Critical Success Factors for Planning, Scheduling and Control in Design and Construction

Elías Bjarnason

Thesis of 30 ECTS credits
Master of Science in Civil Engineering
with specialization in Construction Management

June 2015

Critical Success Factors for Planning, Scheduling and Control in Design and Construction

Elías Bjarnason

Thesis of 30 ECTS credits submitted to the School of Science and Engineering
at Reykjavík University in partial fulfillment
of the requirements for the degree of
Master of Science in Civil Engineering
with specialization in Construction Management.

June 2015

Supervisors:

Kai Haakon Kristensen, Ph.D
Project Manager at Faveo Prosjektledelse AS

Þórður Víkingur Friðgeirsson, Ph.D
Professor, Reykjavík University, Iceland.

Examiner:

Halldór Ó. Zoëga, MPA
Specialist, Icelandic Transport Authority

Abstract

Background: This study is within the field of construction management where the critical success factors for planning, scheduling and control are analyzed for two different management methods, namely Lean Construction Planning Systems and Traditional Construction Management Planning Methods.

Studies have shown that more than 50% of time wasted during construction is attributable to poor management practices. This thesis therefore focuses on the success perspectives of the planners, the objectives (success criteria) of planning, scheduling and control, and the factors that influence the success or failure of planning, scheduling and control. Also, this study aims to identify the strengths, weaknesses, opportunities and threats of the planning methods mentioned above, in regard to successful planning, scheduling and control.

Methods: This is an exploratory study which applies an inductive approach with the use of qualitative case studies, by collecting and analyzing textual data through document analysis, interviews and observations. SWOT analysis was used to evaluate the methods. Statsbygg provided the following two construction projects for this study, both which are being implemented for different educational institutions in Norway. Case 1: A project which applied a traditional approach to design and construction. Case 2: A project which applied a Lean approach to design and construction.

Principle results: The client had an operational, tactical and strategic success perspective whereas the contractor and the design team mainly had an operational success perspective. The objectives (criteria) by which planning and scheduling success can be judged are: *Understand the Goals, Reduce Uncertainty, Apply Realistic Estimates, Improve efficiency, Establish Basis for Control*. The factors which influenced planning and scheduling success were: *Commitment to Planning*, *Human factor* (planning, organizing, coordination and motivating skills), *Motivation, Tendering Method, Feedback Capabilities* and *Project Related Factors*. The objectives (criteria) by which control success can be judged are: *Determine Project Status, Evaluate Performance, Manage Actual Changes.* The factors which influenced planning and scheduling success were: *Commitment to planning*, *Human factor* (planning and cooperation skills), *Control of subcontractors' works, Tendering method.* The Lean approach showed better results than the Traditional approach in the SWOT analysis.

Conclusions: A critical factor for successful planning, scheduling and control is *commitment to planning.* The study findings showed that the Lean approach achieve more successful planning and control than the traditional approach. This study by itself can however not conclude the ultimate capabilities of these methods since it only examined two projects.

Keywords: Critical success factors, Planning, Scheduling, Control, Lean Construction, Traditional Construction.

Ágrip

Titill á íslensku: *Afgerandi velgengnisþættir í skipulagningu, áætlanagerð og stjórnun við hönnun og framkvæmd.*

Bakgrunnur: Þessi rannsókn tilheyrir fræðum framkvæmdarstjórnunar þar sem afgerandi velgengnisþættir fyrir skipulagningu, áætlanagerð og stjórnun eru greindir út frá tveimur mismunandi stjórnunaraðferðum. Þessar aðferðir eru Lean straumlínustjórnun og hefðbundnar framkvæmdastjórnunaraðferðir við mannvirkjagerð.

Rannsóknir hafa sýnt að meira en 50% af þeim tíma sem er sóað í byggingarframkvæmdum má rekja til lélegra stjórnunarhátta. Þessi ritgerð einblínir á velgengnisjónarmið skipuleggjenda, markmið (velgengins viðmið) í skipulagningu, áætlanagerð og stjórnun, en skoðar einnig þá þætti sem hafa áhrif á velgengni eða mistök í skipulaginu, áætlanagerð og stjórnun. Markmið rannsóknarinnar er einnig að bera kennsl á styrkleika, veikleika, ógnanir og tækifæri í stjórnunaraðferðunum, sem nefndar hafa verið, með tilliti til velgengni í skipulagningu, áætlanagerð og stjórnun.

Aðferðir: Þetta er athugunarrannsókn sem notast við tilleiðslu (inductive resoning) í eigindalegri tilviksrannsókn (case study) þar sem gögnum var safnað saman með viðtölum, vettvangsathugunum og skjölum sem tengdust rannsókninni. Þessi gögn voru síðan borin saman og notuð var SVÓT greining til að leggja mat á fyrrnefndar stjórnunaraðferðir. Statsbygg sá um að útvega eftirfarandi framkvæmdarverkefni fyrir rannsóknina en þessi verkefni tengjast mismunandi menntastofnunum í Noregi. Annars vegar verkefni þar sem notast er við hefðbundnar aðferðir við hönnun og framkvæmdir og hins vegar verkefni þar sem notast er við Lean straumlínustjórnun við hönnun og framkvæmdir.

Megin niðurstöður: Velgengnissjónarmið viðskiptavinarins eru framkvæmdarhæfni, notendahæfni og víðtæk stefnumörkun en velgengnissjónarmið verktakans og hönnunarteymisins voru aðallega framkvæmdarhæfni. Markmið (velgengnis viðmið) sem hægt er að nota til að meta velgengni í skipulaginu og áætlanagerð eru: *Skilningur á markmiðum, að draga úr óvissu, beita raunhæfum áætlunum, bæta skilvirkni og stofna eftirlitsgrundvöll.* Þættir sem höfðu áhrif á skipulagningu og áætlanagerð: *Skuldbinding við skipulag, mannlegir þættir* (skipulagning, samhæfing og hvetjandi færni), *hvatning, útboðsaðferðir, geta til að vinna úr athugasemdum* og þættir tengdir *verkefninu*. Markmið (velgengnis viðmið) sem er hægt er að nota til að meta velgengni í stjórnun: *Ákvarða stöðu verkefnisins, meta frammistöðu* og *stjórna raunverulegum breytingum*. Þættir sem höfðu áhrif á velgengni skipulagningar og áætlanagerð: *Skuldbinding við skipulag, mannlegir þættir* (skipulags- og samvinnuhæfni), *stjórnun undirverktaka* og *útboðsaðferðir*. Með SVÓT greiningu sýndi Lean straumlínustjórnun betri niðurstöður en hefðbundnar stjórnunaraðferðir.

Ályktanir: Afgerandi velgengnisþáttur í skipulagningu, áætlanagerð og stjórnun er skuldbinding við skipulag. Niðurstöður rannsóknarinnar sýndu að Lean stjórnunaraðferðin nær fram árangursríkari skipulagningu og stjórnun en hefðbundna aðferðin gerir. Þessi rannsókn getur þó ekki sagt endanlega til um hæfni þessara tveggja aðferða við framkvæmdastjórnun þar sem hún tekur aðeins til tveggja verkefna.

Lykilorð: Afgerandi velgengnisþættir, skipulagning, áætlanagerð, stjórnun, Lean straumlínustjórnun, hefðbundnar stjórnunaraðferðir.

Critical Success Factors for Planning, Scheduling and Control in Design and Construction

Elías Bjarnason

30 ECTS thesis submitted to the School of Science and Engineering
at Reykjavík University in partial fulfillment
of the requirements for the degree of
Master of Science in Civil Engineering with specialization in Construction Management

June 2015

Student: Elías Bjarnason

Elías Bjarnason

Supervisors:

Kai Haakon Kristensen

Þórður Víkingur Friðgeirsson

Examiner: Halldór Ó. Zoëga.

Halldór Ó. Zoëga

DEDICATION

To Gísli Arnkelsson and Katrín Guðlaugsdóttir

Acknowledgements

This project was provided and funded by Statsbygg, the Norwegian government's key adviser in construction and property affairs, building commissioner, property manager and property developer.

I would like to thank Statsbygg for giving me the opportunity to conduct my research at their project sites. The staff at Statsbygg´s headquarters, Gry Ahlsand and Thomas Roel Moen, thank you for getting me in contact with my supervisor and for funding my trips to the project sites. Thank you for granting me access to your personnel, meetings and documents.

The staff at the two different project sites, thank you for your warm welcome and your participation in this research. Thank you for making time in your busy schedules to discuss your work with me and the trust you have showed me. I would especially like to thank the project managers, Bikramjit Singh and Kristin Juul.

My supervisor provided by Statsbygg, Ph.D Kai Haakon Kristensen, thank you for your guidance, wisdom and patience throughout this process. I would also like to thank my supervisor and teacher Þórður Víkingur Friðgeirsson for your counseling and advice.

Thank you to my friends and family in Norway who gave me a place to stay while I was conducting my research. Also I would like to thank Birkir Bjarnason, Bjarni Gíslason, Gríma Katrín Ólafsdóttir, and Hildur Björg Gunnarsdóttir for refining and proofreading parts of the thesis. To all my family and friends, thank you for your support and understanding.

I am very grateful for my learning opportunities at Reykjavik University. Thank you to my fellow students for your wisdom and friendship throughout these last years.

Finally, I would like to thank my lovely wife, Hildur Björg Gunnarsdóttir, for her endless support and motivation during my studies at the University.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ARC	Architect
BIM	Building Information Modeling
CL	Client
CON	Contractor
CRE	Client Representative
CSF	Critical Success Factor
DM	Design manager
DT	Design Team
DTC	Design Team Coordinator
ELE	Electrical Engineer
HSE	Health Safety and Environment
HVE	Heating and Ventilation Engineer
JIT	Just in Time
KPI	Key performance Indicator
NULS	Norwegian University of Life Sciences
PM	Project Manager
PMA	Project Manager Assistant
PPC	Percent Plan Complete
PPM	Production Progress Manager
STE	Structural Engineer
STUC	Sør-Trøndelag University College

1 Introduction

In this chapter the research topic is presented and a foundation set for the study. The aims and objectives are introduced as well as the research questions. The restrictions of the research are explained and the structure of the thesis outlined.

"The starting-point is more than half the whole - Aristotle"

1.1 Background

This study is within the field of construction management where the critical success factors for planning, scheduling and control are analyzed for two different management methods, namely Lean Construction Planning Systems and Traditional Construction Management Planning Methods.

Studies have shown that more than 50% of time wasted during construction is attributable to poor management practices (Koskela, 2000). Well known waste such as overproduction, waiting, inventory, movement, effort, rework and processing (Suzaki, 1987) occur on a daily basis within design and construction projects, mainly due to bad control and unfavorable design (Koskela, 2000).

This caught the attention of the investigator and made him curios to know what factors are critical for success in regard to planning, scheduling and control.

Also, a new approach to design and construction management with the aim of reducing waste and managing flows caught the attention of the researcher, an approach often referred to as Lean Construction (Alarcón, 1997).

The investigator was curious to know whether there is visible difference in regard to successful planning, scheduling and control between construction projects managed by this new approach and projects managed by the traditional approach to construction management.

1.2 Aims and Objectives of the Research

In this section the aims and objectives of the thesis are defined. The aims are concerned with purpose whereas the objectives are concerned with achievement. The research questions are then formed based on these aims and objectives.

The aim of this thesis is to provide a better understanding of the critical factors that influence the success or failure of planning, scheduling and control for design and construction projects.

Another aim is to provide a better understanding of the management methods used in design and construction projects, regarding their capabilities to meet the success criteria for planning, scheduling and control. The two methods examined in this study are Lean construction planning systems and traditional project management planning methods.

The objective of this research is to identify the critical factors that influence the success or failure of planning, scheduling and control for design and construction projects.

Another objective is to assess the methods used in design and construction projects, regarding their capabilities to fulfill the success criteria for planning, scheduling and control. As previously stated, the two methods examined in this study are Lean construction planning systems and traditional project management planning methods.

1.3 Research Questions

With the aims and objectives in mind the following research questions were formed:

(1) How are the critical success factors for planning, scheduling and control defined, in the design and construction phase of construction projects?

a) What success perspective do the client, contractor and design team have?

b) Do the projects achieve the objectives (criteria) for planning, scheduling and control?

c) What factors influence the achievement of the objectives (criteria) for planning, scheduling and control?

(2) How capable are the management methods listed below to achieve the objectives for planning, scheduling and control:

a) The traditional project management planning method?

b) The Lean construction planning system?

The first research question, including the sub questions a, b, and c, is formed specifically to examine the *projects* in regard to the CSFs by examining the key personnel's success perspectives, the achievement of the objectives, and by identifying the factors that influence the achievement of the objectives for planning, scheduling and control. The second question, on the other hand, is formed to assess the planning *methods*, the Lean approach vs. the traditional approach. This is done by applying the findings from question 1 to highlight the methods strengths, weaknesses, opportunities and threats in regard to planning, scheduling and control.

1.4 Restrictions

According to Yin the definition of the research questions is probably the most important step to be taken in a research study (Yin, 2009). This proved to be very true. In the midst of this study, after collecting the data for the research and doing an extensive literature review, it became evident that the original research questions were too broadly defined.

The original research questions implied that the intention was to identify "all" the CSFs for planning, scheduling and control for design and construction projects. However, that was neither possible nor the intention of the investigator. Due to how broadly the questions were defined it also proved difficult to answer them in a structured way without gaining access to more research data by studying more projects, over a longer time period.

Instead of asking *"what are the CSFs"*, as the original research question did, the researcher chose to ask *"how are the CSFs defined"*. This adjustment gave the study a much clearer structure right away. The literature review on CSFs revealed that one must first understand the terms *success*, *success perspective*, *criteria*, and *factors* before one can define a critical success factor for a given subject. Lim's and Mohamed's report, *Criteria of project success: an exploratory re-examination*, explains that some project management literature has failed to distinguish between the terms criteria and factors in regard to project success and CSFs. This caught the researcher attention. In fact, their report inspired the investigator to study the *success perspectives*, *success criteria* and *success factors* for planning, scheduling and control in real-life design and construction projects, with the aim of defining some of the CSFs in that field. Due to time restrictions and limited resources, this study was only able to examine the planning, scheduling and control process for a short time period within two construction projects, during their design and construction phase, wherein the design and construction was done in parallel at both sites. One of these projects applied Lean construction planning systems whereas the other used more traditional construction management planning methods.

The original plan was to also examine *the similarities and differences between the CSFs for the different planning methods*. The problem with that presentation is that it implies that the CSFs for Lean projects are different from those in the traditional projects. Instead of making such assumptions, the researcher chose to examine how capable the methods are to achieve the objectives of planning, scheduling and control, as well as their ability to deal with the influencing factors which contribute to the achievement of those objectives. This was done by examining the planning, scheduling and control process at each construction project. A SWOT analysis was applied to analyze and compare the methods together.

In this context it should also be noted that the original plan was to study four of Statsbygg's construction projects, two projects applying Lean and two using more traditional methods. Due to various reasons the researcher was only handed out two projects, one that applies Lean and one that uses more traditional methods. Obviously, gaining access to two more projects would have increased the internal and external validity of the research.

The main focus area for this study in regard to planning, scheduling and control is the Project Time Management, one of eight sub process of the Planning Process Group as defined by the Project Management Institute (see section 2.2.1.2). The processes within Project Time Management seek to ensure the timely completion of the project. This includes defining activities, sequencing activities, estimating activity resources, estimating activity durations, developing the schedules and controlling the schedules. The most relevant processes within the Project Time Management for this study are *develop schedule* and *control schedule* (Project Management Institute, Inc., 2013).

1.5 Research approach

After careful consideration case study was assessed as the most fitting design for this research. This was, among other things, based on the case study's unique strength to deal with a variety of evidence, namely: documents, artifacts, interviews, observations, and more (Yin, 2009). The researcher, having only studied engineering at the University and therefore more familiar with a deductive and quantitative approach to research, had to use extensive time to get familiar with case studies, which are commonly applied in the social sciences. Fortunately, there are experts such as Yin in the field of case studies who guided the investigator through the research process.

The following picture shows the chosen research methodology for this research based on Creswell's research framework. To summarize, the research will use an inductive approach with the use of qualitative case study, by collecting and analyzing textual data through document analysis, interviews and observations. This is an exploratory study.

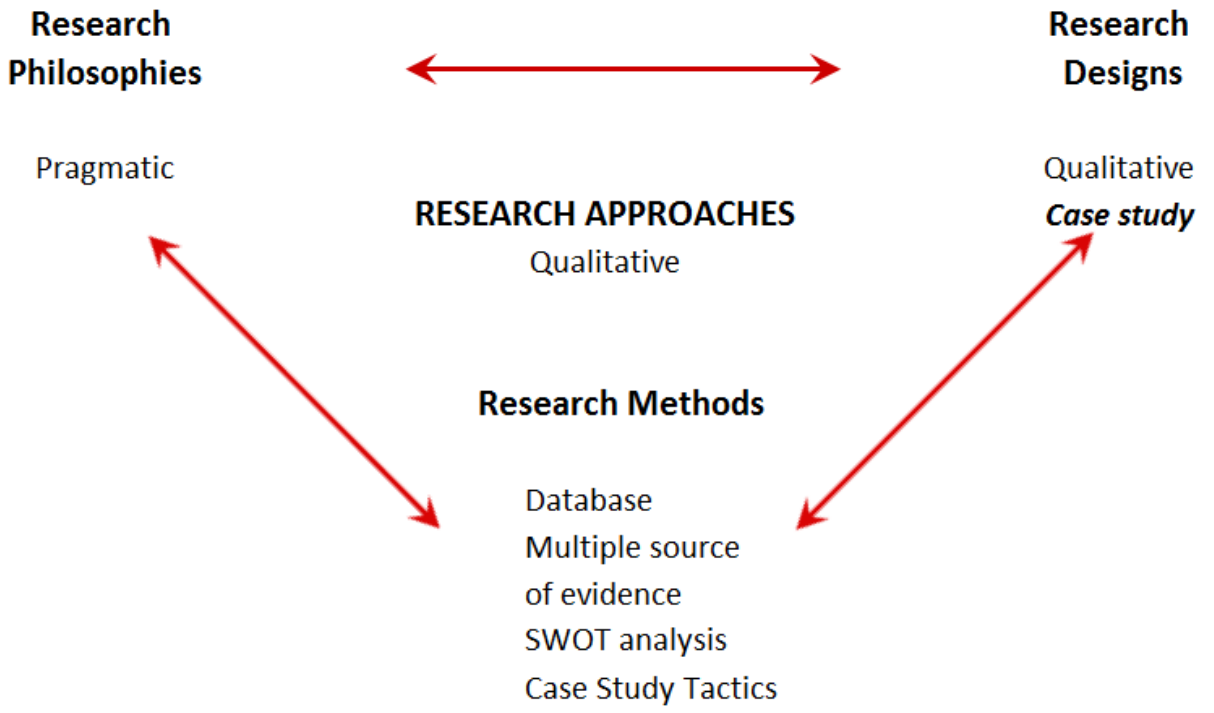


Figure 1 - Research methodology

1.6 Thesis outline

The thesis is structured around the research questions and divided to 8 chapters. Each chapter starts with a short description. Table 1 gives a short description of the contents of each chapter.

Chapter	Description
Chapter 1 Introduction	Outlines the topic of the thesis and defines the aims and objectives of the research. The research questions are presented and the chapter ends with an overview of the thesis.
Chapter 2 Theoretical framework	Gives a brief overview of the literature related to the content of this thesis. The main topics of the chapter are planning, scheduling and control in regards to construction management, critical success factors in project and construction management as well as introducing and comparing traditional construction management methods and Lean construction planning systems.
Chapter 3 Research methodology	Explains step by step how the research methodology was formed for this thesis. The research approach is addressed as well as the research design and methods.
Chapter 4 Case study	The case studies used in this research are outlined in this chapter. Case 1 is the Sør-Trøndelag University College project and case 2 is the Norwegian University of Life Sciences project. This section also describes what data was collected.
Chapter 5 Results and discussion	Reports the main results of the study as well as analyzing and discussing the main findings. As the discussion is interlinked with the results it was decided to merge them into one chapter for clarity.
Chapter 6 Conclusion	The main findings of the thesis are outlined in this chapter. It also contains suggestions for further research.
Chapter 7 References	Literature used in this thesis is outlined in this chapter.
Chapter 8 Appendixes	Additional documents such as the interview guide and organizational charts.

Table 1 - Thesis outline

2 Theoretical framework

The purpose of this chapter is to guide the reader towards the main research topics and to form a sound foundation for the study. The theoretical framework is organized to address the following issues:

- Fundamental aspects of project/construction management.
- Planning, scheduling and control
- Critical success factors
- Traditional construction management planning methods.
- Lean construction planning systems.

2.1 Introduction

This section presents some ideas regarding what defines a project, how a construction project is defined, what project management is and what aspects of construction management are fundamental for planning, scheduling and control.

2.1.1 Project

A project can be defined in many ways. Table 2 shows a variety of definitions to give a more complete picture of what a project is.

Reference	Definition of project
(Turner & Müller, 2003)	*"An endeavor in which human, material and financial resources are organized in a novel way, to undertake a unique scope of work, of given specification, within constraints of cost and time, so as to achieve beneficial change defined by quantitative and qualitative objectives".*
(PMI[1], 2013)	*"A project is a temporary endeavor undertaken to create a unique product, service, or result".*
(Kerzner, 2013)	*"Projects exist to produce deliverables. A project can be considered to be any series of activities and tasks that:* • *Have a specific objective to be completed within certain specifications* • *Have defined start and end dates* • *Consume human and nonhuman resources (i.e., money, people, equipment)* • *Have funding limits (if applicable)* • *Are multifunctional (i.e., cut across several functional lines)".*
(Ballard & Howell, 2003)	*"Projects are temporary production systems".*
(Wysocki, 2011)	*"A project is a sequence of unique complex, and connected activities that have one goal or purpose and that must be completed by a specific time, within budget, and according to specification".*

Table 2 - Project definition

Every project creates a unique product, service, or result (Project Management Institute, Inc., 2013). Projects can thus be classified into types and typologies. The three primary types are: *Business projects, Development projects* and *Change projects.* The four typologies are: *size, institutional/industry context, organizational condition,* and *task features* (Morris, Pinto, & Söderlund, 2010).

The theoretical lifecycle phases of a project can be defined as: Conceptual, Planning, Testing, Implementation, and Closure (Kerzner, 2013).

[1] Project Management Institute, Inc.

2.1.2 Construction Project

Construction is one among many types of project-based production systems (Ballard & Howell, 2003). According to Chitkara's definition, construction project refers to a high-value, time bound and special construction mission with predetermined performance objectives. He further explains that the project mission is accomplished within complex project environments, by putting together human and non-human resources into a temporary organization, headed by a project manager.

The major construction projects can be grouped into Building Construction, Infrastructure Construction, Industrial Construction and Special-purpose projects. Due to the limited scope of this research, only Building Construction will be further addressed.

Building construction constitute the largest segment of the construction business. Building works include residential and commercial complexes, educational and recreational facilities, hospitals and hotels, warehouses and marketing facilities. The building business serves mankind by providing shelter and services for its habitation, educational, recreational, social and commercial needs. The Building works are mostly designed by the Architect/Engineering firms, and are financed by public and private sector and individuals. (Chitkara, 1998).

2.1.2.1 Project Lifecycle

Construction projects, just like other projects, have a predetermined duration with a beginning and an end. The starting point of a project is the time when the project idea is conceived by the client. The end marks the time when the mission is accomplished. The time span between the start and completion of a project represents the project life cycle. The life cycle of a typical construction project can be broadly divided into the following phases: formulation phase, mobilization phase and construction phase.

- The *formulation phase* includes the conception of the project idea, feasibility studies, investment appraisal and project definition.
- The *mobilization phase* covers the preparation of the project preliminary plan, designs and drawings, contracts, resources mobilization and earmarking funds.
- The *construction phase* includes planning and controlling execution, inducting resources, construction and commissioning, and finally, handing over to the client (Chitkara, 1998).

