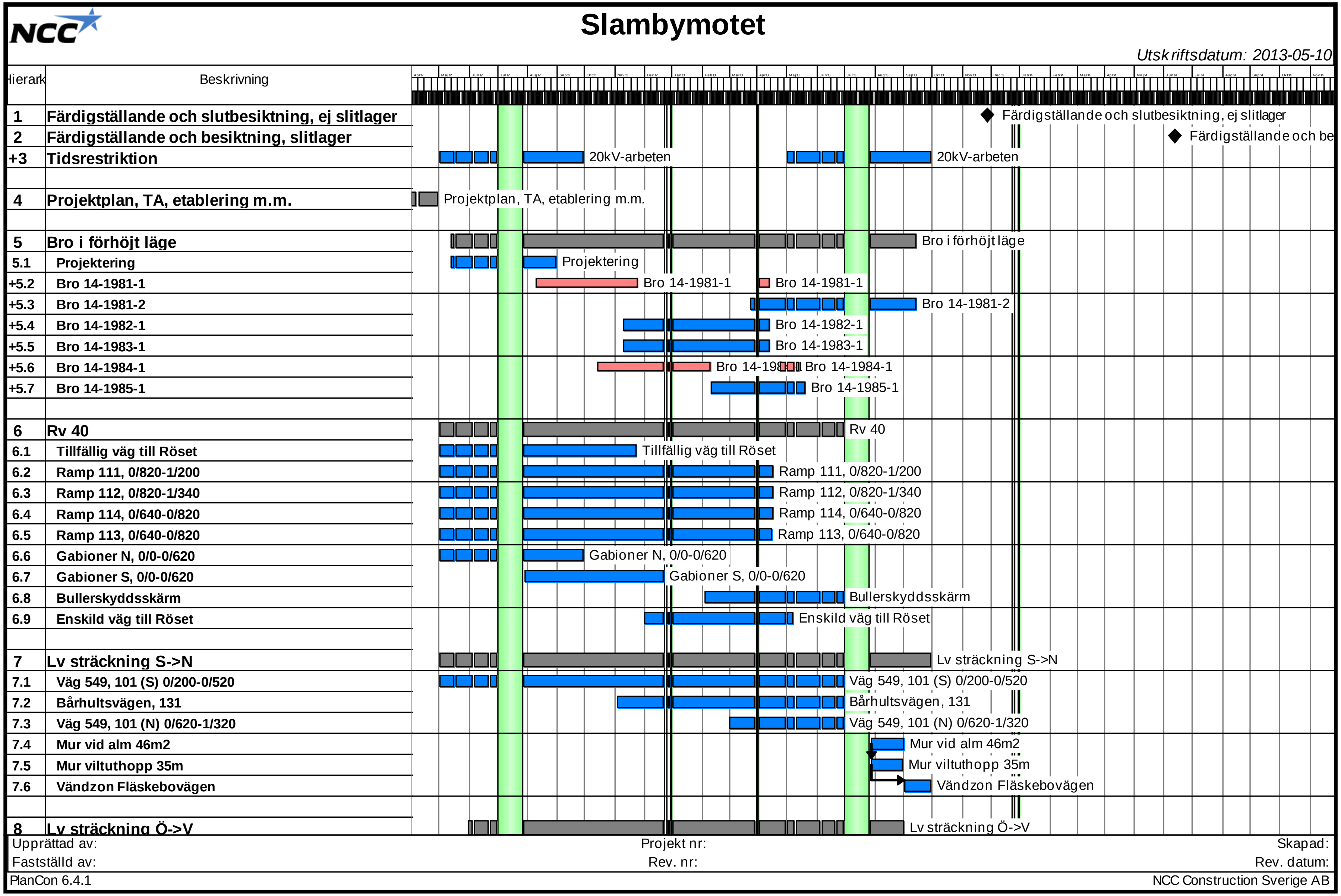
Vad upplever du vara det vanligaste problemen i projektet? Vad gör ni åt det?

Hur upplever du att relationen med beställaren fungerar?

Hur upplever du att relationen med NCC centralt fungerar? Vad för projektstöd får ni/skulle ni behöva?

Är det något du vill tillägga?

Appendix B - Project time plan at Bårhultsmotet



Appendix C - Approximation of benefits

The calculations in this appendix are approximations of what impact the different measures could have. These are based on the observations in the project and have been proportionally multiplied to get an idea of the benefit during the course of the entire project. The benefits are calculated from observations and what practitioners have experienced to get an interval. Summing up the benefits will not provide a representative picture, some there is probably an overlap in the waste that can be eliminated between the different measures.

Partnering contracts

Up to 35 % of project cost are waste (Josephson & Saukkoriipi, 2005), and 80 % of project costs are set during the initial phases (Chou, 2009). This implies that at least 28 % waste is set before NCC is involved, reducing this to 10 % could probably be a rough estimate

Project cost: SEK 137 million

18 % cost reduction ➔ Savings of approximately SEK 25 Million

Project management office

Reducing planning time by one month through concurrent engineering, approximation

Cost of project manager: SEK 80 000/month

Additional employees in initial phase: SEK 80 000

Total approximate savings: SEK 160 000

Data from internal documentation

Reduced uncertainty and risk

Reducing the uncertainty, particularly in the start of projects can significantly reduce the cost of projects. With the use of project management office cost savings of up to 15 % can be achieved (Project Management Solutions, Inc., 2012)

Reaching a 5 % saving = SEK 6.9 million

Based on data from internal document

Visual planning methods

Avoiding inventories
SEK/week 30 000. Project total approximately SEK 1.5 million
Data from machine cost in internal documents

Using models to visualize flow can reduce the cost by identifying clashes in flow, facilitating communication and avoiding mismatch, observed phenomena indicates that perhaps 3 % of the overall cost could be reduced. Some research indicates that savings could be up to 10 % (Azhar, et al., 2008).

Approximate savings at 3 %: SEK 4 Million

Last planner system

Remove 10 % buffer time on activities, if savings of 5 % are achieved would reduce the cost of equipment by SEK 2.5 Million. Data from observations

Improving performance and reducing risk of failure could achieve improved project performance at about 5% leading up to savings of SEK 6.9 million.

Employ standardization of processes and outputs

Reduce defects with about 50%

Number of defects that were observed during three weeks, 2

Cost per defect 15 000 SEK

Total cost of defects 650 000 SEK

Potential cost save 325 000 SEK