2.1.3 Project Management

2.1.3.1 What is Project Management?

Project management as a term seems to first appear in 1953, arising in the US defense-aerospace sector (Johnson, 2006). Since then project management has been defined in many ways, depending on industries, organizations and individuals.

The Project Management Institute describes project management as: "*the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements"* (Project Management Institute, Inc., 2013).

Wysocki describes project management as: *"an organized common-sense approach that utilizes the appropriate client involvement in order to deliver client requirements that meet expected incremental business value"* (Wysocki, 2011).

Kerzner states that project management is designed to manage or control resources on a given activity, within time, cost, and performance. He further explains that time, cost, and performance are the constraints on the project. If the project is to be accomplished for an outside customer, then the project has a fourth constraint: good customer relations. The figure below is Kerzner's pictorial representation of project management.

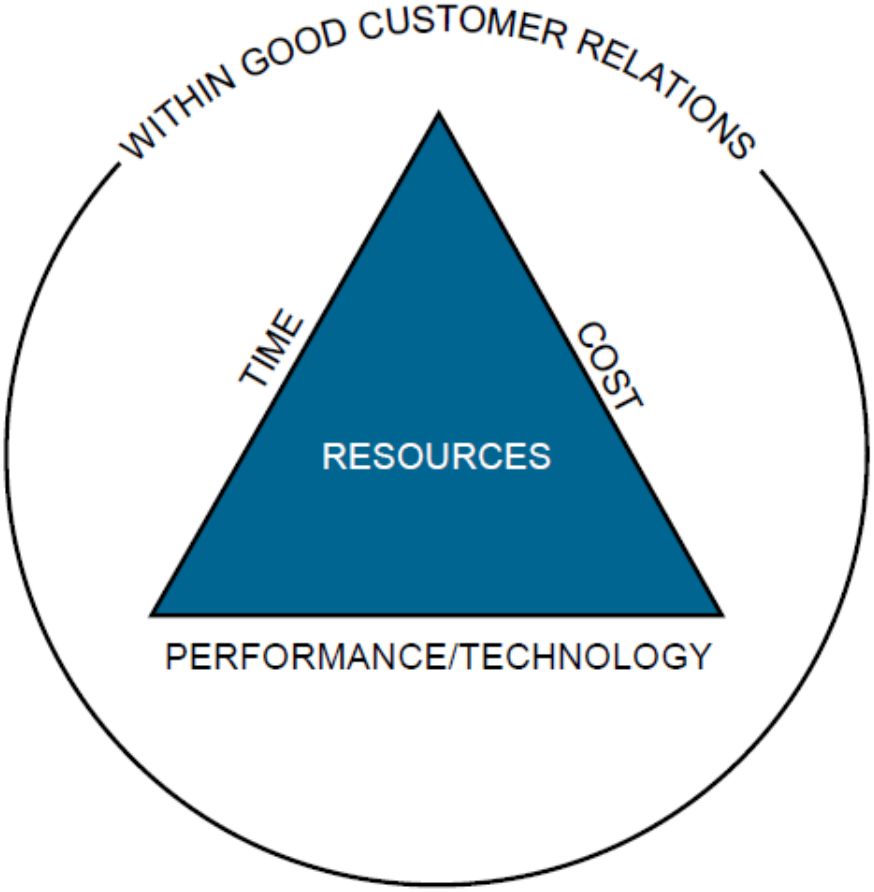


Figure 2 - Project management (Kerzner, 2013).

Project management is not a one-person operation; it requires a group of individuals dedicated to the achievement of a specific goal. Project management includes: A project manager, an assistant project manager, a project (home) office and a project team (Kerzner, 2013).

2.1.3.2 Project Management Methodology

A project management methodology is defined by Kerzner as a management process that can be repeated on each and every project. Its purpose is to ensure repetitive project management success form project to project. Kerzner explains that in order to develop a project management methodology four basic inputs are needed, namely: *people*, *tools*, *organization* and *work*. Good project management methodologies integrate the following management processes into its methodology (Kerzner, 2013):

- *Project Management:* The basic principles of planning, scheduling, and controlling work
- *Total Quality Management:* The process of ensuring that the end result will meet the quality expectations of the customer
- *Concurrent Engineering:* The process of performing work in parallel rather than series in order to compress the schedule without incurring serious risks
- *Scope Change Control:* The process of controlling the configuration of the end result such that value added is provided to the customer
- *Risk Management:* The process of identifying, quantifying, and responding to the risks of the project without any material impact on the project's objectives

Although the methodology is an important part of project management, one must bear in mind that methodologies do not manage projects; people do. Kerzner explains that it is the corporate culture that executes the methodology (Kerzner, 2013).

2.1.4 Construction Management

As mentioned in the first chapter, this thesis focuses on two different approaches to construction management; the Lean approach and the traditional approach. These different methods are presented separately in section *2.4* and *2.5*. In this section some of the fundamental ides of construction management are presented as well as the major management tasks. Also, some important concepts regarding the design and construction processes are presented. But first, the main construction participants and stakeholders are presented.

2.1.4.1 Construction Participants

The five main agencies actively associated with the execution of major works with in design and construction projects are listed in the table below, based on Chitkara's description (Chitkara, 1998):

Agency	Description of participants
Business promoter	The business promoter, also called the client, is the potential owner of the construction project. He sponsors the construction works and ultimately utilizes them. A client can be a government body, a public or private enterprises, or some private individual. It is the client who sponsors the works, finances their construction, and utilizes the facility constructed.
construction management consultants	The consultants are hired by the client for carrying out certain services on contract basis, often for the entire life of the project. The nature of tasks assigned to the consultants vary, but may include but are not limited to: feasibility and cost estimates, soil investigation, coordination of designs, tendering and awarding contracts to bidders, develop detailed construction plans and supervising works.
Architect and engineering associates	Architect and engineering associates are the firms employing the architects and engineers. An architect is an individual who designs the buildings, landscapes and other artistic features. The engineers associated with architects develop structural, electrical, mechanical and other specialist systems and designs.
Input suppliers	Input suppliers within the construction industry exist in the form of men, materials, machinery and money. The workforce connected with construction includes architects, engineers, managers, technical and non-technical staff, highly skilled operators, and skilled and unskilled manpower.
Construction contractors	Construction contractors form the backbone of the construction business as they execute most of the construction works. In the competitive construction business, which requires special resources for different types of construction work, the contractors generally tend to specialize in a particular area of construction.

Table 3 - Construction participants

Kerzner defines stakeholders as individuals and/or organizations that are involved in or may be affected by project activities. Internal stakeholders are those who are directly involved in a project (those who are listed in the table above), whereas others, i.e. neighbors, are referred to as external stakeholders (Kerzner, 2013). The figure below illustrates what stakeholders might be involved or affected by project activities (Project Management Institute, Inc., 2013).

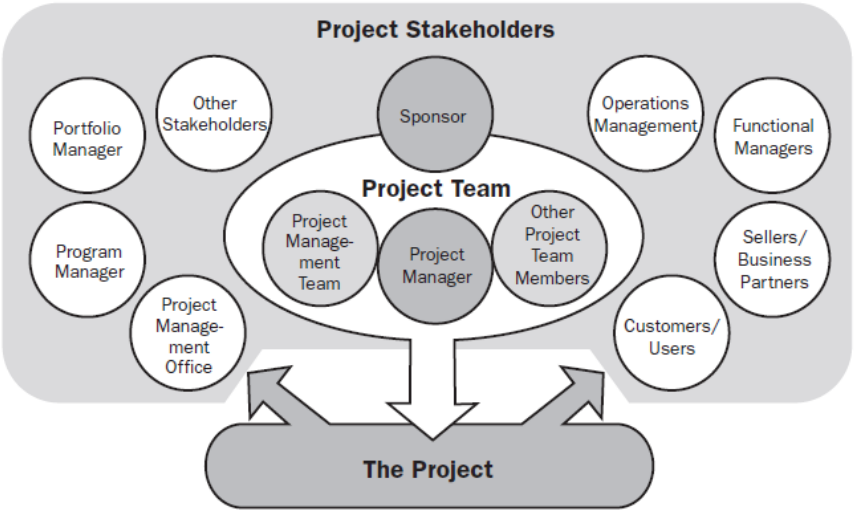


Figure 3 - Project stakeholders (Project Management Institute, Inc., 2013)

2.1.4.2 Production Processes in Design and Construction

Production processes can be conceived in the following three ways:

(1) Process of converting inputs to outputs.
(2) Flow of materials and information through time and space.
(3) Process for generating value for customers.

Ballard explains that these concepts are all appropriate and necessary. However, in the history of the AEC (architectural/engineering/construction) industry the conversion model has been dominant. In recent years some practitioners have with great success implemented projects by placing more emphasis on the flow and value generation. This is further addressed in sections 2.4 and 2.5. The table below shows a summary of all three views on design and construction based on Koskela's and Ballard's descriptions (Ballard, 2000b), (Anumba et al., 2006).

	Conversion View	Flow View	Value Generation
Nature of Design/ Construction	A series of activities which convert inputs to outputs.	The flows of information & resources, which release work: composed of conversion, inspection, moving and waiting	A value creating process which defines and meets customer requirements.
Main Principles	Hierarchical decomposition of activities; control and optimization by activity.	Decomposition at joints. Elimination of waste (unnecessary activities), time reduction.	Elimination of value loss - the gap between achieved and possible value.
Methods & Practices	Work breakdown structure, critical path method. Planning concerned with timing start and responsibility for activities through contracting or assigning.	Team approach, rapid reduction of uncertainty, shielding, balancing, decoupling. Planning concerned with timing, quality and release of work. Tool integration.	Development and testing of ends against means to determine requirements. Planning concerned with work structure, process and participation.
Practical Contribution	Taking care to do necessary things (what has to be done).	Taking care that the unnecessary is done as little as possible.	Taking care that customer requirements are met in the best possible manner.

Table 4 - Conversion, flow and value generation concepts of design and construction.

2.1.4.3 Design and Construction Processes

Koskela divides construction projects into two main processes, i.e. design process and construction process. Based on his description these processes are defined as follows (Koskela, 1992):

(1) The design process is a theatrically knowledgeable clarification of specifications where needs and wishes are transformed into requirements and later to detailed designs. Also, this is a process of detecting and solving problems.

(2) The construction process consists of two types of flows:

- The material process which consists of the flows of material to the site, including processing and assembling on site.
- The work processes of construction teams. Koskela explains that the temporal and spatial flows of construction teams on site are often closely associated with the material processes.

Koskela explains that the following three processes control or support the main processes of design and construction (Koskela, 1992):

- Project management process by the owner.
- Design management process by the design project manager.
- Construction management process by the project manager. In this process the detailed design is transformed into a construction plan. This means daily coordination and control of the processes on site.

The management process, which is the main focus area of this study, is illustrated in the figure below. This process applies to both design and construction management. It consists of the following sub processes: *initiating, planning, executing, monitoring and controlling* and *closing.*

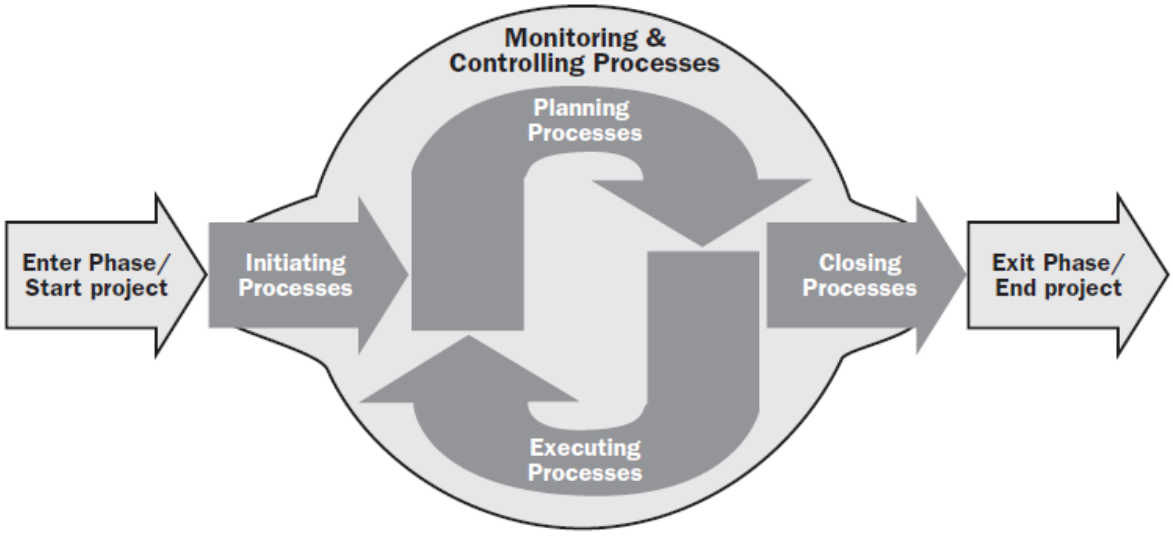


Figure 4 - The management processes (Project Management Institute, Inc., 2013)

In the projects that are examined in this study the design and construction phase overlap like the figure below illustrates:

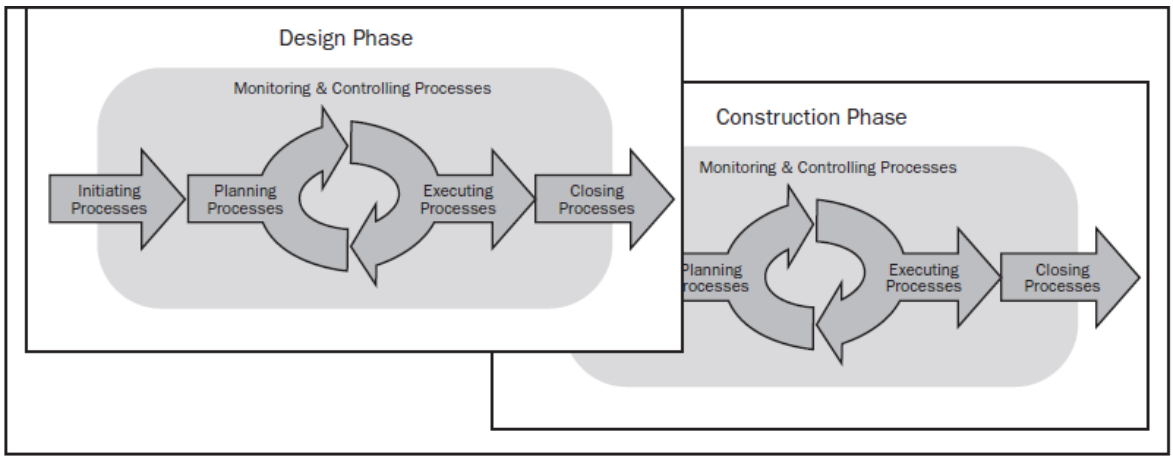


Figure 5 - Overlapping design and construction phases (Project Management Institute, Inc., 2013)

2.1.4.4 Fundamental Ides for Planning, Scheduling and Control

Since construction projects are in many ways similar to other enterprise projects many of the general principles of management also apply to construction management. To understand what principles are useful in managing construction projects one should look at basic general definition of management. Pierce Jr. defines management as: *"the process of planning, organizing, directing and controlling"*. The definition of these well-known concepts can be further extended by looking at the specific concepts contained within it. The ideas that are most important for the purposes of schedule and control construction projects are: *goals*, *process*, *planning* and *control*. These ideas are further explained in the following text, based on Pierce's definitions (Pierce Jr., 2013):

(1) First, one recognizes that *goals* are always involved. From a philosophical perspective one could state that without a set of goals, there is no point in even taking actions. From a construction company's perspective it is obvious that the company must have profit as an overall goal, and completing the work on time is essential part of meeting profit goals.

(2) Second, defining *process* as a set of continuing systematic actions over time. The management must be executed in a systematic way, continually throughout the life of the project. Management also means that rational decisions must be made in order to achieve the goals. The systematic method of management is namely set up to deliver accurate, timely information to the decision makers, so they can plan and control the project.

(3) Third, defining *planning* as deciding what tasks must be performed to accomplish the goals of the project. This means establishing realistic schedules and budgets, coordinating resources and making sure everyone knows what the plan of action is.

(4) Fourth, *controlling* is the final action in the management process. To achieve and maintain control, the project manager must monitor the progress of the project.

2.1.4.5 The Major Project Management Tasks

These fundamental ides form a basis for the management practices within construction projects. The following tasks, based on the concepts above, are defined by Pierce as *the three major project management tasks* (Pierce Jr., 2013):

(1) First, establishing and focusing on *goals* that will be general at first, then increasingly specific and job oriented as the work is planned. The project manager should set intermediate goals for the construction process, goals that meet the ultimate requirements of cost and time.

(2) Second, *establishing* an effective *management process* that will operate in a systematic way. The management system should be designed to address the following elements:

- **Time**: Establishing a plan of action to ensure the work is done in the correct order and within the time allowed.
- **Cost**: The work must be performed efficiently.
- **Resources:** Determine how much, when and where the required resources are needed (resources such as labor, equipment, or materials).
- **Finances:** Predicting the amount of funds needed to support all the work.

(3) Third, *using* this *systematic management process* to make the best possible decisions coordinating the work of the project and then continue planning and controlling the work throughout the project lifecycle. Feedback is a key to manage and control a construction projects, however, to do so the project manager must perform the following tasks (Pierce Jr., 2013):

- **Plan:** Establishing realistic and usable schedules and budgets.
- **Communicate:** The plans must be communicated clearly and effectively to the people who will be executing them.
- **Monitor and control:** Ensure that the project goals are met and take action if necessary.

2.2 Planning, Scheduling and Control

Mubarak explains that even though planning, scheduling, and project control are extremely important functions of construction management, it also includes components such as cost estimating and management, procurement, project and contract administration, quality management, and safety management (Mubarak, 2010). However, due to the limited scope of this research only planning, scheduling, and control will be addressed in this review.

2.2.1 Planning

To begin with it is appropriate to refer to one of Kerzner's sayings: *"Failing to plan is planning to fail".* In this section planning is defined.

2.2.1.1 What is Planning?

Project planning can be defined in many ways. Four definitions of planning are shown in Table 5 here below.

Reference	Definition of planning
(Pierce Jr., 2013)	*„Planning can be defined as deciding what tasks must be performed to accomplish the goals of the project. This means establishing realistic schedules and budgets, coordinating resources to get the work done, and most importantly, make sure everyone knows what the plan of action is".*
(Chitkara, 1998)	*„Planning involves deciding in advance what is to be done, how and in what order it is to be done in order to achieve the objectives. Planning aims at deciding upon the future course of action".*
(Mubarak, 2010)	*„The process of choosing the one method and order of work to be adopted for a project form the various ways and sequences in which it could be done".*
(Kerzner, 2013)	*„Planning, in general, can best be described as the function of selecting the enterprise objectives and establishing the policies, procedures, and programs necessary for achieving them. Planning in a project environment may be described as establishing a predetermined course of action within a forecasted environment. The project's requirements set the major milestones".*

Table 5 - Defining planning.

Kerzner explains that planning is determining what needs to be done, by whom, and when (Kerzner, 2013). Mubarak adds that planning also covers answering how, how much, why and where (Mubarak, 2010). Kerzner's nine major components of planning are:

- *Objective:* a goal, target, or quota to be achieved by a certain time.
- *Program:* the strategy to be followed and major actions to be taken in order to achieve or exceed objectives.
- *Schedule:* a plan showing when individual or group activities or accomplishments will be started and/or completed.
- *Budget:* planned expenditures required to achieve or exceed objectives.
- *Forecast:* a projection of what will happen by a certain time.
- *Organization:* design of the number and kinds of positions, along with corresponding duties and responsibilities, required to achieve or exceed objectives.
- *Policy:* a general guide for decision-making and individual actions.
- *Procedure:* a detailed method for carrying out a policy.
- *Standard:* a level of individual or group performance defined as adequate or acceptable.

The four basic reasons for project planning are to eliminate or reduce uncertainty, improve efficiency of the operation, obtain a better understanding of the objectives and to provide a basis for monitoring and controlling work (Kerzner, 2013)

2.2.1.2 The Planning Process Group

The PMBOK defines the Planning Process Group as *those processes performed to establish the total scope of the effort, define and refine the objectives, and develop the course of action required to attain those objectives* (Project Management Institute, Inc., 2013). The overall planning process is presented in the following figure.

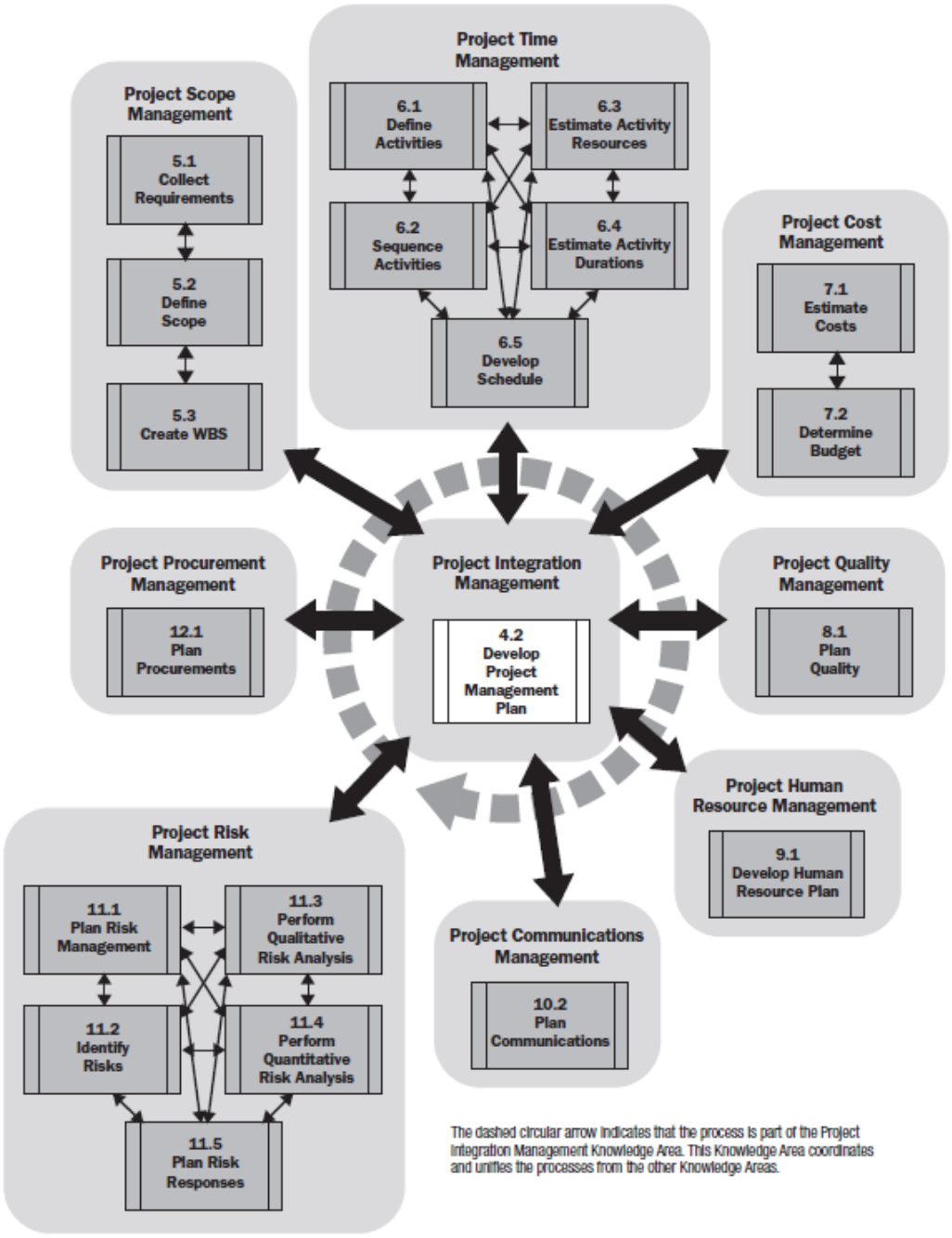


Figure 6 - Planning process group (Project Management Institute, Inc., 2013).

The main focus area for this study is the Project Time Management. The processes within Project Time Management seek to ensure the timely completion of the project. This includes defining activities, sequencing activities, estimating activity resources, estimating activity durations, developing the schedules and controlling the schedules. The most relevant processes for this study are

develop schedule and *control schedule*. These processes are defined as follows (Project Management Institute, Inc., 2013):

- *Develop Schedule* is the process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.
- *Control Schedule* is the process of monitoring the status of the project to update project progress and managing changes to the schedule baseline.

These processes are better explained in sections 2.2.2 and 2.2.3.

2.2.1.3 The Project Plan

A project plan is fundamental to the success of any project (Kerzner, 2013). It is a formal, approved document that defines how the project is executed, monitored and controlled, and closed (Project Management Institute, Inc., 2013). The main purpose of applying a project plan is to document planning assumptions and decisions, facilitate communication among stakeholders, and document approved scope, cost, and schedule baselines. (Frigenti and Comninos, 2002).The project plan serves as a guideline for the lifetime of the project and may be revised as often as needed. The project plan is a standard from which performance can be measured by the customer and the project team (Kerzner, 2013). All appropriate stakeholders should be involved when planning the project and developing the project management plan and other project documents (Project Management Institute, Inc., 2013).

2.2.1.4 Successful Planning

Project planning must be systematic, flexible to handle unique activities, disciplined through reviews and controls, and capable of accepting multifunctional inputs (Kerzner, 2013). Successful project management requires planning and commitment form executives throughout the project, not just at the start (Jugdev & Müller, 2005). The project manager is the key to successful project planning. It is desirable that he/she is involved from project conception through execution (Kerzner, 2013). Good communications are always the make-or-break in management (Office of Government Commerce, 2002)

No matter how hard one tries, planning is not perfect, and sometimes plans fail. Typical reasons include (Kerzner, 2013):

- Corporate goals are not understood at the lower organizational levels.
- Plans encompass too much in too little time.
- Financial estimates are poor.
- Plans are based on insufficient data.
- No attempt is being made to systematize the planning process.
- No one knows the ultimate objective.
- No one knows the staffing requirements.
- No one knows the major milestone dates.
- Project estimates are best guesses, and are not based on standards or history.
- Not enough time has been given for proper estimating.
- No one has bothered to see if there will be personnel available with the necessary skills.
- People are not working toward the same specifications.
- People are consistently shuffled in and out of the project with little regard for schedule.

In this context it is worth mentioning that the main reasons why projects are not completed on time and within cost are behavioral rather than quantitative problems. This may be due to poor morale, poor human relations, poor labor productivity and lack of commitment by those involved in the project (Kerzner, 2013).

2.2.1.5 Planning: Research Framework

This research will use the following objectives (criteria) as the standard by which planning success or failure will be judged. These objectives for planning are mainly based on Kerzner's and Pierce's descriptions (Kerzner, 2013), (Pierce Jr., 2013): The objectives for planning are to:

- Understand the goals: Knowing what needs to be done to accomplish the project goals.
- Reduce uncertainty: Establishing realistic schedules and budgets.
- Improve efficiency: Coordinating resources to get the work done.
- Provide basis for monitoring and control: Establishing baselines.

If the objectives above are met, planning will be viewed as sufficient.

2.2.2 Scheduling

In this section scheduling is defined.

2.2.2.1 What is Scheduling?

The two terms, planning and scheduling, are often thought of as synonymous. However, they are not. Scheduling is just one part of the planning effort. Mubarak explains that schedules are the result of asking "when" during planning (Mubarak, 2010). Scheduling is part of the Project Time Management process (Project Management Institute, Inc., 2013). The table below shows four different definitions of scheduling.

Reference	Definition of scheduling
(Popescu, 1995)	*"Scheduling is defined as the process of assigning the schedule start and finish calendar dates to all or a group of activities that belong to a project."*
(Project Management Institute, Inc., 2013)	*„…the process of analyzing schedule activity sequences, schedule activity durations, resource requirements, and schedule constraints to create the project schedule".*
(Mubarak, 2010)	*"Scheduling is the determination of the timing and sequence of operations in the project and their assembly to give the overall completion time."*
(McCarthy & McCarthy, 2010)	*"…the real time of the activities and the project is determined as the result of the resources assigned to activities".*

Table 6 - Defining scheduling.

The purpose of scheduling is to provide a ''roadmap'' that represents the delivery of the project scope over time as defined by the project team (Project Management Institute, Inc., 2013). Kerzner explains that a schedule is a plan showing when activities or accomplishments will be started and/or completed. The primary objective of scheduling is to coordinate activities to complete the project with the: best time, least cost and least risk (Kerzner, 2013).

2.2.2.2 Developing Schedules

This subsection describes the process of developing a schedule, based on a practice standard developed by The Project Management Institute. The first steps are selecting a *scheduling method* and a *scheduling tool*. The *schedule model* is formed as specific project data is inserted into the scheduling tool. The model is then used to generate (print) project schedules. These aspects are explained separately below:

The *scheduling methods* provide the framework which schedule models are developed. Example of scheduling method is the Critical Path Method (most commonly used method). The scheduling methods are further addressed in sections 2.4 and 2.5.

The *scheduling tool* provides the means of adjusting various parameters and components that are typical in a modeling process. The scheduling tool includes the capability to:

- Select the type of relationship, such as finish-to-start or finish-to-finish
- Add lags and leads between activities
- Apply resources
- Add constraints
- Capture a specific schedule as a baseline or target schedule
- Change various parameters within the schedule model such as imposing a different project completion date in an attempt to shorten the overall project duration to analyze the impact that these changes would have on the project schedule
- Compare the most recent schedule against the previous one or against a target or baseline to identify and quantify trends or variances.

By inserting specific project data, such as activities, durations, and resources into the scheduling tool the *schedule model* is created. The schedule model then produces project schedules, which contains the planned dates for completing project activities. In this way the schedule model provides a tool for analyzing alternatives. Once this model is developed, it should be updated on a regular basis to reflect progress and changes (Project Management Institute, 2007). This practice standard refers to the scheduling engine populated with project data as the schedule model. However, in general practice the printed schedule and the schedule model are both referred to as the schedule (Project Management Institute, Inc., 2013).

Figure 7 illustrates the interrelationships of the scheduling method, tool and model.

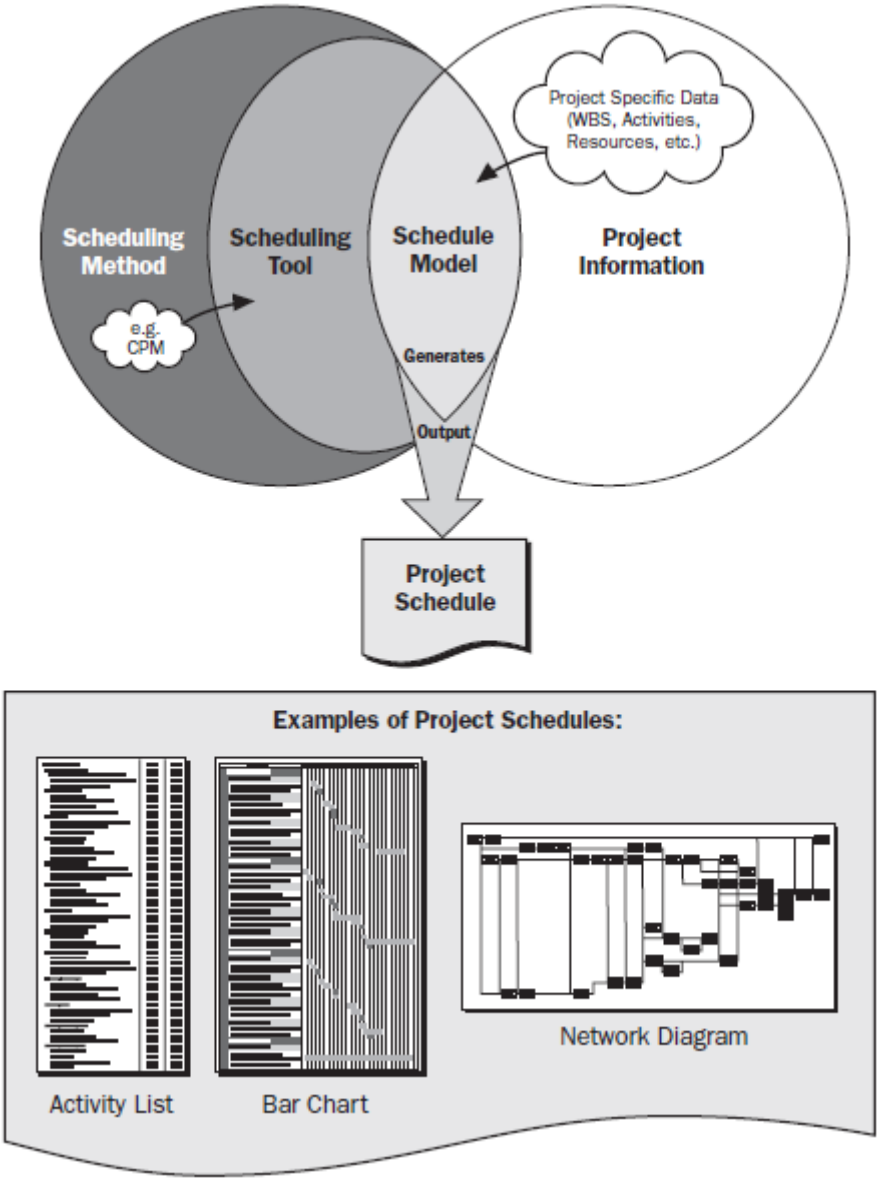


Figure 7 - Scheduling overview (Project Management Institute, Inc., 2013).

2.2.2.3 Types of Schedules

Like the figure above shows, there are different types and formats of schedules. Examples of schedule formats are *milestone charts*, *bar charts* and *project schedule network diagrams*. These formats are briefly described as follows (Project Management Institute, Inc., 2013):

- A *milestone chart* is similar to bar charts, but it only identifies the scheduled start or completion of major deliverables and key external interfaces.
- A *bar chart* represents activities by applying bars which show activity start and end dates, as well as expected durations. Bar charts are relatively easy to read, and are frequently used in management presentations.
- A *project schedule network diagram* with activity date information, usually show both the project network logic and the project's critical path schedule activities.

Examples of schedule types are baseline schedules, detailed schedules, master production schedules, lookahead schedules and weekly work plans. These schedule types are briefly explained as follows:

- A *baseline schedule* is a schedule usually prepared by the contractor before the start of the project and used for performance comparison (Mubarak, 2010).
- *Detailed schedules* are prepared for almost every activity. Each and every detailed schedule should fit into one master schedule to verify that all activities can be completed as planned.
- A *master production schedule* is a statement of what, how many and when the different units will be made. It is a production plan, not a sales plan (Kerzner, 2013).
- A *lookahead schedule* helps the project team to detect issues a few weeks ahead before it becomes a problem. The lookahead window (the period of time one chooses to look ahead) is typically 3 to 12 weeks, depending on project characteristics, the reliability of the planning system, and the lead times for acquiring information, materials, labor, and equipment (Ballard, 2000b).
- A *weekly work plan* is a detail level schedule to hand out assignments, which typically yields multiple assignments for each activity (Ballard, 2000b).

There are many other types of plans and schedules as well for budgets, logistics, transportation, procurement, and quality assurance to name a few. However, those plans will not be addressed here. For further information on the matter see Kerzner's book: *Project Management: A Systems Approach to Planning, Scheduling, and Controlling.*

2.2.2.4 The Tripod of Good Scheduling

Mubarak's *tripod of good scheduling system* describes three important factors to consider when scheduling. He states that if anyone of the three "legs" is missing, the system will fail. The *tripod of good scheduling system* is defined as follows (Mubarak, 2010):

> (1) *The Human Factor:* A proficient scheduler or scheduling team that understands the concepts, definitions, and applications or project scheduling
> (2) *The Technology:* A good scheduling computer system (software and hardware) along with capable IT support
> (3) *The Management:* A dynamic, responsive, and supportive management that believes in the use of scheduling as part of the management effort

Kerzner explains that every scheduling technique has its advantages and disadvantages. However, there are some scheduling problems that can impact all scheduling techniques. These include (Kerzner, 2013):

- Using unrealistic estimates for effort and duration
- Inability to handle employee workload imbalances
- Having to share critical resources across several projects
- Overcommitted resources
- Continuous readjustments to the WBS primarily from scope changes
- Unforeseen bottlenecks

The Project Management Institute explains that developing an acceptable schedule is often an iterative process. This development often requires the planners to review and revise their duration estimates and resource estimates to create an acceptable schedule. In fact, to maintain realistic schedules it is necessary to review and revise them throughout the project (Project Management Institute, Inc., 2013).

There are five techniques commonly used for scheduling compression. These are *overtime*, *additional resources*, *reducing scope*, *outsourcing* and *doing series work in parallel*. However, Kerzner explains that each of these compression techniques have significant limitations that perhaps makes them more of a myth than reality. This is explained in the table below, based on Kerzner's description (Kerzner, 2013).

Compression Technique	Myth	Reality
Use of overtime	Work will progress at the same rate on overtime.	The rate of progress is less on overtime: more mistakes may occur; and prolonged overtime may lead to burnout.
Adding more resources	The performance rate will increase due to the added resources.	It takes time to find the resources; it takes time to get them up to speed' the resources used for the training must come from the existing resources.
Reducing scope	The customer always requests more work than actually needed.	The customer needs all of the tasks agreed to in the statement of work.
Outsourcing	Numerous qualified suppliers exist.	The quality of the suppliers' work can damage your reputation: the supplier may go out of business: and the supplier may have limited concern for your scheduled dates.
Doing series work in parallel	An activity can start before the previous activity has finished.	The risks increase and rework becomes expensive because it may involve multiple activities.

Table 7 - Scheduling compression.

2.2.2.5 Scheduling: Research Framework

This research will use the following objectives (criteria) as the standard by which scheduling success or failure will be judged. These objectives for scheduling are mainly based on Kerzner's descriptions (Kerzner, 2013):

- Applying realistic estimates: complete on time, within cost, and with minimum risk.

If the objectives above are met, scheduling will be viewed as successful.

2.2.3 Control

In this section control is defined.

2.2.3.1 What is Control?

Planning and controlling are closely related. In fact, some practitioners state that these functions cannot be separated. Without objectives and plans, control is not possible because performance has to be measured against some established criteria (Koontz, 2010). In Table 8 here below four different definitions of control (and/or controlling) are presented.

Reference	Definition of control
(Project Management Institute, Inc., 2013)	*"Control is comparing actual performance with planned performance, analyzing variances, assessing trends to effect process improvements, evaluating possible alternatives, and recommending appropriate corrective action as needed".*
(Koontz, 2010)	*"…controlling is the measurement and correction of performance in order to make sure that enterprise objectives and the plans devised to attain them are being accomplished".*
(Kerzner, 2013)	*"Controlling is a three-step process of **measuring** progress toward an objective, **evaluating** what remains to be done, and taking the necessary **corrective** action to achieve or exceed the objectives".*
(Pierce Jr., 2013)	*"Controlling is the final action in the management process. To achieve and maintain control, the project manager must monitor the progress of the job. When short-term goals are not being met, the project manager must take action to get everything back on track".*

Table 8 - Definition of control.

In the table above Kerner explains that controlling is a three step process of measuring, evaluating, and correcting. He defines these key processes for control as follows (Kerzner, 2013):

- *Measuring:* determining through formal and informal reports the degree to which progress toward objectives is being made.
- *Evaluating:* determining cause of and possible ways to act on significant deviations from planned performance.
- *Correcting:* taking control action to correct an unfavorable trend or to take advantage of an unusually favorable trend.

Monitoring and controlling includes controlling changes and recommending preventive action in anticipation of possible problems, monitoring the ongoing project activities against the project management plan and the project performance baseline, and influencing the factors that could circumvent integrated change control so only approved changes are implemented (Project Management Institute, Inc., 2013).

2.2.3.2 The Monitoring and Controlling Process Group

Monitoring and controlling consists of those processes required to track, review, and regulate the progress and performance of the project, as well as identifying and making the required changes. As previously noted, the project time management is the main focus area of this research. In this context it is monitoring and controlling the schedules. Controlling the schedules is done by monitoring the status of the project to update the project progress and manage changes to the schedule baseline. Schedule control is therefore concerned with (Project Management Institute, Inc., 2013):

- Determining the current status of the project schedule,
- Influencing the factors that create schedule changes,
- Determining that the project schedule has changed, and
- Managing the actual changes as they occur.

The overall monitoring and controlling processes are presented in figure 8 here below.

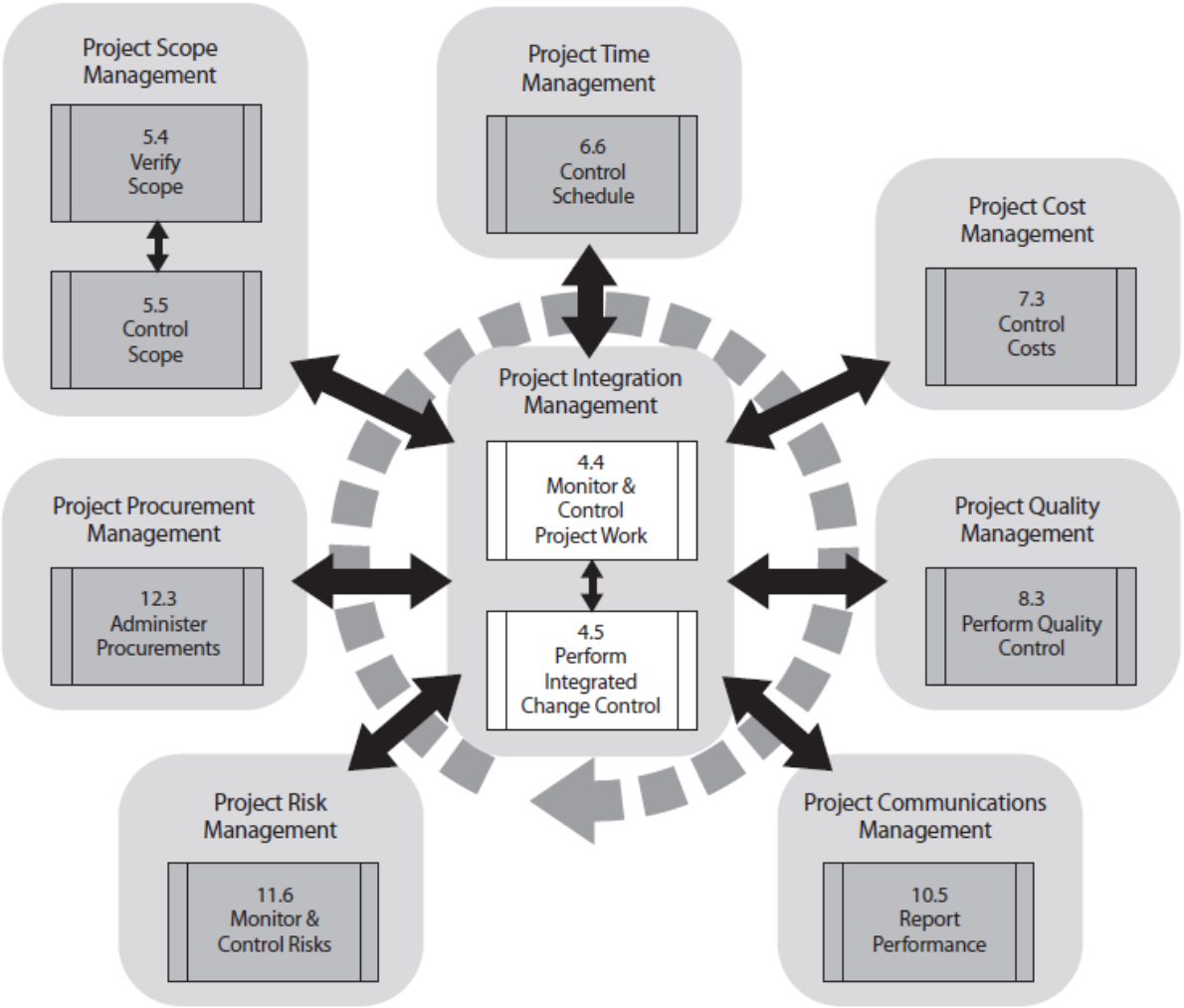


Figure 8 - Monitoring & Controlling Process Group (Project Management Institute, Inc., 2013).

2.2.3.3 Adequate Control

This section describes what components are necessary to maintain an adequate control when scheduling. The control schedule process can be broken down into three components, namely *inputs*, *tools and techniques* and *outputs*. Figure 9 shows the different aspects included in each of these components. These inputs, tools and techniques and outputs are briefly addressed below, based on The Project Management Institute's descriptions (Project Management Institute, Inc., 2013).

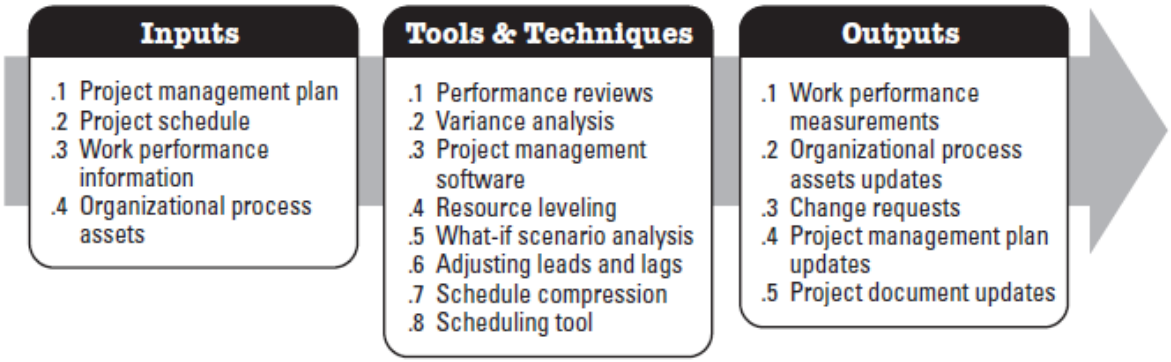


Figure 9 - Control Schedule Overview (Project Management Institute, Inc., 2013).

The ***inputs*** are (Project Management Institute, Inc., 2013):

- The *project management plan* provides the baseline for comparison with actual results (*The most resent schedules* and *work performance information*) to determine if a change, corrective action, or preventive action is necessary.
- The *organizational process assets* that influence the control schedule process include control-related policies, procedures, and guidelines as well as the schedule control tools and the monitoring and reporting methods to be used.

The ***tools and techniques*** are (Project Management Institute, Inc., 2013):

- *Performance reviews* measure, compare, and analyze schedule performance such as actual start and finish dates, percent complete, and remaining duration for work in progress.
- *Variance analyses* are used to assess the magnitude of variation to the original schedule baseline.
- *Project management software* for scheduling provides the ability to track planned dates versus actual dates, and to forecast the effects of changes to the project schedule.
- *Resource leveling* is used to optimize the distribution of work among resources.
- *What-if scenario analysis* is used to review various scenarios to bring the schedule into alignment with the plan.
- *Adjusting leads and lags* and *schedule compression* techniques is used to find ways to bring project activities that are behind into alignment with plan.
- The *scheduling tool* and the supporting schedule data are used in conjunction with manual methods or other project management software to perform schedule network analysis to generate an updated project schedule.

The ***outputs*** are (Project Management Institute, Inc., 2013):

- *Work performance measurements* are documented and communicated to stakeholders.
- *Organizational process assets* that may be updated include causes of variances, corrective action chosen and the reasons, and other types of lessons learned from project schedule control.
- *Change requests* may include recommended changes to reduce the probability of negative schedule variances.
- *Project management plan updates* may include changes to the schedule baseline, changes to the way the schedule is managed and the cost baseline may be updated to reflect changes caused by compression or crashing techniques.
- *Project documents* that may be updated include the scheduling data and the project schedules. An updated project schedule will be generated from the updated schedule data to reflect the schedule changes and manage the project.

2.2.3.4 Control: Research Framework

This research will use the following objectives (criteria) as the standard by which control will be judged as success or failure. These objectives are mainly based on Kerzner's and The Project Management Institute's descriptions (Kerzner, 2013), (Project Management Institute, Inc., 2013). The objectives for control are to:

- Determine the current status of the project schedules (Measuring).
- Determine cause of and ways to act on deviations form the plan (Evaluating).
- Manage the actual changes as they occur (Correcting).

If the objectives above are met, control will be viewed as successful.

2.3 Critical Success Factors

This section discusses the critical success factors (CSFs). First, some key terms are explained and then some examples are presented to illustrate how professionals have defined and applied CSFs to project and construction management.

2.3.1 Defining Success

It has often proved difficult to define words such as *success*, because it means different things to different people and is very context-dependent. Trying to pin down what success means in the project context is like asking a group of people to define "good art" (Jugdev & Müller, 2005).

The following table shows how several English dictionaries define success.

Dictionary	Definition of success
Collins (Sinclair, 2001)	*The favorable outcome of something attempted.*
Macmillan (Rundell, 2005)	*The achievement of something that you planned to do or attempt to do.*
Oxford (Stevenson, 2010)	*The accomplishment of an aim or purpose.*
Oxford Advanced (Hornby, 2011)	*The fact that you have achieved something that you want and have been trying to do or get.*
Cambridge Advanced (Walter, 2008)	*The achieving of the results wanted or hoped for. Something that achieves positive results.*

Table 9 - Definition of success.

Success can also be defined as the attainment of wealth, fame, etc., (Sinclair, 2001) but since that does not apply to the main topic of the research it will not be addressed any further.

The different views of project success will be discussed in the next sections.

2.3.2 The Evolving Understanding of Project Success

In the 1960s-1980s project success was thought of as the achievement of predetermined project goals, which commonly included parameters such as time, cost and performance. (Lim & Mohamed, 1999), (Kerzner, 2013), (Jugdev & Müller, 2005). In the 1980s-1990s the literature focused on the importance of stakeholder satisfaction. In this period a number of useful CSFs were identified, but they were not grouped or integrated. In the 1990s-2000s integrated frameworks for project success emerged (Jugdev & Müller, 2005), i.e. implementation success, perceived values and client satisfaction (Munns & Bjeirmi, 1996). Researchers understood that project success was stakeholder-dependent. Today in the 21st Century investigators understand that project success is a complex and ambiguous concept. Projects are about managing expectations, and expectations have to do with perceptions on success. To ensure project success researcher emphasize the importance of involving key stakeholders throughout the project. Successful project management requires planning and commitment to complete the project (Jugdev & Müller, 2005).

2.3.3 Success Perspectives

Success can be viewed from several perspectives. In this section some of these perspectives are addressed.

2.3.3.1 Macro and Micro View

Lim & Mohamed classify project success into two categories: the *macro* and *micro* viewpoints. To describe the difference between these viewpoints they use the forest and the trees analogy: *Are we looking at the forest? Or are we looking at the trees?*

The *macro* viewpoint is like looking at the forest, focusing on the big picture. It involves the longer-range perspective in determining whether or not the original project concept is achieved. This is referred to as *project success* (or failure), depending on user satisfaction.

The *micro* viewpoint deals with smaller component levels of project achievements. It looks at the trees, not the forest. The *micro* viewpoint involves assessing *project management success*, often based on completion of a project phase or similar objectives (Lim & Mohamed, 1999).

2.3.3.2 Operational, Tactical and Strategic

Samset on the other hand explains that success can be viewed form three different perspectives; *operational* (the project outputs), *tactical* (the project goal) and *strategic* (the project purpose). These perspectives based on Samset's descriptions are explained further below.

The *operational* view is measured according to whether the project was completed on time, within costs and to the expected quality. Samset states that these are the most commonly applied measures of success, as well as the most limited perspective which only gives an indication of the delivery of the project itself.

The *tactical* perspective gives a broader interpretation of the concept and focus on the extent to which the project has achieved its formal goal. This concerns whether the impact of the project is predominantly positive and whether the project is relevant in relation to people's (e.g. user) needs.

The *strategic* perspective is the broadest interpretation of project success. This perspective can for example be based on measures of whether the project contributes to economic growth or positive changes in society. It focuses on whether its positive effects are sustainable in the long term.

Samset's three success perspectives are illustrated in figure 10.

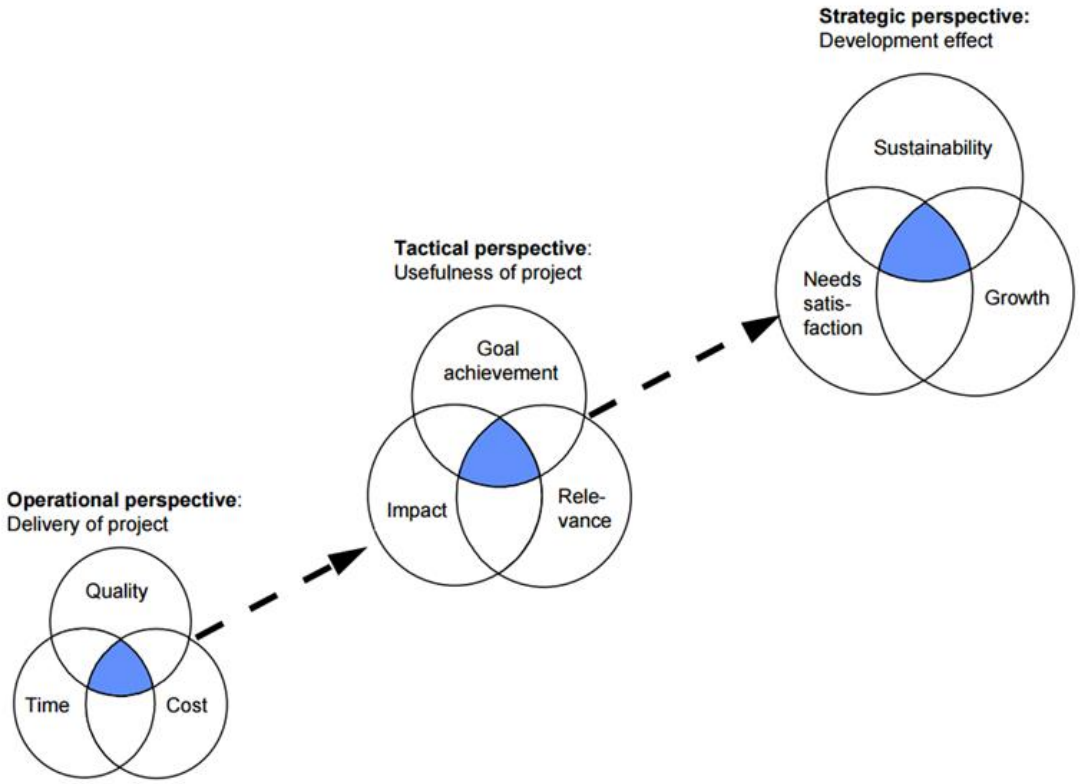


Figure 10 - Operational, tactical and strategic success perspective (Samset, 1998)

In the following subsections project success and project management success are presented separately before addressing how they are linked together.

2.3.3.3 Project Success

As previously stated, historically, project success has been defined as the completion of an activity within the constraints of time, cost and performance. Kerzner explains that today, the definition of project success has been modified to include completion with acceptance by the customer and/or user, within the allocated time period, within the budgeted cost, at the proper performance or specification level, with minimum or mutually agreed upon scope changes and the list goes on (Kerzner, 2013).

De Wit indicates that project success involves broader objectives from the viewpoints of stakeholders throughout the project lifecycle (de Wit, 1988). Similarly, Cooke-Davies defines project success, being measured against the overall objectives of the project (Cooke-Davies, 2002). In this context it must be pointed out that the definition of success can vary according to who the stakeholder is. For example, each of the following can have their own definition of success on a project (Kerzner, 2013):

- Consumers: safety in its use
- Employees: guaranteed employment
- Management: bonuses
- Stockholders: profitability
- Government agencies: compliance with federal regulations

Bowen states that in regard to construction projects, the clients of the construction industry are primarily concerned with quality, time and cost (Bowen, Cattel, Hall, Edwards, & Pearl, 2012)

2.3.3.4 Project Management Success

Success in project management includes getting the job done within the constraints of time, cost and quality, while utilizing the assigned resources effectively and efficiently (Kerzner, 2013)**,** (de Wit, 1988)**,** (Cooke-Davies, 2002). Successful project management can therefore be defined as having achieved the project objectives within these constraints. Recently, project management success has also been defined as meeting the customer's expectations.

Kerzner explains that successful project management, regardless of the organizational structure, is only as good as the individuals and leaders who are managing the key functions (Kerzner, 2013). Similarly Cooke-Davies states that when it comes to project management, it's the people that count (Cooke-Davies, 2002).

2.3.3.5 Project vs. Project Management Success

Munns and Bjeirmi note that project success and project management success are often intertwined (Munns & Bjeirmi, 1996)**.**

One can argue that good project management can contribute towards project success. However, one can also state that good project management is unlikely to be able to prevent project failure (de Wit, 1988). Jugdev and Müller further address this distinction, by using an often heard saying: *"The operation was a success, but the patient died"*. Like the saying above indicates, there are examples of projects that are managed well from a project management perspective, yet are perceived to be unsuccessful. This can also be the other way around. Projects can be poorly managed from a project management perspective, yet be viewed as successful. A textbook example of this is the Sydney Opera House. It took over 15 years to build and was 14 times over budget, yet it is proudly displayed as an engineering masterpiece. This example was a failure in terms of project management success, but it was a success in terms of project success. (Jugdev & Müller, 2005).

Kerzner states that it is unrealistic to believe that all projects will be completed successfully. Having said that, one could state that the only true project failures are the ones from which nothing is learned. Failure can be viewed as success if the failure is identified early enough so that the resources can be reassigned to other more opportunistic activities.

To help project managers and other stakeholders to implement a successful project so called success factors can be used (Kerzner, 2013). These factors are further explained in the following section.

2.3.4 Criteria and Factors that Determine and Influence Project Success or Failure

Lim and Mohamed explain that the terms *criteria* and *factors* have been viewed as synonyms by some project management literature (Lim & Mohamed, 1999). This needs clarifications.

2.3.4.1 Criteria

Criteria are the sets of principles or standards by which success can be judged. In other words, the conditions on which judgment can be made. Lim and Mohamed explain that there are two sets of conditions for determining project success:

- The set of *completion criteria*.
- The set of *satisfaction criteria*.

To determine project success from the macro viewpoint both sets of completion criteria and satisfaction criteria are sufficient. To determine project success form the micro viewpoint the set of completion criteria alone is sufficient (Lim & Mohamed, 1999).

Samset explains that in the planning framework most commonly used in planning and evaluation of projects, the success measure is based on five criteria: efficiency, effectiveness, impact, relevance and sustainability. These five criteria cover all of Samset's success perspectives (explained in section *2.3.3)* as follows (Samset, 1998):

Operational perspective:

(1) Efficiency: The delivery of the project in regard to time, cost and quality.

Tactical perspective:

(2) Effectiveness: The extent to which the project goal has been achieved.
(3) Impact: The sum of positive and negative, planned and unforeseen changes and effects of the project in society.
(4) Relevance: The degree to which the project respond to real needs and priorities in society.

Strategic perspective:

(5) Sustainability: The extent to which the positive effects of the project will continue in the future.

2.3.4.2 Factors

Factors are the sets of circumstances, facts, or influences which contribute to the project outcomes. These are the influential forces which either facilitate or impede project success. The factors contribute to the success or failure of a project, but do not form the basis of the judgment. By placing the word critical in front of the word factor one is emphasizing its importance; critical factors are therefore *extremely* important factors (Lim & Mohamed, 1999).

2.3.4.3 Linking Criteria and Factors to Project Success

The figure below is a pictorial representation given by Lim and Mohamed of the criteria and factors as applied to project success. As previously explained, the criteria are the sets of principles or standards by which judgment is made, whereas factors are the set of circumstances, facts or influences which contribute to the result (Lim & Mohamed, 1999).

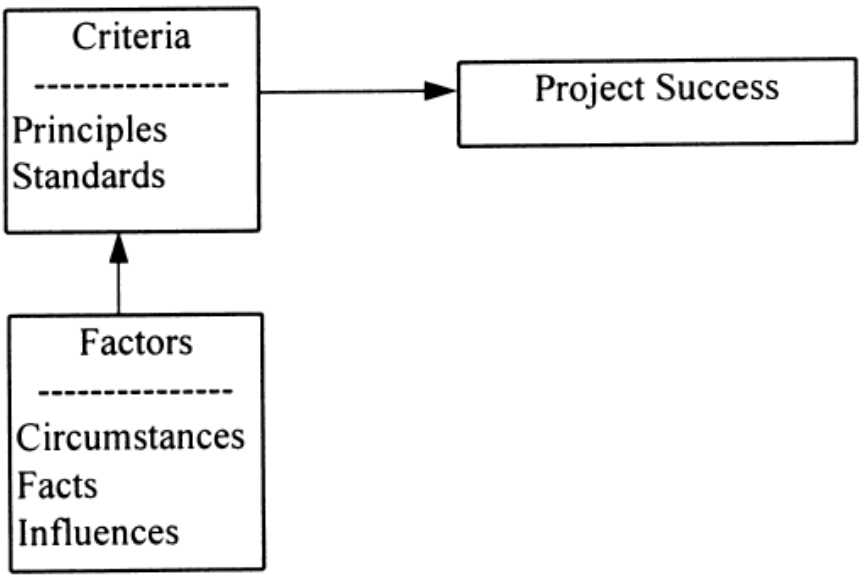


Figure 11 - Factors, criteria and project success (Lim & Mohamed, 1999).

2.3.5 Defining CSFs

Success factors first came to the surface within the field of project management in the 1960s when studies with the aim of identifying the best practice of project management where carried out. These studies were financed by governments to investigate the poor success of publicly funded projects (Morris et al., 2010). Since then, extensive research has been done where researchers have been trying to discover which factors lead to project success (Cooke-Davies, 2002).

By reading through the literature on critical success factors one clearly sees the impact Rockart has had on the subject, judging by how many authors (Boynton, Zmud and Kerzner, to name a few) refer to him when defining these factors.

Rockart describes that *"critical success factors thus are, for any business, the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization. They are the few key areas where "things must go right" for the business to flourish. If results in these areas are not adequate, the organization's efforts for the period will be less than desired"* (Rockart, 1979).

He further explains that as a result, the critical success factors are areas of activity that should receive constant and careful attention from management. He also states that the current status of performance in each area should be continually measured, and that information should be made available.

Kerzner summaries Rockart's definition in the following way: *„Critical success factors are those elements which must exist within the organization in order to create an environment where projects may be managed with excellence on a consistent basis"* (Kerzner, 1998). Similarly Koskela explains that the CSFs for construction projects are factors that are important for achieving outstanding project results (Koskela, 1992). Kerzner explains that the purpose of the critical success factors is to identify what is necessary to meet the desired deliverables of the customer (Kerzner, 1998).

According to Kerzner, the concept of critical success factors may be applied to any area such as the project itself, to project management, to the project's organization and environment, and to senior management (Kerzner, 1998).

2.3.6 CSFs in Project and Construction Management

A review of the literature showed that the topic has been studied extensively, particularly in the eighties. Some of the major works in regard to CSFs in the field of project and construction management are presented here below.

In previous section Kerzner's definition of project success and project management success was briefly addressed, as well as his definition of CSFs. Here below are his six critical success factors for successful projects (Kerzner, 1998):

(1) Corporate understanding of project management,
(2) Executive commitment to project management,
(3) Organizational adaptability,
(4) Project manager selection criteria,
(5) Project manager's leadership style, and
(6) Commitment to planning and control

Pinto is widely known for his list of the 10 critical success factors. Briefly, the 10 CSFs are defined as follows (Pinto, & Slevin, 1988):

(1) *Project mission* - Initial clarity of goals and general directions.
(2) *Top management support* - Willingness of top management to provide the necessary resources and authority/power for project success.
(3) *Project schedule/plans* - A detailed specification of the individual action steps required for project implementation.
(4) *Client consultation* - Communication, consultation, and active listening to all impacted parties.
(5) *Personnel* - Recruitment, selection, and training of the necessary personnel for the project team.
(6) *Technical tasks* - Availability of the required technology and expertise to accomplish the specific technical action steps.
(7) *Client acceptance* - The act of "selling" the final project to its ultimate intended users.
(8) *Monitoring and feedback* - Timely provision of comprehensive control information at each phase in the implementation process
(9) *Communication* - The provision of an appropriate network and necessary data to all key factors in the project implementation.
(10) *Troubleshooting* - Ability to handle unexpected crises and deviations from plan.

The figure below illustrates how the CSFs spread through the project lifecycle phases. The factors are placed in order of importance within each phase.

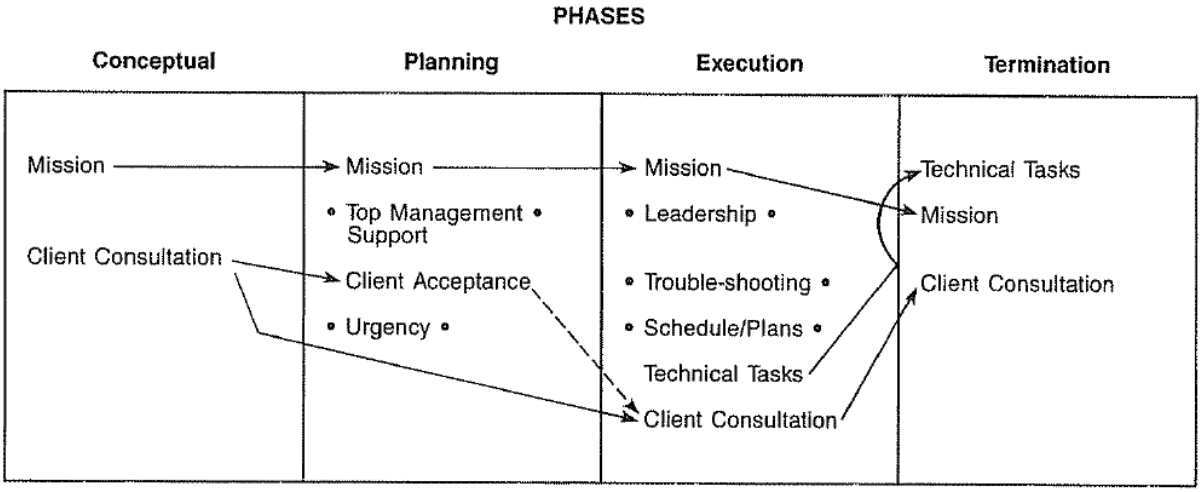


Figure 12 - Critical factors at each project phase (Pinto, & Slevin, 1988)

In Pinto's article *Planning and Tactical Factors in the Project Implementation Process* he groups the CSFs into planning and tactical categories. Of the 10 CSFs, project mission, top management support, schedule/plans, and client consultation were placed in the planning category and the rest under tactical. As a result of that study he explains that CSFs are not of equal importance throughout the lifecycle stages of conceptualization, planning, execution and termination. In fact, only one factor is of great important in all four phases, namely the project mission (Pinto & Prescott, 1990).

A literature study published in the Journal of Construction Engineering and Management by ASCE suggests that the critical success factors for construction management can be grouped under five main categories. These groups are: *human-related factors*, *project-related factors*, *project procedures*, *project management actions*, and *external environment*. The following figure illustrates how these categories and their factors can lead to project success (Chan, Scott, & Chan, 2004).

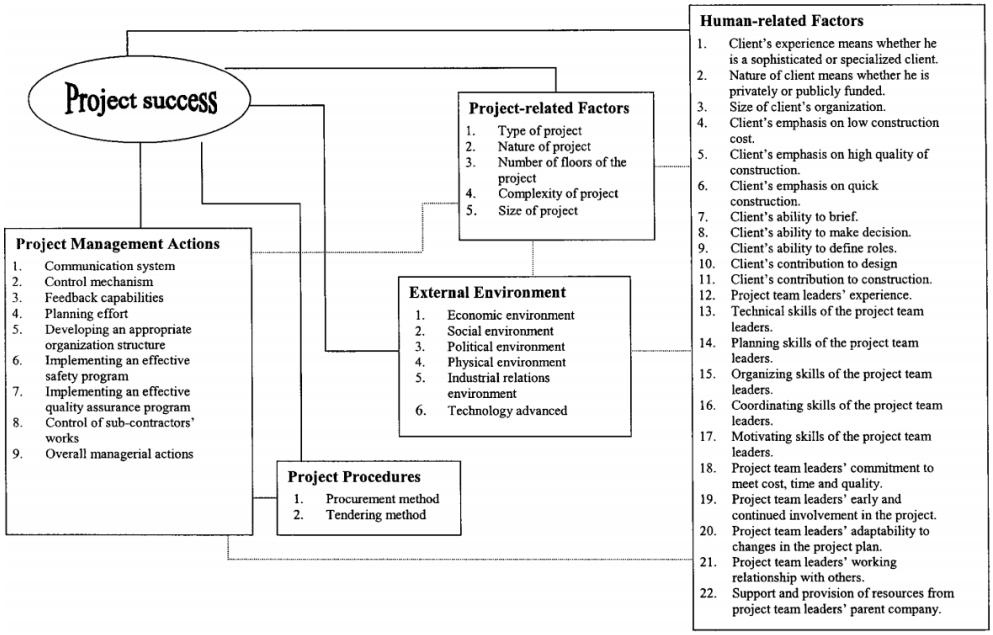


Figure 13 - CSFs for construction management (Chan et al., 2004)

The following represents Jugdev's and Müller's four conditions that are necessary for project success (Jugdev & Müller, 2005):

> (1) Success criteria should be agreed on with the stakeholders before the start of the project, and repeatedly at configuration review points throughout the project.
> (2) A collaborative working relationship should be maintained between the project owner (or sponsor) and project manager, with both viewing the project as a partnership.
> (3) The project manager should be empowered with flexibility to deal with unforeseen circumstances as they see best, and with the owner giving guidance as to how they think the project should be best achieved
> (4) The owner should take an interest in the performance of the project.

2.3.7 CSFs: Research Framework

This research will use the following framework to define and analyze the critical success factors for planning, scheduling and control. The framework is based on Lim's, Mohamed's and Samset's description (Lim & Mohamed, 1999), (Samset, 1998), and includes:

- **Success perspectives:** Operational, tactical and strategic
- **Success criteria (objectives):** The set of principles or standards by which success is or can be judged.
- **Success factors:** The set of circumstances, facts, or influences which contribute to the project outcomes.
- **Critical success factors**: Extremely important factors for project and/or project management success.

2.4 Traditional Construction Management Methods

In this section the traditional approach to construction management is presented. First, the underlying philosophy is addressed, and then some of the main characteristics of traditional construction management are explained.

2.4.1 Traditional Production Philosophy

The traditional understanding of production is to view it as a conversion process. The traditional production philosophy is described below.

A production process is a conversion of an input to an output. The conversion process can be divided into sub-processes, which also are conversion processes. The cost of the total process can be minimized by minimizing the cost of each sub-process. The value of the output of a process is associated with costs (or value) of inputs to that process (Koskela, 1992).

Figure 14 here below illustrates the traditional view of a production process as a conversion process (Koskela, 1992):

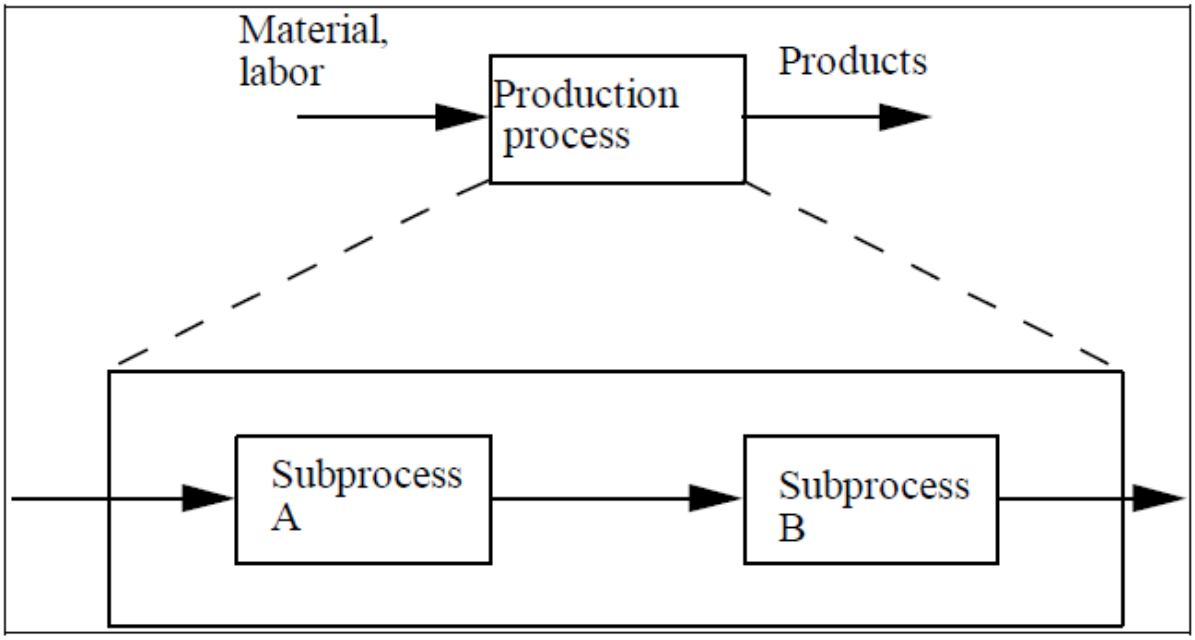


Figure 14 - The traditional understanding of production (Koskela, 1992)

This model is ideal for measuring productivity, for example the ratio of output to the input in a given time period. Koskela notes that value is not of great importance in this production philosophy. He further explains that the value of the output can only be raised by using better material and more skilled specialists, the costs of which are higher.

This view of production also applies to how traditional management and organization is practiced, in fact several disciplines have used this idea as basis for understanding production (Koskela, 1992).

2.4.2 Traditional Construction Management Planning Methods

2.4.2.1 The Development of the Methods

The construction culture and many of its methods have their roots in periods before explicit scientific analysis. However, various developments occurred after the Second World War, leading to strategic initiatives like industrialization, computer integrated construction, and total quality management. This also lead to improvements in operational and tactical techniques such as project planning and control tools, organizational methods, project success factors, and productivity improvement methods (Koskela, 1992).

2.4.2.2 Traditional Planning Methods and Tools

After the technological developments after the Second World War project management has been epitomized by tools such as Performance Evaluation and Review Technique (PERT) and Critical Path Method (CPM), Work Breakdown Structures (WBS), and Earned Value Method (EVM) (Morris, Pinto, & Söderlund, 2011). These methods are briefly explained below.

PERT is a network planning technique that applies critical path analysis to reveal interdependencies and problems that are not obvious with other planning methods. In that way, PERT determines where the greatest effort should be made to keep a project on schedule (Kerzner, 2013).

The CPM calculates the theoretical early start and finish dates, and late start and finish dates, for all activities without regard for any resource limitations. This is done by performing a forward and backward pass analysis through the schedule network. The resulting early and late start and finish dates indicate the time periods within which the activity could be scheduled, given activity durations, logical relationships, leads, lags, and other known constraints (Project Management Institute, Inc., 2013).

The WBS breaks the work down into smaller elements. It is a product-oriented family tree subdivision of the hardware, services, and data required to produce the end product. It is structured in accordance with the way the work will be performed and reflects the way in which project costs and data will be summarized and eventually reported. When preparing the WBS one also considers other areas that require structured data, such as scheduling, configuration management, contract funding, and technical performance parameters (Kerzner, 2013).

The EVM is a method of performance measurement. It integrates project scope, cost, and schedule measures to help the managers assess and measure project performance and progress. It requires the formation of an integrated baseline against which performance can be measured for the duration of the project. EVM develops and monitors three key dimensions for each work package and control account, namely: Planned Value, Earned Value and Actual Cost (Project Management Institute, Inc., 2013).

These tools and techniques were developed by and for practitioners who needed them to improve the efficiency of project implementation (Morris et al., 2011). These so called traditional tools and techniques are widely recognized in the field of construction management and are applied to manage construction projects up to professional standards (Pierce Jr., 2013).

2.4.2.3 Construction as an Activity

Koskela notes that the most general understanding of construction is to view it as a set of activities aimed at a certain output, namely conversions. He further explains that this activity view of construction is shared both by the old traditions of construction and the newer methods, construction management is an activity-oriented mind set. The traditional method of cost estimation is a good example of this activity view. First, the building is divided into elements, and for each element, the costs of needed materials and labor are estimated. Second, contracts (output), which specify a part of the building, and compensations (input) are established. Koskela explains that this is exactly how the conversion model works; the total production process consists of a set of sub-processes which convert an input to an output, which can be realized and analyzed in isolation from each other. Similarly, in network based project planning the activities needed for producing the various elements of the building are the basic unit of analysis (Koskela, 1992).

2.4.2.4 The Traditional Construction Planning Process

Ballard explains that pulling is a method of introducing materials or information into a production process. The alternative method is to push inputs into a process based on target delivery or completion dates. In traditional construction management the schedules are push mechanisms, seeking to cause intersections in the future of interdependent actions (Ballard, 2000b). This Traditional (push) Planning System is illustrated in figure 15. Ballard and Howell explain that the construction industry devotes tremendous energy and resources to planning projects and developing the schedules, budgets and other requirements that collectively tell project personnel what they *should* do. Thereafter the personnel monitor and enforces conformance of what they *did* to what they *should do*. Planning at the beginning of the project is replaced by control during project execution. In this traditional management practice, if one actor fails to deliver on time it causes a chain reaction, which quickly leads to delays and late deliveries from other actors as well. Ballard and Howell describe as slack disappears from the schedule, more and more pressure is put on the personnel to produce more and faster, which usually makes things even worse. They explain that in this traditional approach to planning the project management team is usually responsible for finding the methods of meeting the control budgets and schedule rather than justifications for not meeting them. That indicates that there are no legitimate reasons for failing, which results in failure to identify where the planned work failed as well as failure to learn and improve the methods. One could describe this approach to project control as steering a car by only looking in the rear mirror, it is a *after the fact reaction*. As a result, this approach too often fails to fit the "we *should* do" to what "we really *did* do" (Alarcón, 1997).

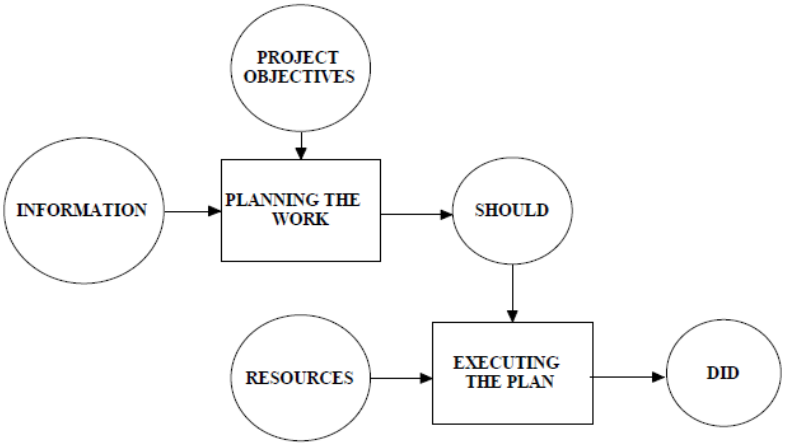


Figure 15 - A Traditional (push) Planning System (Ballard, 2000b).

The traditional approaches have had some major shortcomings regarding project delivery showing in extensive delays in the planned schedules, cost overruns, serious problems in quality, and an increase in the number of claims and litigation associated with construction projects (Bowen et al., 2012). Some practitioners believe that the traditional methods remain underused because of how poorly they are understood and that they may seem more complicated than they really are (Pierce Jr., 2013). Other practitioners such as Laufer, Tucker and Koskela suggest an overall re-examination of the project management philosophy, due to the growing realization of the flaws of the traditional approach (Koskela, 1992). In this context, Ballard and Howell state that the traditional conversion process model conceals things that need to be revealed; particularly the design of systems and processes to manage work and work flow (Alarcón, 1997).

2.4.2.5 Characteristics of Traditional Construction

Koskela characterizes the situation in traditional construction as follows (Koskela, 1992):

- The conceptual basis of construction engineering and management is conversion oriented (though the term activity is most commonly used)
- The managerial methods deteriorate flows by violating principles of flow process design and improvement
- As a consequence, there is considerable waste in construction
- Waste is invisible in total terms, and it is considered to be inactionable
- Improvement efforts have been hampered by their neglect of flow aspects.

The traditional methods generally views problems as unavoidable part of construction and that it is necessary to learn to live with them. The problems are best to be solved shortly after they arise, regardless of how one solves them. However, in Kostkela's opinion the starting point for improving construction is to change the way of thinking, rather than seeking isolated solutions to the various problems at hand (Koskela, 1992).

This, among other aspects, later led to the new production philosophy which is the basis for Lean construction. This new philosophy along with Lean construction is presented in the next section.

2.5 Lean Construction Planning Systems

Lean construction has at least two foci that distinguish it from traditional construction management. One focus is on waste and the reduction of waste. The other focus is on managing flows (Alarcón, 1997). In this section the Lean philosophy is addressed as well as its main characteristics in regard to construction management.

"Lean Construction is like driving on a highway. If everybody drives at the same speed we all get there on time and a lot of traffic flows through. But if anybody goes either to fast or to slow it's those cars that mess everything up." - Greg Howell at an AGC meeting in 1993

2.5.1 The New Production Philosophy

In this section to new production philosophy is introduced.

2.5.1.1 Background

The new production philosophy has its origins tracing back to development and experiments of the JIT (Just in Time) production system and quality control initiated by Ohno and Shingo at Toyota Manufacturing in Japan in the 1950's (Koskela, 1992). JIT is a method of pulling work forward from one process to the next 'just-in-time', when the successor process needs it. One benefit of manufacturing JIT is reducing work-in-process inventory, and thus working capital. Another great benefit is reducing production cycle times, since materials spend less time sitting in queues waiting to be processed. However, perhaps the greatest benefit of manufacturing JIT is forcing reduction in flow variation, thus contributing to continuous, ongoing improvement (Alarcón, 1997).

2.5.1.2 The New Production Philosophy

The new production philosophy can be defined as follows:

Production is a flow of material and/or information from raw material to the end product. In this flow there are four kinds of inherently different activities; the material is processed, it is inspected, it is waiting and it is moving. Processing represents the conversion aspect of production whereas inspecting, moving and waiting represent the flow aspect of production. The flow processes can be characterized by time, cost and value, where value refers to the fulfillment of customer requirements. Generally, the processing activities are the only value-adding activities. For material flows, processing activities are alterations of shape or substance, assembly and disassembly (Koskela, 1992).

Figure 16 graphically explains production as a flow process. The shaded boxes represent non value-adding activities whereas the white boxes value-adding processing activities (Koskela, 1992).

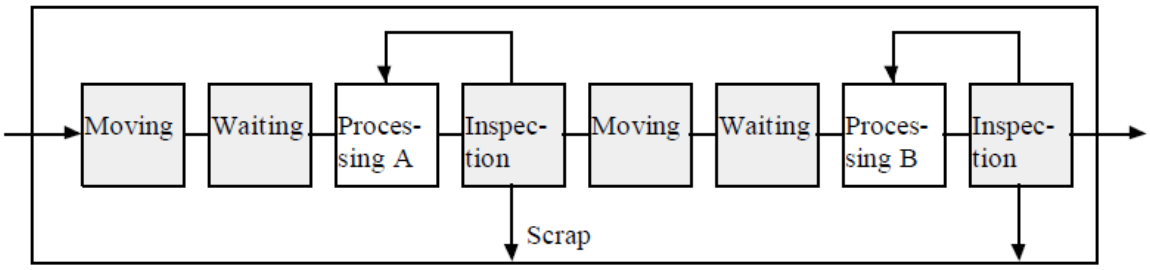


Figure 16 - Production as a flow process (Koskela, 1992)

This new approach implies a dual view of production that consists of both conversions and flows. While all activities expend cost and consume time, only conversion activities add value to the material and/or information being transformed to a product. Therefore, the flow activities of inspecting, moving and waiting should be reduced or eliminated, whereas the conversion activity made more efficient.

2.5.1.3 Principles for the Flow Process

The following principles demonstrate how the flow process can be designed, controlled and improved in practice (Koskela, 1992):

(1) Reduce the share of non-value adding activities.
(2) Increase output value through systematic consideration of customer requirements.
(3) Reduce variability.
(4) Reduce the cycle time.
(5) Simplify by minimizing the number of steps, parts and linkages.
(6) Increase output flexibility.
(7) Increase process transparency.
(8) Focus control on the complete process.
(9) Build continuous improvement into the process.
(10) Balance flow improvement with conversion improvement.
(11) Benchmark.

Koskela stresses that the best possible process is usually not obtained by design alone; generally the designed and implemented process provides a starting point for continuous improvement, based on measurements of actual process behavior.

2.5.1.4 Key Factors for Implementation

Since this study is focusing on CSFs it is worth mentioning that experience shows that there are four key factors that have to be balanced in implementing this new philosophy (Koskela, 1992):

(1) Management commitment,
(2) Focus on measurable and actionable improvement,
(3) Employee involvement and
(4) Learning.

In the next section the main characteristics of Lean construction management are explained.

2.5.2 Lean Construction Planning Systems

From a Lean perspective, construction is viewed as being composed of flow processes (Koskela, 1992). As previously noted, projects can be defined as temporary production systems. When those systems are structured to deliver the product while maximizing value and minimizing waste, they are said to be *Lean* projects (Ballard & Howell, 2003).

2.5.2.1 What is Lean?

"I think of Lean as a fundamental management philosophy. It's not a specific toolkit of methods or tools. It uses methods and tools that are available whether they emerged in the Lean community or were developed somewhere else" –Glenn Ballard at an NCC Seminar in Sweden 2013

Lean Construction can be defined as*: an application to construction of a management philosophy defined by the* ***ideal*** *it pursues, the* ***principles*** *followed in pursuit of the ideal, and the* ***methods*** *used to implement the principles* (Lean Construction Institute, 2013).

A statement of the Lean *ideal* is giving the customers exactly what they need to accomplish their purposes, by maximizing value and minimizing waste (Ballard & Howell, 1998).

Lean thinking can be summarized in five principles, namely (Womack & Jones, 2010).:

(1) Precisely specify value by specific product.
(2) Identify the value stream for each product.
(3) Make value flow without interruptions.
(4) Let the customer pull value from the producer.
(5) Pursue perfection.

Lean thinking forces attention on how value is generated rather than on how any one activity is managed. The aim is perfection: the meeting of customer requirements, in zero time, with nothing in stores. The overriding concern is to reduce waste. By clearly understanding these principles, and then tying them all together, managers can make full use of Lean techniques and maintain a steady course (Womack & Jones, 2010).

The Lean production principles are defined by Ballard and Howell as follows (Ballard & Howell, 1998):

(1) Stopping the Line.
(2) Pulling Product Forward.
(3) One-Piece Flow.
(4) Synchronize and Align.
(5) Transparency.

Applying Lean production principles to construction entails treating the project as one large operation. This need not necessarily involve the standardizing of products (Ballard & Howell, 1998). Before addressing the methods and tools that are commonly applied in Lean Construction the Lean Project Delivery System is introduced.

2.5.2.2 Lean Project Delivery System

In Lean project management, production is defined as designing and making things. Ballard and Howell explain that since designing and making something for the first time is done through a project, projects must be the fundamental form of production systems. To be able to manage and control a project-based production system, theory, rules and tools must be developed (Ballard & Howell, 2003). In this context Koskela explains that production systems are designed to achieve three fundamental goals, namely to deliver the product, maximize value, and minimize waste (Koskela, 2000). One contribution to that objective is the Lean Project Delivery System (Ballard & Howell, 2003). The Lean Project Delivery System is illustrated in figure 17 here below.

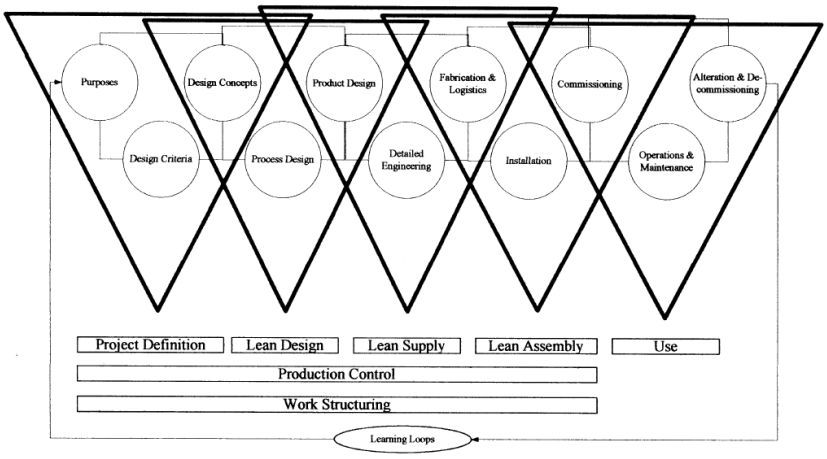


Figure 17 - Lean Project Delivery System (Ballard & Howell, 2003)

Like described in sections *2.1.1 and 2.1.2*, projects have long been understood in terms of phases, for example predesign, design, procurement and installation. Some of the key differences between traditional and Lean project delivery concerns the definition of these phases, the relationship between phases and the participants in each phase.

For examples, in the Project Definition stage representatives of every stage in the lifecycle of the facility are involved, including members of the production team which is to design and build the product. Also, Lean Design differs from traditional practice in systematically deferring decisions until the last responsible moment in order to allow more time for developing and exploring alternatives. In traditional practices the design decision are made as soon as possible (Ballard & Howell, 2003).

The essential features of the Lean Project Delivery System include (Ballard, 2000a):

- The project is structured and managed as a value generating process.
- Downstream stakeholders are involved in front end planning and design through cross functional teams.
- Project control has the job of execution as opposed to reliance on after-the-fact variance detection.
- Optimization efforts are focused on making work flow reliable as opposed to improving productivity.
- Pull techniques are used to govern the flow of materials and information through networks of cooperating specialists.
- Capacity and inventory buffers are used to absorb variability.
- Feedback loops are incorporated at every level, dedicated to rapid system adjustment; i.e., learning.

For a more detailed presentation of the Lean Project Delivery System see Ballard's presentation in the following reference (Ballard, 2000a)

2.5.2.3 Lean Construction Planning Process

The Last Planner is well suited to demonstrate the Lean Construction planning process. In contrast to the Traditional Push System the Last Planner is a Pull System which allows materials or information to be pulled into the production process, but only if the process is capable of doing that work. Ballard explains that in his Last Planner system, conformance of assignments to quality criteria constitute such a check on capability. Further, making assignments ready in the look-ahead process is explicitly an application of pull techniques. Consequently, Last Planner is a type of pull system. The essential elements of a planning system are those that determine what *should* be done, what *can* be done, and what *will* be done. In contrast to the traditional production control system where only the terms *should* and *did* are applied, the Last planner adds two terms, namely *can* and *will*. Again, in contrast to the traditional approach the Last Planner is an active control. The Last Planner can be described as steering the car towards its destination – causing the future, not reacting to the past. Figure 18 shows the Last Planner system (the bold lines) and illustrates the Lean Construction planning process (Ballard, 2000b):

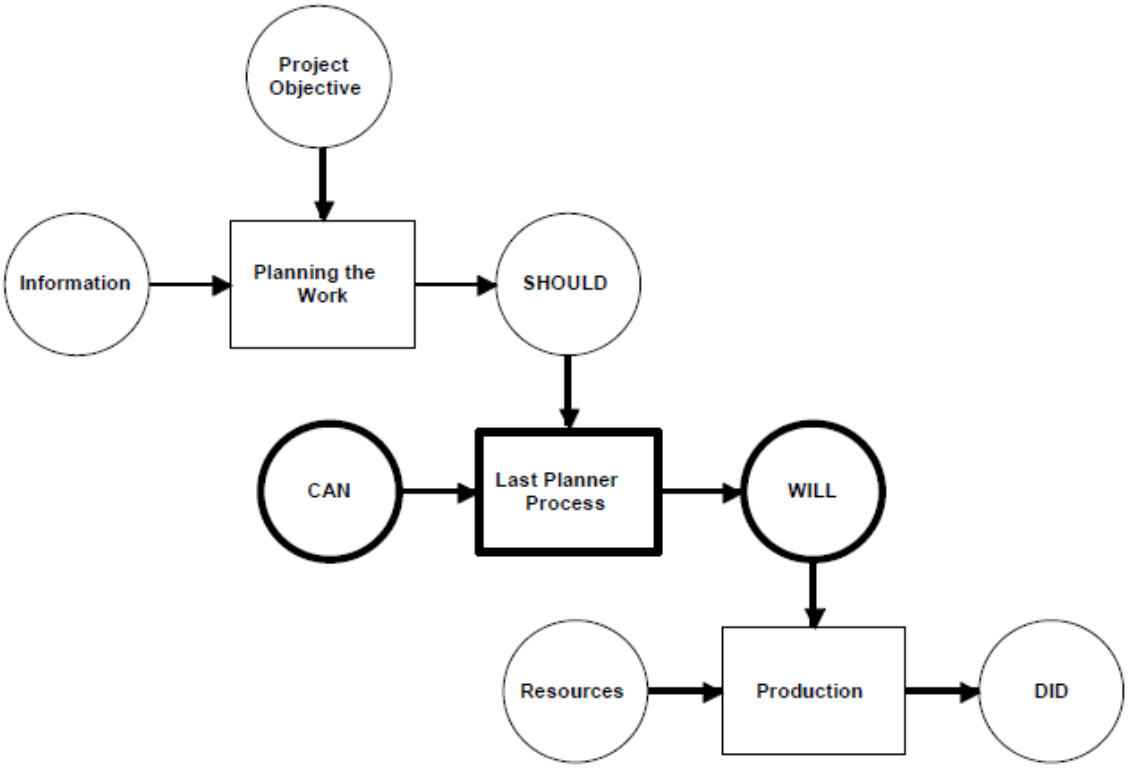


Figure 18 - The Last Planner System (Ballard, 2000b).

To increase the match between *will* and *did*, planners should only include tasks that are sound, sequenced, sized, and well defined. To make ready what *should* be done so it *can* be done the Last Planner encourages planners to analyze and remove constraints, re-plan when constraints cannot be removed in time, breakdown tasks into operation and design new operations collaboratively. The figure below illustrates how *should*, *can*, *will* and *did* relate to the different levels of planning in the Last Planner System of Production Control. The figure is based on Ballard's and Howell's description of the Last Planner (Ballard & Howell, 2003).

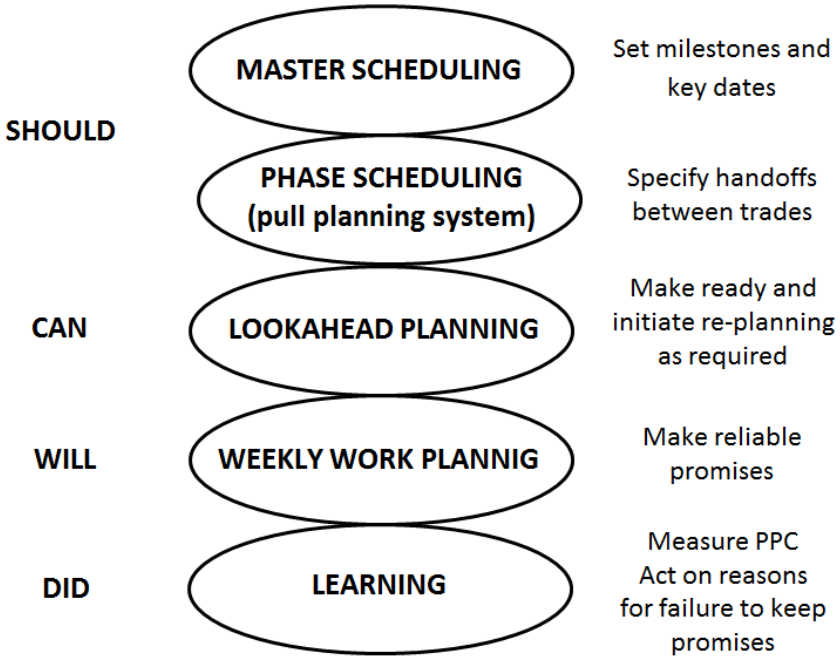


Figure 19 - Last Planner System of Production Control.

Some of the fundamental Last Planner Principles are (Ballard, 2000b):

- Plan in great detail as you get closer to doing the work.
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make reliable promises.
- When promises are broken, find root causes and preventions – learn from those breakdowns.

To improve the planning the Last Planner measures the Percent Plan Complete (PPC), identifying reasons for non-completion, and tracing reasons back to root causes that can be eliminated to prevent repetitions. PPC is the number of planned activities completed divided by the total number of planned activities, expressed as a percentage (Ballard, 2000b).

In this context it is worth mentioning that studies by Ballard and Howell have shown that the vast majority of failures to complete planned work are rooted in the quality of plans. Consequently, planning system performance at the commitment (*will*) level can be improved by such actions as educating planners, improving the supply or quality of planning information, clarifying or modifying directives, etc. (Alarcón, 1997).

2.5.2.4 Lean Construction Techniques and Tools

Many powerful techniques and tools have been developed to manage Lean projects. However, there is no accurate list, as innovation is very much underway and new tools and techniques are still emerging. Some of the Lean tools are conceptual, some are procedural, and some are embedded in software. Whereas several tools are simple, others are more complex. The Last Planner system presented above is an example of a complex tool, itself including multiple rules and techniques. (Best & Valence, 2007).

Tanskanen, Wegelius and Nyman explain that the techniques and tools used to manage and control Lean projects must meet the requirements of the fundamental principles and goals of Lean manufacturing. They summarize the requirements for Lean construction planning and controlling tools as following (Alarcón, 1997):

- Graphical presentation of information.
- Interactive way to process information.
- Understand and specify the goals of planning and controlling.
- Support continuous improvement of performance.
- Provide feedback on the actual trend of the performance of planned business process.

Some commonly applied techniques and tools in Lean construction and design projects worth mentioning are the *Last planner* (explained above), *Five Big Ideas*, *Big Room* (Obeya), *Building Information Modeling (BIM)* and *Concurrent Engineering*.

The *Five Big Ideas* is an approach which strives to coherently address each level of the Lean Project Delivery System. The Five Big Ideas are (Lichtig, 2005):

- Collaborate, really collaborate.
- Optimize the project, not the pieces.
- Tightly couple learning with action.
- Increase relatedness.
- Projects as networks of commitments.

Big Room or *Obeya*, is a concept adopted from the Toyota Production System in Japan. It is also sometimes referred to as colocation. Its purpose is to enhance effective and timely communication (Forbes & Ahmed, 2010). Similar in concept to traditional "war rooms," an Obeya contains highly visual charts and graphs showing milestones and progress to schedules among other data. The idea is that the project leaders have their desks in the Obeya to shorten the *plan, do, check, act* cycle (Aasland & Blankenburg, 2012).

BIM is a tool used to reduce waste in design and construction. It is a digital representation of physical and functional characteristics of what is being designed. BIM provides a solid platform for the *Big Room* concept were designers, owners, and constructors can work interactively to make decisions that influence the overall project (Forbes & Ahmed, 2010).

Concurrent Engineering equals teamwork. It is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to make the developers, from the outset, to consider all elements of the product lifecycle, including quality, cost, schedule, and user requirements (Anumba et al., 2006).

2.6 Comparison of the Methods

In this section the differences between the traditional and the Lean approach are summarized. First the fundamental differences of the production philosophies are discussed and then the differences between the product delivery systems are highlighted.

2.6.1 Comparing the Production Philosophies

There are two kinds of aspects in all production systems, namely conversions and flows. However, the traditional managerial principles have only considered the conversions and therefore treat all activities as though they were value-adding conversions. As a consequence the flow processes have not been controlled or improved in an orderly fashion.

In the new production theory on the other hand both aspects are considered. Through Koskela's eleven principles for flow process design and improvement, the efficiency of flow processes can be considerably and rapidly improved.

The most important differences between the traditional and the new philosophy, according to Koskela, are summarized in Table 10 (Alarcón, 1997).

Comparison	Traditional production philosophy	New (Lean) production philosophy
Conceptualization of production	Production consists of conversions (activities). All activities are viewed as value-adding.	Production consists of conversions and flows. There are value-adding and non-value-adding activities.
Focus of control	Cost of activities.	Cost, time and value of flows.
Focus of improvement	Increase of efficiency by implementing new technology.	Elimination or suppression of non-value adding activities, increase of efficiency of value adding activities through continuous improvement and new technology.

Table 10 - The traditional and the new production philosophy.

2.6.2 Comparing the Delivery Systems

Table 11 lists the main differences between the traditional and the Lean approach to project delivery. The table is based on Ballard's and Howell's summary of Lean and non-Lean project delivery systems (Ballard & Howell, 2003).

Traditional approach	Lean approach
Focus is on transactions and contracts.	Focus is on the production system.
Conversion goal.	Conversion, flow and value goals.
Decisions are made sequentially by specialists and 'thrown over the wall'.	Downstream players are involved in upstream decisions.
Product design is completed, then process design begins.	Product and process are designed together.
Not all product lifecycle stages are considered in design.	All product lifecycle stages are considered in design.
Activities are performed as soon as possible.	Activities are performed at the last responsible moment.
Separate organizations link together through the market and take what the market offers.	Systematic efforts are made to reduce supply-chain lead times.
Learning occurs occasionally.	Learning is incorporated into project, firm and supply-chain management.
Stakeholder interests are not aligned.	Stakeholder interests are aligned.
Buffers are sized and located for local optimization.	Buffers are sized and located to perform their function of absorbing system variability.

Table 11 - Traditional versus Lean project delivery.

3 Research Methodology

This chapter explains step by step how the research methodology was formed for this thesis. First, the research approach is explained. Second, the research philosophy the researcher brings to the study is presented. Third, the research design is addressed. Fourth, the appropriate research methods are explained.

"Research is a systematic attempt to provide answers to questions"
(Tuckman & Harper, 2012)

3.1 Introduction

This thesis research methodology was formed by applying Creswell's framework for research. With other words, his framework was used to assess what research approach was most fitting for this study. The key terms that form his framework are: *Research Approaches*, *Research Philosophies*, *Research Designs*, and *Research Methods*. These terms based on Creswell's definition are as follows (Creswell, 2013):

- ***Research Approaches*** are plans and procedures for a research that span the steps from broad assumptions to detailed methods of data collections, analysis and interpretation.
- ***Research Philosophy*** (worldviews) is the philosophical assumptions the researcher brings to the study.
- ***Research Designs*** are the types of the inquiry within a research approach.
- ***Research Methods*** are the different forms of data collections, analysis and interpretation.

Figure 20, based on Creswell's framework for research, explains how the key components interact with each other (Creswell, 2013).

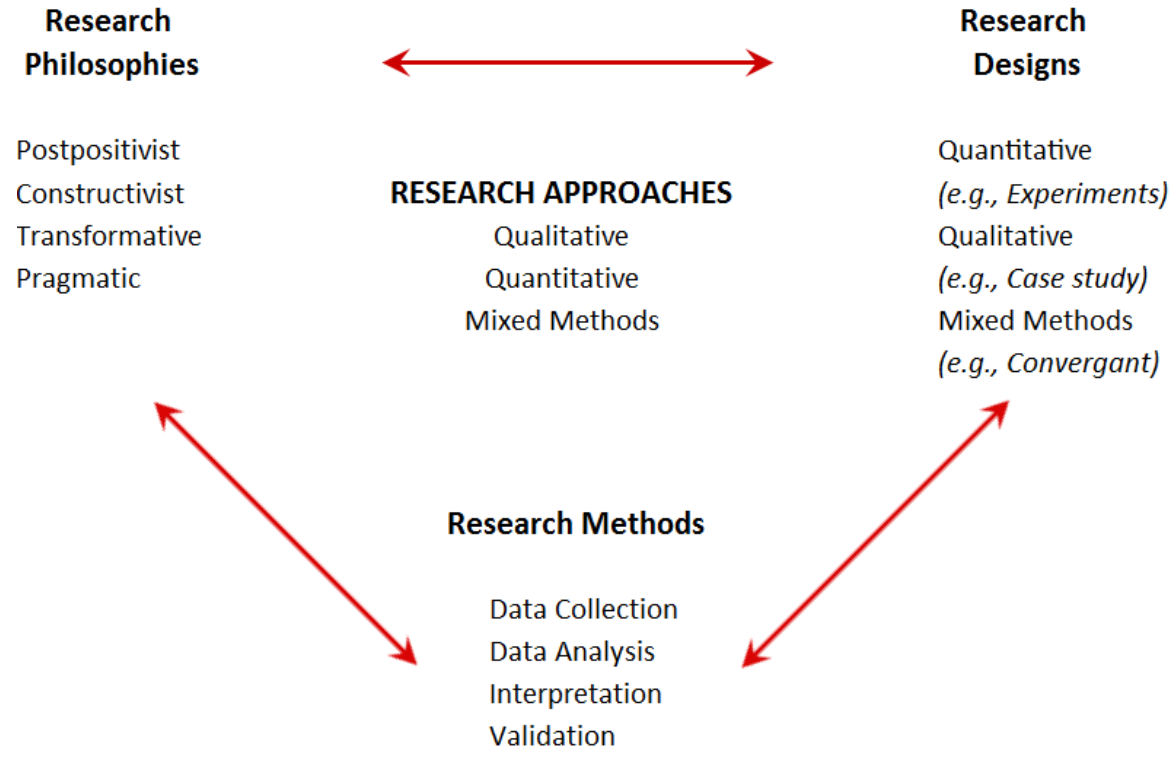


Figure 20 - Creswell's framework for research (Creswell, 2013).

The following sections describe what research approaches, philosophies, designs and methods can be applied to scientific research and, step by step, what approaches were applied to this research.

3.2 Research Approach

Creswell and Borrego describe three research approaches: qualitative, quantitative and mixed methods (Creswell, 2013)(Borrego, Douglas, & Amelink, 2009). The following definitions are based on their description:

Qualitative research is an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. It's fitting for inductive approaches to data analysis. Olsson & Sörensen explain that inductive reasoning is based on discoveries from reality which then leads to laws and theories (Olsson & Sörensen, 2003).

Quantitative research is an approach for testing objective theories by examining the relationship among variables. It's fitting for deductive approaches, where a theory or hypothesis justifies the purpose statement and the direction of the narrowly defined research questions. Olsson & Sörensen explain that deductive reasoning is based on a theory, but presents an assumption about reality in a hypothesis (Olsson & Sörensen, 2003).

Mixed methods research is an approach to inquiry involving collecting both qualitative and quantitative data, integrating the two forms of data.

The choice of research approaches should always be driven by the research question/s (Borrego et al., 2009)(Yin, 2009). After careful consideration a qualitative approach was evaluated as the best fitting approach for this research, based on the nature of the research questions. The reason for this decision is better explained in the next sections.

3.3 Research Philosophy

Creswell notes that philosophical ideas influence the practice of research and can explain why individuals choose a given research approach. He describes worldviews as a general philosophical orientation about the world and the nature of research that a researcher brings to a study. He also mentions that worldviews arise based on discipline orientation, student's advisors inclinations and past research experience. The major elements of Creswell's four philosophical worldviews are presented in Table 12.

Postpositivism	Constructivism
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meanings • Social and historical construction • Theory generation
Transformative	**Pragmatism**
• Political • Power and justice oriented • Collaborative • Change-oriented	• Consequences at actions • Problem-centered • Pluralistic • Real-world practice oriented

Table 12 - Research philosophies (Creswell, 2013).

The investigator of this research leans towards a pragmatic worldview where one emphasizes the research problem and uses all approaches available to understand the problem. Pragmatism is not committed to any one system of philosophy and reality. Individual researchers have the freedom of choice, free to choose the method, techniques, and procedures of research that best meet their needs and purposes (Creswell, 2013).

Having said that, one could state that this thesis is under more influence of the constructivism philosophy than pragmatism since it only applies a qualitative approach. However, that was mainly due to time restrictions and limited resources. If not for those obstacles, quantitative methods would have also been applied by submitting surveys to provide data for statistical analysis. Another reason for selecting this approach was that one of the thesis advisors had previous experience with case studies. The qualitative approach was seen as a better fit for the research questions (with the limitations in mind), but the investigator hopes to continue with the research later by applying both qualitative and quantitative methods of investigation.

3.4 Research Design

Research designs are types of inquiry within qualitative, quantitative and mixed methods approaches (Creswell, 2013). A research design is a logical plan for getting from here (the questions) to there (the answers) (Yin, 2009). It can cover what questions to study, what data are relevant, what data to collect and how to analyze the results (Philliber, Schwab, & Sloss, 1980). Table 13 is based on Creswell's alternative research designs.

Quantitative	Qualitative	Mixed Methods
• Experimental designs • Non experimental design, such as surveys	• Narrative research • Phenomenology • Grounded theory • Ethnographies • Case study	• Convergent • Explanatory sequential • Exploratory sequential • Transformative, embedded, or multiphase

Table 13 - Research designs (Creswell, 2013).

After careful consideration case study was assess as the most appropriate design for this research. This was based on Yin's teachings that case studies generally are the preferred design when (Yin, 2009):

(1) "how" and "why" questions are being posed,
(2) the investigator has little control over events, and
(3) the focus is on a contemporary phenomenon within a real-life context.

This study meets all these requirements by:

(1) asking "how are the CSFs defined?" and "how do the methods meet the requirements?",
(2) investigating events which the investigator has little or no control over, and
(3) focusing on evolving factors and methods that are applied to real-life design and construction projects.

This decision was also based on the case study's unique strength to deal with a variety of evidence, namely documents, artifacts, interviews and observations (Yin, 2009). Another argument for applying this design is based on Eisenhardt's statement that case study research is most appropriate to provide freshness in perspective to an already researched topic (Eisenhardt, 1989).

3.4.1 Case Study Designs

Robson's definition of a case study is: *"a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon with in its real life context using multiple sources of evidence"* (Robson, 1993). Yin explains that there are four basic types of designs for case studies, i.e.

- holistic single-case designs
- embedded single-case designs
- holistic multiple-case designs
- embedded multiple-case designs

This research will use an embedded multiple-case design, meaning that more than one case will be studied with multiple units of analysis. This decision was based on Yin's advice, when one has the choice and resources, multiple-case designs are preferred over single-case designs (Yin, 2009). This is because the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust (Herriott & Firestone, 1983).

The selection of the appropriate unit of analysis occurred when the primary research questions were specified. This research applies two units of analysis, namely:

1. The *critical success factors* in planning, scheduling and control for design and construction projects.

2. The *methods* used in design and construction projects regarding their capability to meet the requirements of the critical success factors. The two methods examined in this research are Lean construction planning systems and traditional project management planning methods.

3.5 Research Method

Research methods are described by Creswell as methods that involve the forms of data collection, analysis, and interpretation that researchers propose for their studies. The decision of applying qualitative case study design narrows down the appropriate research methods for this study. Table 14 which is based on Creswell's quantitative, mixed and qualitative methods, indicates what methods might match the thesis design (Creswell, 2013).

Quantitative Methods	Mixed Methods	Qualitative Methods
Pre-determined	Both predetermined and emerging methods	Emerging methods
Instrument based questions	Both open- and closed- ended questions	Open-ended questions
Performance data, attitude data, observational data, and census data	Multiple forms of data drawing on all possibilities	Interview data, observation data, document data, and audiovisual data
Statistical analysis	Statistical and text analysis	Text and image analysis
Statistical interpretation	Across database interpretation	Themes, patterns interpretation

Table 14 - Research methods (Creswell, 2013).

In this section the research methods will be further addressed, by explaining what methods were applied and why.

3.5.1 Data Collection

As previously mentioned, case studies do not need to be limited to a single source of evidence. In fact, good cases studies usually rely on a variety of sources. Yin mentions six sources case study evidence may come from, i.e: documents, archival records, interviews, direct observation, participant-observation, and physical artifacts. This study applies three sources in data collection, namely: interviews, direct observations and documents.

3.5.1.1 Interviews

Yin states that one of the most important sources of case study information is the interview. The interviews were performed as guided conversations where the line of inquiry was followed in an open-ended focused interview. A focused interview is when a person is interviewed for a short period of time (for example an hour) following a certain set of questions derived from the case study protocol (Yin, 2009). This gave the interviewees the chance to go outside of the investigators line of questions, if they felt the need to come across information they weren't directly ask for. An interview guide was made for each interview. A summary of the interview guides can be found in appendix A. The interviews were recorded, transcribed and sent to the interviewees for verification and approval. Key personnel form the client, contractor and design team were interviewed at each project.

3.5.1.2 Direct Observations

Direct observations are when the investigator has the opportunity to observe a "case" in its natural setting within a case study. The advantage of using observational evidence is that it often provides additional information about the topic being studied. The observations can be so valuable that one may even consider taking photographs at the site. A common procedure to increase the reliability of observational evidence is to have more than a single observer making an observation (Yin, 2009). Unfortunately the resources did not permit multiple observers in this study. Both formal and casual observations were applied in this research, formal observations during various meetings and casual observation throughout the field visits, during and in between the interviews and meetings. Photographs were taken during the field visits, meetings and other observation.

3.5.1.3 Documentation

Documentary information is relevant to almost every case study topic. An investigator must arrange access to examine the files of any organization being studied and then sort and review what appears central to one's inquiry. The most important use of documents in a case study is to corroborate and augment evidence from other sources (Yin, 2009). Steering documents, presentations, e-mails, minutes of meetings, action lists, progress plans, decision plans, and other documents were made accessible by the project managers and used as a source for evidence in this case study.

3.5.1.4 Case study database

Yin explains that a case study database is a way of organizing and documenting the data collected for a case study. He states that every case study project should strive to develop a formal, presentable database, so that other investigators can review the evidence directly and not be limited to the final report alone. In this manner, a case study database markedly increases the reliability of the entire case study. To do this the data collected needs to be organized, categorized, complete and available for later access. Even though one develops a database, every report should still contain enough data so that the reader of the report can draw independent conclusions about the case study (Yin, 2009).

A database was created for the collected data, stored at a file hosting service, where the author and the advisors had access to it. Each case has its folders where the sources of evidence is organized and categorized in a systematic way. A detailed database overview makes it accessible so that other investigators can review the evidence. Most of the documents and data in the database are complete and well readable.

3.5.2 Data Analysis

Data analysis consists of examining, categorizing, tabulating, testing, or otherwise recombining evidence, to draw empirically based conclusions. Every case study analysis should follow a general analytic strategy, defining priorities for what to analyze and why. Yin's four analytic strategies are as follows:

- Relying on theoretical propositions.
- Developing case descriptions.
- Using both quantitative and qualitative data.
- Examining rival explanations.

Any of the following strategies can be used in practicing five specific techniques for analyzing case studies. These are (Yin, 2009):

- Pattern matching.
- Explanation building.
- Time-series analysis.
- Logic models.
- Cross-case synthesis.

The first and most preferred strategy, according to Yin, the *relying on theoretical propositions*, was chosen as the analytic strategy for this research, even though it also to some extent, *examines rival explanations*. This means that the propositions which formed the original objectives and design for this case study, and which also reflect the research questions, are based on literature and new hypotheses form experts in the field such as Lauri Koskela, Glenn Ballard and Greg Howell, to name a few. These propositions shaped the data collection plan and helped to focus attention on certain data and to ignore other data.

Pattern matching was applied for this study, which is according to Yin one of the most desirable techniques for case study analysis (Yin, 2009).

It was kept in mind while reviewing the documents (especially e-mails and other personal documents) that the documents were written for some specific purpose and some specific audience, other than the investigator.

3.5.2.1 SWOT analysis

SWOT analysis has its origins in the 1960s (Christensen, Andrews, Bower, & Learned, 1973). SWOT is the acronym for "strengths, weaknesses, opportunities and threats" (Hill & Westbrook, 1997). The aim of SWOT analysis is to identify the strengths and weaknesses of an organization and the opportunities and threats in the environment. By identifying these aspects, strategies can be developed by building on the strengths, eliminating the weaknesses, exploiting (invest in) the opportunities and countering (identify) the threats.

The strengths and weaknesses are identified by an internal appraisal of the organization and the opportunities and threats by an external appraisal. The internal appraisal examines all aspects of the organization covering, for example, personnel, facilities, location, products and services, in order to identify the organizations strengths and weaknesses. The external appraisal scans the political, economic, social, technological and competitive environment with a view to identifying opportunities and threats. The advantage of SWOT analysis is its attempt to connect internal and external factors to stimulate new strategies (Dyson, 2004).

SWOT analysis was used to analyze the different methods in regard to planning, scheduling and control.

3.5.2.2 Multiple source of evidence

The biggest advantage of using multiple source of evidence, according to Yin, is the development of converging lines of inquiry, a process of data triangulation. Triangulation of data sources encourages an investigator to collect information from multiple sources but aimed at corroboration the same fact or phenomenon. When an investigator has really triangulated the data, the events or facts of the case study has been supported by more than a single source of evidence. With data triangulation, the potential problems of construct validity also can be addressed because the multiple source of evidence provides multiple measures of the same phenomenon (Yin, 2009).

3.5.3 Reliability and Validity

This section focuses on the validity and reliability of the research by applying different tests and tactics. Yin explains that since a research design is supposed to represent a logical set of statements, one can also judge the quality of any given design according to certain logical tests (Yin, 2009). Concepts that have been offered for these tests include trustworthiness, credibility, conformability, and data dependability (Kidder & Smith, 1986). Four tests can be used to establish the quality of a case study research, namely:

- *Construct validity:* identifying correct operational measures for the concepts being studied.
- *Internal validity:* seeking to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships.
- *External validity:* defining the domain to which a study´s findings can be generalized.
- *Reliability:* demonstrating that the operations of a study – such as the data collection procedures – can be repeated, with the same results (Yin, 2009).

The table below shows how Yin encourages investigators to apply different case study tactics within the given tests. He also describes in which phase of the research the tactics should take place.

TESTS	Case Study Tactics	Phase of research in which tactic occurs
Construct validity	• Use multiple source of evidence • establish chain of evidence • have key informants review draft case study report	• data collection • data collection • composition
Internal validity	• do pattern matching • do explanation building • address rival explanations • use logic models	• data analysis • data analysis • data analysis • data analysis
External validity	• use theory in single-case studies • use replication logic in multiple-case studies	• research design • research design
Reliability	• use case study protocol • develop case study database	• data collection • data collection

Table 15 - Case study tests and tactics (Yin, 2009).

In this context it's important to note that the original plan was to study four of Statsbygg's construction projects, two projects applying Lean and two using more traditional methods. Due to various reasons the researcher was only handed out two of Statsbygg's projects, one that applies Lean and one that uses more traditional methods. Obviously, gaining access to two more projects would have increased the internal and external validity of the research.

3.5.3.1 Construct validity

All of the tactics listed above to construct validity were applied to this research, by using multiple source of evidence, establishing chain of evidence, and having the thesis advisors to read through parts of the thesis. The chain of evidence was maintained by linking the study questions, protocol, case study database and the final report together, allowing (hypothetical) external observers to follow the derivation of any evidence from initial research question to ultimate case study conclusions. All interviews were reviewed by the interviewees which also increases the validity of the report.

3.5.3.2 Internal validity

A threat to internal validity is if the investigator incorrectly concludes that there is a causal relationship between x and y without knowing that some third factor z may actually have caused y. Another threat is the broader problem of making inferences when an event cannot be directly observed (Yin, 2009). The tactics used for internal validity in this case study were pattern matching and addressing rival explanations, which is better explained in the data analysis section of this report.

Due to limited resources and time restrictions this research did not have the opportunity to achieve good internal validity by providing extensive data over a longer period. Due to these limitations, in some situations, the investigator had to rely solely on a single source of evidence, namely verbal reports from interviewees.

3.5.3.3 External validity

External validity deals with the problem of knowing whether a study's findings are generalizable beyond the immediate case study (Yin, 2009). Since this is a multiple-case study the tactic to ensure external validity is to use replication logic. The research is based on two case projects where similar data were conducted at both sites. The projects are alike in many ways which made the replication straightforward and clear. This entails that the findings can perhaps only be generalized with similar projects. To increase the external validity, more (diverse) cases should be studied as well.

3.5.3.4 Reliability

The goal of reliability is to minimize the errors and biases in a study. If a later investigator followed the same procedures as described by an earlier investigator, he should arrive at the same findings and conclusions (Yin, 2009). The tactics listed above to ensure reliability were applied, i.e. a case study protocol was used and a case study database developed. For further explanations see the sections about the protocol *(section 4.1)* and database *(section 3.5.1.4)*.

3.6 Literature Review

The purpose of literature review is not to determine the answers about what is known on a topic, in contrast, experienced investigators review previous research to develop sharper and more insightful questions about the topic. Its purpose is to highlight the state of the art knowledge about the research topic (Yin, 2009).

The investigator made an extensive literature review for this research. Literature was found by searching for relevant keywords, mainly through search engines and databases such as *Google Scholar* and *Leitir*. Some literature was also recommended by the thesis advisors. Reference lists proved to be a useful source for literature. The researcher south out to rely solely on peer reviewed literature published by refereed journals or publishers. A reference management software was used to manage and organize the literature.

4 Case Study

This chapter briefly addresses the two design and construction projects provided by Statsbygg for this study. This section also addresses what data was collected via interviews and observations as well as what documents were provided. Before giving a brief introduction of Statsbygg the case study protocol is presented, explaining what preparations were made on forehand regarding the data collection.

4.1 Case Study Protocol

A case study protocol is a document made by and intended for the investigator, preparing him for the execution of the study. The purpose of a case study protocol is to keep the investigator focused on the research topic (Yin, 2009). The case study protocol for this research consisted of informal notes by the investigator. These notes addressed the following topics:

- An overview of the case study aims and objectives.
- List of relevant readings about the topic being investigated.
- Field procedures.
- Case study questions.
- A guide for the case study report.

With minor adjustments these aims and objectives formed the primary aims and objectives of this study presented in chapter *1.2 Aims and Objectives*. The list of relevant readings later formed the structure of the literature review presented in chapter *2. Theoretical Framework*. The guide for the case study report formed the framework of this report. The field procedures and the case study questions from the protocol are addressed briefly in the following two sections.

4.1.1 Field Procedures

In a case study like this the researcher has very little or no to control over the data collection environment. When interviewing key persons, he must adapt to the interviewee's schedule and availability. Similarly, when the investigator is observing real-life activities he is intruding into the world of the subject being studied (Yin, 2009). The list below includes some of the focus areas Yin describes in relation to field procedures, which were adapted to this studies protocol:

- Gaining access to Statsbygg's projects and key persons.
- Having the right equipment while in the field. A personal computer, recording devise, camera, paper and pen were among the items the researcher relied on during data collection.
- Be able to ask for assistance and guidance from thesis advisors. The investigator had good access to his thesis advisors via phone and mail during data collection.
- A rough schedule of data collection activities was formed. This included a list of interview objectives, observations and documents to be collected.
- Preparing for unanticipated events. The investigator tried to be flexible during data collection and adapt to the interviewee's schedule and availability.
- Protecting the interviewees and other participants by informing them about the risks and conditions associated with the research. Each interviewee was informed about the nature of the research and how the data would be treated and later displayed in this thesis.

4.1.2 Case Study Questions

An insight into asking good questions is to understand that research is about questions and not necessarily about answers. The study questions are the investigators reminders of what information needs to be collected. Case study questions are a set of substantive questions reflecting the actual line of inquiry. These questions are not necessarily intended as the literal questions to be asked of any given interviewee. Each question should be accompanied by a list of likely sources of evidence. Such sources may include the names of individual interviewees, documents, or observations (Yin, 2009). The following questions in table 16 were originally formed in the case study protocol.

Case study questions	Sources of Evidence
How does the tender-, contract- and implementation strategy affect the planning, scheduling and control?	Interviewees, documents, and observations.
How does the planning, scheduling and control process appear in design and construction? What are the CSFs?	Literature review, interviewees and observations.
How do the main stakeholders cooperate and communicate when planning, scheduling and controlling the project?	Interviewees and observations.
How realistic are the plans and estimates? Are they able to stick to their plans? If no, why?	Interviewees, documents, and observations.
How do the managers monitor and control their plans and schedules? How detailed overview do they have?	Interviewees, documents, and observations.
What distinguishes the different planning methods? Are they equally capable of meeting the requirements of the CSFs in planning, scheduling and control?	Literature review, interviewees, documents, and observations.

Table 16 - Case study questions

4.2 Statsbygg

Statsbygg is the Norwegian government's key adviser in construction and property affairs, building commissioner, property manager and property developer. Statsbygg has close to 900 employees in total, where roughly 100 work in the building commissioning division. Their head office is in Oslo but there are regional offices in Oslo, Porsgrunn, Bergen, Trondheim and Tromsø.

Statsbygg plans, quality assures, budgets, and follows up construction projects. At any given time, Statsbygg organizes, plans, and implements around 160 projects, both large and small, of which 20-30 major projects are completed every year (Statsbygg, 2014).

Statsbygg has its own project lifecycle model. The project is divided into six phases. These phases loosely translated to English are: Initiation, Programing phase, Conceptual design phase, Detail design phase, Construction phase and Follow-up & troubleshooting phase. Figure 21 illustrates the sequence of the phases (See the original lifecycle model in Appendix D, in section 84).[2]

Figure 21 - Statsbygg's project phases

Statsbygg provided the following two construction projects for this study, both which are being implemented for different educational institutions in Norway:

(1) The Sør-Trøndelag University College (STUC): a project which applies a rather traditional approach to design and construction management and planning.

(2) The Norwegian University of Life Sciences (NULS): a project which applies Lean construction planning systems to design and construction.

These projects are further addressed in the following sections. In this thesis Statsbygg will be referred to as the *client* (byggherre in Norwegian).

[2]Information obtained from the project documents provided by the project managers at The Sør-Trøndelag University College and The Norwegian University of Life Sciences.

4.3 Case 1: Sør-Trøndelag University College

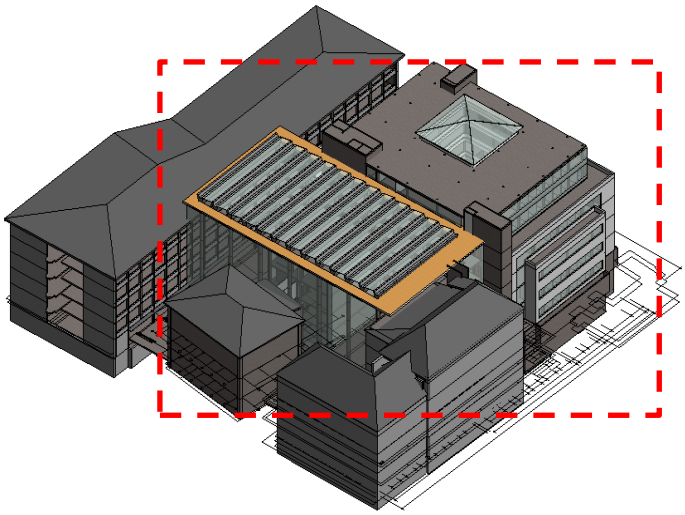


Figure 22 - Sør-Trøndelag University College[3]

4.3.1 Background

The new building is approximately 15.000 m^2, built between the existing University buildings at Sverres gate 12, Trondheim. In 2002 there was an architectural competition with prequalified participants, architects and engineers (design team). The pilot project was completed in 2004 based on a functional program, but was not given the initiation grant due to changes in government at the time. During 2009-2010 and again in 2013 the pilot project was revised and updated to meet new energy standards. In April 2014 it was opened for tendering. The project aims to be ready for use in December 2016. In November/December 2014, during the site visit to STUC and data collection the project was in the detail design phase whereas construction was in the final stages of the ground work, almost ready for the concrete works.

4.3.2 Contract - Design & Build

There are various types of construction contracts. The choice of contract depends on the basis of pricing and the contract strategy that best meets the project objectives. The various types offer different ways of handling pricing, risk transfer, responsibility for performance, cost certainty, and complexity (Office of Government Commerce, 2002).

Statsbygg's project manager explained that they did a market survey among the largest contractors in Trondheim where 4 out of 6 contractors listed partnering (samspill in Norwegian) as their first choice of contract type. Statsbygg's project managers also preferred partnering but the contract committee at Statsbygg insisted on design & build, a fixed price contract only evaluated on price. As a result, Betonmast Trøndelag AS got the contract as the main contractor or so called "Total-Contractor" (Totalentreprenør in Norwegian) by submitting the lowest bid.

Design & Build (Totalentreprise in Norwegian) is using a single contractor to act as the sole point of responsibility to a public sector client for the design, management and delivery of a construction project on time, within budget and in accordance with a pre-defined output specification using reasonable skill and care (Office of Government Commerce, 2007). In this project they designed and built in parallel.

[3]Figure obtained from the project documents provided by the project manager at The Sør-Trøndelag University College

4.3.3 Organizational Chart

The figure below is a simplified organizational chart for the organization of the main stakeholders at The Sør-Trøndelag University College. The figure is presented to illustrate the interfaces between the main stakeholders examined in this study, namely:

- The client (CL): Statsbygg
- The main contractor (CON): Betonmast
- The design team (DT): Main architects and engineers

In Appendix B, section 8.2, the original organizational chart for Sør-Trøndelag University College may be found.

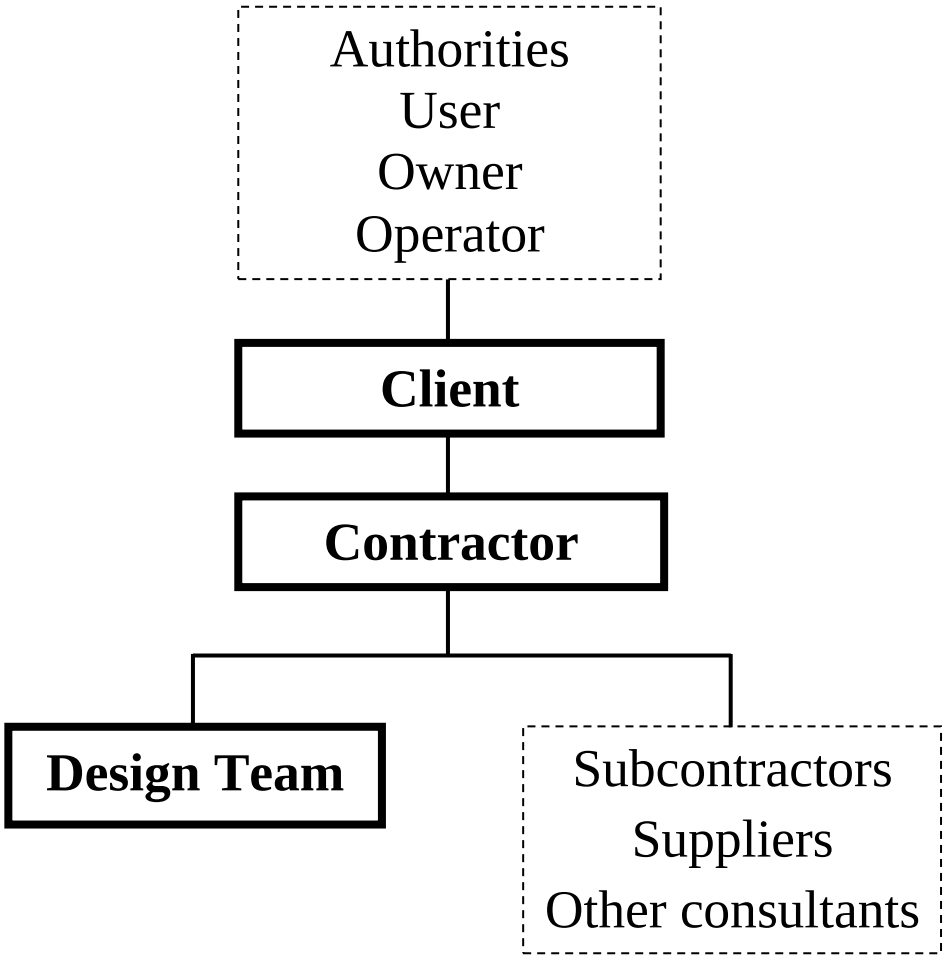


Figure 23 - Organizational Chart - Case 1

4.3.4 Data Collection

This section describes what research data was collected at The Sør-Trøndelag University College.

4.3.4.1 Interviews

The following table gives an overview of the interviews that were conducted during the site visitation at Sør-Trøndelag University College. The names and roles of the interviewees are listed, as well as the purpose of the interview, when it was conducted and the duration of the interview. All interviews, except the one with Per Aksel, were carried out at Statsbygg's/Betonmast's office at the construction site. The interview with Per Aksel was conducted at Statsbygg's headquarters in Oslo at Biskop Gunnerus Gate 6.

Interviewee	Role	Purpose of interview	Date	Duration
Andreas Henschel	Architect, Slyngstad Aamlid Arkitekter AS	Gather detailed information about the design planning process from the DT's perspective.	26.11.2014	35 min
Gabriel Johan Bjørseth	Design Manager, Betonmast	Gather detailed information of the planning, scheduling and control process from the CON's perspective.	28.11.2014	25 min
Harald Hasfjord	Design manager for technical subjects, Caverion	Gather detailed information of the design planning process from the DT's perspective.	27.11.2014	40 min
Hege Furunes	Production progress manger, Betonmast	Gather detailed information of the planning, scheduling and control process from The CON's perspective.	26.11.2014	25 min
Kristin Juul	Project Manager, Statsbygg	Gather necessary documents and detailed information about the project, the project strategy and the planning, scheduling and control process from the CL's perspective.	26.11.2014 and 27.11.2014	35 min
Leif Morten Lauritzen	Project Manager, Betonmast	Gather detailed information of the planning, scheduling and control process from the CON's perspective.	28.11.2014	35 min
Per Aksel Larsen	Project Manager Assistant, Statsbygg	Gather detailed information about the project strategy, the project and the planning, scheduling and control process from the CL's perspective.	5.12.2014	50 min
Pual Gunnar Svildal	Project Manager Assistant, Betonmast	Gather detailed information of the planning, scheduling and control process from the CON's perspective.	26.11.2014	35 min
Steinar Trygstad	Structural Engineer, Ph.D., THiLT Engineering AS	Gather detailed information of the planning, scheduling and control process from DT's perspective.	27.11.2014	40 min
Truls Jøstensen	Client's representative, Statsbygg/Rambøll	Gather detailed information of the planning, scheduling and control process from the CL's perspective.	28.11.2014	20 min

Table 17 - Interview overview, Sør-Trøndelag University College.

4.3.4.2 Observations

Table 18 shows an overview of the different observations that were made at Sør-Trøndelag University College during the site visitation. A brief description of each observation is listed as well as the purposes, date and duration of each event.

Observation	Description	Purpose	Date	Duration
Introductory meeting	Introductory meeting with PM Kristin Juul and a short "tour" around the office.	Obtain basic information about the project and make a plan for the research procedures during the visit.	26.11.2014	35 min
Triangle meeting (user meeting)	The CL's PM, the CRE and User Coordinator discussed different issues relevant for the users.	Gain an insight to the project organization and cooperation between the stakeholders. Gather further information about the design process.	26.11.2014	90 min
HSE meeting	Health, Safety and Environment (HSE) meeting. HSE managers from Statsbygg and Betonmast were among those who attended the meeting.	The investigator attended this meeting to join the construction site tour (Safety inspection), which took place directly after the meeting. To gain an insight on the projects implementation.	26.11.2014	60 min
Safety inspection (Construction site tour)	PM Kristin Juul among HSE team guided the researcher on a tour around the construction site during a safety inspection.	Gain an insight on the projects implementation.	26.11.2014	45 min
Progress meeting	Statsbygg and Betonmast attended this meeting to discuss different progress issues, including the User Coordinator.	Gather further information and understanding about the planning, scheduling and control process by monitoring the key personnel in the meeting.	26.11.2014	100 min
Meeting between client and contractor	Meeting for key personnel form Statsbygg and Betongmast including the PM's to discuss changes and additions to the project and the contract.	Gain an insight of the contract, organization and cooperation between the client and the contractor. Gather information about the design process.	27.11.2014	150 min
Design meeting	16 people attended this meeting including the PM's, DM's and the DT to coordinate the design and to make interdisciplinary clarifications.	Gather further information and understanding about the design process by monitoring the cooperation of the key personnel in the meeting.	27.11.2014	240 min

Table 18 - Observations at Sør-Trøndelag University College

4.3.4.3 Documents

The table below gives an overview of the documents that were provided for the study by the project manager at Sør-Trøndelag University College. The table gives a brief description of the documents, purpose of collection and the date when each document was made available.

Document	Description	Purpose	Granted access
Progress Plan	Microsoft Project plan that gives an overview over HiST's main progress plan.	Gather information about the planning, scheduling and control process, method and tools.	6.10.2014
Decision Plan	Decision Plan from meeting between the client and contractor, set up in a Microsoft Excel Worksheet.	Gather information about the planning, scheduling and control process, method and tools.	28.11.2014
Power Point Presentation - Per Aksel	Presentation of the CL's project management plan.	Gather information about the CL and their different contract and project strategies.	28.11.2014
Power Point Presentation - Kristin Juul	Basic facts about the project. Presentation of the CL's project management plan.	Gather information about the contract and project strategy as well as further information about the planning, scheduling and control process, method and tools.	28.11.2014
Minutes of meeting	Minutes (action list) from design meeting saved as a PDF file.	Gather information about the planning, scheduling and control process, method and tools.	28.11.2014
Minutes with comments	Comments from the CL's PM's on different contents of minutes via E-mail.	Get an insight into the cooperation between the client and contractor. Gather information about the design and planning process, method and tools.	28.11.2014

Table 19 - Documents, Sør-Trøndelag University College.

4.4 Case 2: Norwegian University of Life Sciences

Figure 24 - STUC's building also called Urbygningen (Statsbygg, 2015)

4.4.1 Background

NULS is a restoration project of a 115 years old university building with a total area of 8.000 m^2. This project is located at Olav Sverres plass 1, Ås. The building is under the protection of The Cultural Heritage, which applies to the exterior, interior and surrounding garden. The project has been on Statsbygg's assignment list since 2004. The first pilot project was ready in 2007, but was not approved by the Ministry of Finance. A new proposal was submitted in 2009 and in 2013 they got the initiation grant. The project finish date is 1st of January 2016. In December 2014, during the site visit to STUC and data collection the project was passsed the detailed design and in the construction phase.

4.4.2 Contract - Prime Contracting

As previously mentioned, there are various types of construction contracts. This project applies a so called Prime Contracting, a design, bid and build contract. This is when a single contractor acts as the sole point of responsibility to a public client for the management and delivery of a construction project on time, within budget and fit for the purpose for which it was intended for (Office of Government Commerce, 2007). The Building commissioner (Statsbygg) is responsible for the design (manages the design team) whereas the contractor (Skanska) is responsible for the construction. This project first entered the detailed design phase and then the construction phase, with other words, the design and construction were not done in parallel to the same extent as in design and build project (see 4.3.2). However, the design was not entirely finished before the construction works started. During the construction works the designers were mainly producing work drawings for the contractor as well as finishing small details.

4.4.3 Organizational Chart

The figure below is a simplified organizational chart for the organization of the main stakeholders at The Norwegian University of Life Sciences. The figure is presented to illustrate the interfaces between the main stakeholders examined in this study, namely:

- The client (CL): Statsbygg
- The main contractor (CON): Skanska
- The design team (DT): Main architects and engineers

In Appendix C, section 8.3, the original organizational chart for The Norwegian University of Life Sciences may be found.

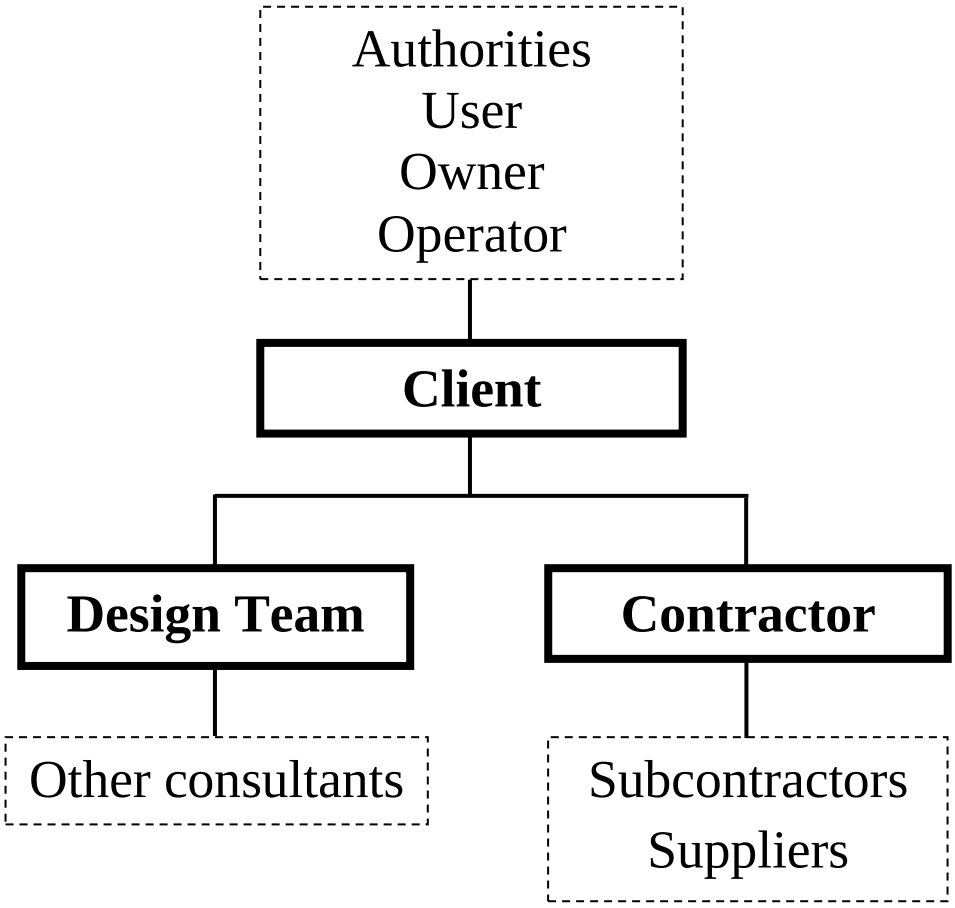


Figure 25 - Organizational Chart - Case 2

4.4.4 Data Collection

This section describes what research data was collected at The Norwegian University of Life Sciences.

4.4.4.1 Interviews

The following table gives an overview of the interviews that were conducted during the site visitation at The Norwegian University of Life Sciences. The names and roles of the interviewees are listed, as well as the purpose of the interview, when it was conducted and the duration of the interviews. All interviews were carried out at the CL's and CON's office at the construction site.

Interviewee	Role	Purpose of interview	Date	Duration
Alf Øivind Skarphol	Electrical Engineer, ÅF Infrastruktur	Gather detailed information of the planning, scheduling and control process from the DT's perspective.	3.12.2014	30 min
Audun Sandvold	HVAC Engineer, Erichsen & Horgen	Gather detailed information of the planning, scheduling and control process from the DT's perspective.	3.12.2014	35 min
Bikramjit Singh	Project Manager, Statsbygg	Gather necessary documents and detailed information about the project, the project strategy and the planning, scheduling and control process from the CL's perspective.	3.12.2014 and 4.12.2014	35 min
Johnny Bastiansen	Design manager, Statsbygg	Gather detailed information of the planning, scheduling and control process from the CL's perspective.	4.12.2014	25 min
Jonas Wilson	Production progress manger, Skanska - hired from Lean Communications	Gather detailed information about the project strategy and the planning, scheduling and control process from the CON's perspective.	4.12.2014	20 min
Lise Yksnøy	Architect, 4b Arkitekter AS	Gather detailed information of the planning, scheduling and control process from the DT's perspective.	3.12.2014	35 min
Trond Ellingsen	Design Team Coordinator, A.L. Høyer Skien AS	Gather detailed information of the planning, scheduling and control process from the DT's perspective.	3.12.2014	35 min

Table 20 - Interview overview, Norwegian University of Life Sciences.

4.4.4.2 Observations

Table 21 shows an overview of the different observations that were made at The Norwegian University of Life Sciences during the site visitation. A brief description of each observation is listed as well as the purposes, date and duration of each event.

Observation	Description	Purpose	Date	Duration
Construction meeting	The PM, DT, and CON gathered to clarify different design and construction actions and to make interdisciplinary coordination.	Gather further information and understanding of the planning, scheduling and control process by monitoring the key personnel in the meeting.	3.12.2014	50 min
Design team meeting	A meeting for the DT to coordinate their work. The meeting agenda was controlled through an action list.	Gather further information and understanding of the design process by monitoring the DT.	3.12.2014	70 min
Introductory meeting and observation of meeting room	Introductory meeting with PM Bikramjit and a short "tour" around the meeting room where the production plans were pinned to the walls.	Obtain basic information about the project and make a plan for the research procedures during the visit. Get an overview and further understanding of the progress plans and the planning process.	3.12.2014	75 min
Observation of the workplace	In between interviews, meetings and other observations the researcher observed the key personnel's work environment.	Gain an insight on the project organization and cooperation between the key personnel.	3.12.2014 and 4.12.2014	120 min
8 weeks meeting	CL's DM, DT, CON and subcontractor gathered to coordinate the design and to make interdisciplinary clarifications. The meeting agenda was guided by using an action list.	Gather further information and understanding of the design process by monitoring the cooperation of the key personnel in the meeting.	4.12.2014	105 min
Construction site tour	PM Bikramjit guided the researcher on a tour around the construction site.	Gain an insight on the construction process and see how the BIM screens function on site.	4.12.2014	35 min

Table 21 - Observations at the Norwegian University of Life Sciences

4.4.4.3 Documents

The table below gives an overview of the documents that were provided for the study by the project manager at The Norwegian University of Life Sciences. The table gives a brief description of the documents, purpose of collection and the date when each document was made available.

Document	Description	Purpose	Granted access
Lean - Interaction	The PDF file describes how the CL wishes to use Lean in their projects and specific goals for Lean at Urbygningen.	Gather information about how the CL wishes to use Lean in their projects.	10.12.2014
Invitation to Bids - Competitive Bidding	General information about the assignment and requirements for the bid.	Gather information about the tendering method and contract strategy.	10.12.2014
Progress plan	Progress plan set up in Microsoft Excel where the project is divided into control areas and daily based activities.	Gather information about the planning, scheduling and control process, method and tools.	10.12.2014
Action List - design team	Action list set up in Microsoft Excel used in design team meetings.	Gather information about the planning, scheduling and control process, method and tools.	15.12.2014
Action List - design meeting	Action list set up in Microsoft Excel used in design meetings with the design team, client, contractors and other parties.	Gather information about the planning, scheduling and control process, method and tools.	15.12.2014
Minutes of meeting	Minutes from construction meeting with the CL, CON and DT.	Gather information about the planning, scheduling and control process, method and tools.	15.12.2014
Steering Document	PDF document that highlights the project objectives, structures and strategies.	Gather information about the project strategy and the planning, scheduling and control process, method and tools.	15.12.2014

Table 22 - Documents, the Norwegian University of Life Sciences.

5 Results and Discussion

This chapter presents the results from both case studies. First, the success perspectives of the key personnel are examined. Second, the objective achievement and influencing factors are presented. Third, the SWOT analysis of the methods is presented.

The results are sorted according to the methods used in data collection, i.e. interviews, observations and document analysis. The investigator tried to remain neutral when presenting the findings and only report what was observed during the investigation. The following results are based on data collected between the 26st of November and the 15th of December of 2014, with one exception of a document which was provided in October 2014 (see section *4.3.4* and *4.4.4* for data collection).

5.1 Success Perspectives

In this section the success perspectives of the key personnel involved in the planning, scheduling and control are presented as they appeared in the case studies. This section addresses the findings relevant to research question **1 a)** which is defined as:

- *What success perspective do the client, contractor and design team have?*

5.1.1 Case 1: Sør-Trøndelag University College

In this section the success perspectives of the client (CL), contractor (CON) and the design team (DT) are presented as they appeared in this case study.

5.1.1.1 Interviews

The Client: The PM emphasized the objectives regarding the project delivery (cost, time, quality and safety) and on the objectives of meeting the needs of the user and operator. She stressed the importance of involving the future users and owner/operating organization in the planning process to make sure that their needs were satisfied.

The CL's PMA explained that the main objective is to deliver the project on time and within budget. He explained that the university's ambitions are high; to be one of the most attractive schools in the country. He further explained that the operating organization wants a building which is rational to operate. He was confident that these goals would be achieved.

The CRE explained that the aim is to meet the project's success criteria presented in the project plan. The main objective is to deliver within the constraints of time, cost and quality.

The Contractor: The contractor's PM and DM noted that they had adopted the client's objectives for the project, as described in the tender documents.

The PM, PMA and the DM described that their main objectives were to profit from the project, but also to deliver the building within the constraints of time and quality, ensure adequate HSE (Health Safety and Environment) management, and achieve the environmental goals (reduce waste: e.g. materials and energy)

The PPM was mainly concerned with the time management of the project, to deliver on time.

The Design Team: The DM explained that the he and the technical subjects had already achieved their main objective of "selling" their energy concept (passive houses) to the project. This meant extensive scope changes to the project, but it was accepted due to the need to modernize the project and to meet new standards regarding energy consumption.

The STE was mainly concerned with productive progress planning, that the activities are done in the right order.

The ARC explained that he and his firm could easily score higher financially if they wanted. However, that was not their main objective. Their main objective is to design a building that satisfies the user.

5.1.1.2 Observations

Both the client and the contractor were concerned with HSE.

The client: The CL included representatives from the user and the operating organization in several meetings. In fact, specific user/operator meetings (triangle meetings) are arranged every 2nd week to make sure that their needs are being met. The PM noted several times during the meetings that the user (e.g. lab equipment) and operator (e.g. energy costs) needs must be taken into account. Both PM and PMA were concerned with significant delays regarding the construction progress.

The Contractor: During the observations it became clear that the success perspective of the contractor was related to the achievement of the project outputs. The contractor was concerned about the delays in construction and was seeking to find ways to get back on track. The contractor's PM and PMA noted that they were missing some drawings from the ARC and decisions from the user coordinator to be able to make adjustments to the progress plans. The contractor was also concerned about contracts with (and involvement of) subcontractors and suppliers to ensure no further delays in construction.

The Design Team: During the design meeting the designers discussed their design with inputs from the CL and contractor, as well as the user and operator representatives. The designers were concerned with what tasks they should perform next and what description they should rely on during design. The designers were mostly concerned with the project outputs (time, cost and quality).

5.1.1.3 Documents

The client: In the detailed presentations of the project plan which include comments from the PM and PMA the following objectives of the CL appeared several times:

- *Operational* goals (the project outputs): Time, cost, quality and HSE.
- *Tactical* goals (the project goal): Satisfying the user (students and staff) and owner/operator.
- *Strategic* goals (the project purpose): The University's objective of becoming a leading, regional and national, venue for engineering and science education by cooperating with other higher educational institutions and the economy.
- *Environmental* goals: reducing energy waste, use environmental friendly materials, and recycle the wastes during construction.

The Contractor: In the CL's PM presentation of the project plan it is described that the contractor guarantees the implementation of the project. It is described in the CL's PMA presentation of the project plan that the contractor got the job based on price (lowest bid). It is further explained that the contractor has the total responsibility for the design and construction. In the meetings minutes the contractor was very concerned with price (minimize isolation, drop specific course for staff). The contractor focused on the basis for the design (asked the CL and designers to make clarifications). The contractor asked for comments from the CL and design team regarding the progress plan. The contractor was also concerned with HSE.

The Design Team: By reviewing the meeting minutes it became evident that the designers were mainly concerned with what to deliver and when (time, cost and quality). The CL, users and operator were usually the ones assisting the designer to know what to deliver and the contractor decided when. The designers, both architects and engineers, took the user and operator needs into account, even planned specific meetings with them to clarify design details. This was mainly due to poor descriptions in the project/tender documents.

5.1.1.4 Summary

The table below shows the main success perspectives of the client, contractor and design team depending on the source of evidence from case 1.

When the word *mainly* is placed before a specific success perspective it implies that the interviewee also saw success from other perspectives, but did not emphasize or explain those thoughts any further.

Source of evidence	Client	Contractor	Design Team
Interviews	**PM**: Operational and tactical **PMA**: Operational and tactical **CRE**: Mainly operational	**PM**: Mainly operational **PMA**: Mainly operational **DM**: Mainly operational **PPM**: Operational	**STE**: Mainly operational **DM**: Mainly operational **ARC**: Mainly tactical
Observations	Operational and tactical	Mainly operational	Mainly operational
Documents	Operational, tactical and strategic	Mainly operational	Mainly operational

Table 23 - Success perspectives: Case 1

5.1.2 Case 2: Norwegian University of Life Sciences

In this section the success perspectives of the client (CL), contractor (CON) and the design team (DT) are presented as they appeared in this case study.

5.1.2.1 Interviews

The client: The PM explained that the main objective is to finish the project on time, but also within cost and to the right quality. He emphasized the importance of satisfying the users, operating organization and owner during the design phase, as well as taking the demands from the Cultural Heritage into account.

The DM explained that it is his responsibility to guide the design team, to make sure that they deliver on time, within cost, and to the right quality. He explained that wants and demands of The Cultural Heritage and the user were taken into account in the design phase. He was also concerned with HSE.

The Contractor: The PPM explained that his goal was to implement the project with the least risk and to minimize the cost and to reduce the duration. He emphasized the importance of doing work in a rational order. He noted that he sometimes felt that the CON was more concerned with the efficiency of the project's outcomes than the CL.

The Design Team: The DTC explained that his biggest concern is the management of resources within the design team. He explained that he bases his delivery plans on the contractors progress plans to be able to deliver the right drawings on time. He noted that it is the CL's responsibility to communicate with The Cultural Heritage and the user, to ensure that their needs are being met. The design team's only interface is with the CL.

The ELE noted that the project has many goals. First he mentioned the goals of delivering a building that satisfies the user and operator, within budget, on time and which fulfills the demands of The Cultural Heritage. He noted that the CL is their DT's customer, so they don't interact with the user, operator or Cultural Heritage directly themselves. He was mostly concerned with delivering drawings to right quality and on time. He explained that they use the progress plan to know "when" to deliver and the documents form pilot project to know "what" to deliver.

The HVE explained that his objectives are to deliver the drawings on time and to the right quality. He noted that the contractor's progress plan controls when he delivers the different drawings. He explained that both the user and The Cultural Heritage had come with unpredictable requirements and that it was time consuming to get feedback from them and the CL regarding the design.

The ARC explained that their main goal is to deliver the required drawings on time with as few errors as possible. She explained that to be able to meet all the deadlines they have been working a lot of overtime. Time was of most importance in her opinion, not a big issue to go over budget.

5.1.2.2 Observations

The client: During the 8 weeks meeting the DM was concerned with the progress plan, what tasks were critical to maintain a steady progress, what procurement orders need to be placed in time etc. During the construction meeting the CLF addressed the HSE management and progress regarding the design and construction.

The Contractor: The contractor was mainly concerned with the construction progress and the design tasks which could influence the construction progress in the near future. For example the PPM noted that the tasks which are performed first out on the construction site (e.g. wall: frame first, then boards) must be a priority of the design team when the produce work drawings.

The Design Team: During the design meeting the DTC was concerned with making certain drawings ready for specific procurement orders, due to long delivery time. He was concerned about the drawing delivery status: what was delivered last week, what must be delivered this week and what should be the focus for the next week.

5.1.2.3 Documents

The client: In the project plan the project goals are listed. These goals are divided into four categories, presented in the following order: *strategic*, *tactical*, *operational* and *environmental* goals.

- The *strategic* goals (the project purpose) are the Universities goal of being a high level educational institution within life sciences veterinary medicine and to preserve the cultural heritage of the building.
- The *tactical* goals (the project goal) are the goals concerning the users, both students and staff. These goals imply that the building should be suitable for teaching and learning.
- The *operational* goals (the project outputs) are the criteria for the project implementation. The following order shows the priorities among these goals: cost, quality and functionality, and progress and time.
- The *environmental* goals are defined as reducing energy waste, preserving the building, use environmental friendly materials, and recycle the wastes during construction.

The Contractor: In the project plan it is noted that the contractor has agreed to deliver the project to a specific date. In that same document it is noted that the contractor is responsible for the progress planning in the construction phase.

The Design Team: In the project plan it is noted that the project team work on an hourly rate. Their reports must show what they deliver vs. what they bill. The design team is responsible to make a detailed progress plan in cooperation with the contractor. The project plan also describes to what quality the design team should deliver the building (e.g. use traditional materials).

5.1.2.4 Summary

The table below shows the main success perspectives of the client, contractor and design team depending on the source of evidence from case 2.

When the word mainly is placed before a specific success perspective it implies that the interviewee also saw success from other perspectives, but did not emphasize or explain those thoughts any further.

Source of evidence	Client	Contractor	Design Team
Interviews	**PM**: Operational and tactical **DM**: Operational and tactical	**PPM**: Mainly operational	**DTC**: Mainly operational **ELE**: Mainly operational **HVE**: Mainly operational **ARC**: Mainly operational
Observations	Operational	Operational	Operational
Documents	Operational, tactical and strategic	Operational	Mainly operational

Table 24 - Success perspectives: Case 2

5.2 Objective Achievement and Success Factors

This section addresses the findings relevant to research question **1 b)** and **c)**, which are defined as follows:

> b) Do the projects achieve the objectives (criteria) for planning, scheduling and control?
>
> c) What factors influence the achievement of the objectives (criteria) for planning, scheduling and control?

The following table shows how the projects will be evaluated, in regard to objective achievement for planning, scheduling and control. As previously explained, scheduling is just one part of the planning effort and have therefore been merged together as shown in the table below, due to similar objectives described in section *2.2.1.5* and *2.2.2.5*. The objective achievements and the influencing factors are addressed as they appeared in each project in the order of the objectives listed in the table below.

		Objective	Description	Evaluation question
Planning		Understand the Goals	Know what needs to be done to accomplish the project goals.	Do the planners know what needs to be done to accomplish the project goals?
		Reduce Uncertainty	Reduce and reveal uncertainty.	Do the planners take actions to reduce and reveal uncertainty?
	Scheduling	Apply Realistic Estimates	Apply realistic schedule and budget estimates.	Do the planners apply realistic schedule and budget estimates?
	Scheduling	Improve Efficiency	Coordinate resources to get work done within the constraints of time, cost and quality.	Are resources coordinated to get work done within the constraints of time, cost and quality?
		Establish Basis for Control	Provide basis for monitoring and control.	Do the planners establish a basis for monitoring and control?
Control		Determine Project Status	Measure progress to determine the current status of the project.	Are the planners able to measure and determine the current status of the project?
		Evaluate Performance	Determine cause of and ways to act on deviations form the plan.	Do the planners know the reason for delays and cost overruns? Do they have a plan of action?
		Manage Actual Changes	Correct and update the plans. Activate plan of actions.	Do the planners correct and update the plans? Is the plan of actions activated?

Table 25 - Objectives for planning, scheduling and control

5.2.1 Case 1: Sør-Trøndelag University College

In this section the objective achievements and influencing factors of this case study are presented.

5.2.1.1 Understand the Goals

Do the planners know what needs to be done to accomplish the project goals?

Objective Achievement

Interviews: CL and the CON explained that they had a series of meetings in the beginning of the project to clarify strategies regarding project budgets, progress, project assurance and expectations of each other and to the project.

The CL explained that to accomplish the project on time, within cost and to the expectations of the user/owner/operator, commitment to planning, stakeholder involvement, and good organization is necessary. To support this they sponsored a Lean course for the CON and the design group. They were not convinced that the CON felt the need for Lean thinking and they realize that they couldn't force them to apply it. They were not satisfied with the CON's planning and organizing. The CL had the feeling that the CON didn't fully understand how extensive and demanding the project was and what it really meant to build for a public client.

The CON explained that to accomplish the project goals the basis for design must be clear. Also, they must have the freedom to deliver the functionality as they feel best (within the constraints of time, cost and quality as described in tender/project documents). To accomplish their own main goal (profit from the project) they must achieve functionality in the cheapest possible way. They explained that the key to profit is good planning. Stakeholder involvement (e.g. subcontractors) and cooperation is also of great importance to accomplish the goals.

The DT explained that to be able to accomplish the project goals, the basis for design must be clear and the organization (coordination) must be good so they know what and when to deliver. The ARC also emphasized the importance of satisfying the user needs by involving the user. The DM explained that to accomplish their own financial goals (already accomplished) they needed to sell their product (concept of passive hose/ceiling).

The engineers believed that the implementation methodology has changed for the better after the Lean course, but compared to Lean thinking they noted that the management was still far off. They felt that this project used a very traditional implementation approach.

The DT and the CON noted that the basis for design was unclear and contained contradictions. They were therefore uncertain of what to deliver. They noted that the CL and the user have during the past 10 years formed many thoughts and expectations of the project which are difficult for them to fully obtain. The CON and DT have only been involved in the project for less than a year which is a very short time compared to the user and CL.

The CON and DT also noted that the interface between the CL, user and operator was unclear. The CL also noted that they were trying to make those interfaces clearer to prevent misunderstandings.

Also see section *5.1.1.1*.

Observations: See section *5.1.1.2*.

Documents: See section *5.1.1.3.* In the CL's PMA's presentation on the project plan it is described what the project must succeed with in order to achieve its overall goals:

- Focus on project objectives.
- Be able to take necessary actions.

CSFs that were mentioned are: *management*, *organization*, *information flow*, *responsibility*, and *surroundings.*

Influencing Factors

The table below illustrates what factors influenced the achievement of *Understand the Goals*.

Factor	Description	Source of evidence
Commitment to planning	All interviewees noted the importance of good planning. However, commitment not visible at the project.	Interviews, Observations
Motivation	Different success perspectives among planners. Aim at own goals rather than focusing on the same project goals.	Interviews, Observations, Documents
Tendering method	Only based on price: lowest bid got the contract. CON focuses on profit. The DT consultants hired by the CON: Own interests dominant.	Interviews, Observations, Documents.
Organizing skills	Old pilot project documents caused conferment among the CON and DT. The basis for design was unclear.	Interviews, Documents
Client's ability to define roles	The interfaces between the CL, user and operator/owner not clear.	Interviews

Table 26 - Factors Case 1: Understand the Goals

5.2.1.2 Reduce Uncertainty

Do the planners take actions to reduce and reveal uncertainty?

Objective Achievement

Interviews: The CL explained that they studied the ground at the construction site on forehand to reduce uncertainty in the ground works. The CL noted that they included cost contingency in their budget estimates, e.g. for unforeseen circumstances in the groundwork (old oil tank in the ground). The CON, on the other hand, requested additional funding to finish the sheet and pipe piling during the ground works, because of uncertainty. The CON and CL explained that they perform uncertainty analyses together every 3rd month to identify and reduce uncertainty.

The interviewees explained that the project needed modernization due to the long project lifetime, causing scope changes and much rework for the DT. The interviewees noted that they use BIM modeling to reveal and reduce uncertainty during design and construction.

Observations: During the clients meeting the CL and CON discussed potential actions to remove an old oil tank in the gourd. Sampling had shown that the soil was contaminated. They also discussed the effect vibrations from the ground works could have on nearby buildings and what actions could be made if cracks would appear. The BIM Model was used during the design meeting to view specific design features. The model was not complete yet.

Documents: In the CL's PM's presentation on the project plan the main project uncertainties are described as contaminated soil due to an old oil tank as well as vibration from the ground works. In the same document the CL explained their main uncertainty management principles, which are divided in to two processes. Between the two processes decisions are made. The processes are:

(1) Input: Identify and analyze uncertainty.
(2) Output: Respond to and follow up uncertainty.

In the CL's PMA's presentation on the project plan it is described that in the programming phase the plan for uncertainty analysis is made and then performed in the pilot project by the CL before the tendering. Tools such as S-curve and tornado diagrams were applied in the analysis.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Reduce Uncertainty*.

Factor	Description	Source of evidence
Commitment to planning	The CL had made effort to reveal and reduce uncertainty on forehand. The CON requested additional funding due to uncertainty in the ground; did not show the same planning effort as the CL.	Interviews, Documents
Project-related factors	Unpredictable conditions of an old oil tank in the ground, contaminated soil, and the effect vibrations from the ground works could have on nearby buildings.	Interviews, Observation, Documents
Political environment	Political environment affected the long project lifetime and the need for modernizing the project; rework and scope changes.	Interviews

Table 27 - Factors Case 1: Reduce Uncertainty

5.2.1.3 Apply Realistic Estimates

Do the planners apply realistic schedule and budget estimates?

Objective Achievement

The interviewees noted that the CON only got 5 weeks to prepare the project schedules and documents after getting the contract. That resulted in ill-defined plans and project documents. The CL regrets not giving the CON more for planning.

The CON and the DT explained that the DT gets the opportunity to review and comment on the drawings delivery plans and suggest realistic deadlines. Subcontractors and suppliers also get the opportunity to comment on production and delivery dates relevant to the construction works to make sure that the work can be performed on time.

The DT noted that they will use more time than planned to complete the design due to changes and modifications to the project. They explained that much rework has been done already.

Observations: During the meetings the planners noted that they were repeatedly going back to the pilot project instead of focusing on the detailed design due to design and scope changes. This affected the progress and budget estimates of the DT and CON.

Documents: By reviewing the meeting minutes the investigator noted that many decisions and actions exceeded the original deadlines listed in the minutes.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Apply Realistic Estimates*.

Factor	Description	Source of evidence
Commitment to planning	Too short time set aside for planning. Project documents and schedules not completed on time. Decisions and actions exceed original deadlines.	Interviews, Documents
Feedback capabilities	The DT and relevant stakeholder get the opportunity to influence the deadlines a few weeks ahead of time.	Interviews
Project-related factors	The DT and CON noted that design and scope changes affect their progress and budget estimates.	Interviews, Observations

Table 28 - Factors Case 1: Apply Realistic Estimates.

5.2.1.4 Improve Efficiency

Are resources coordinated to get work done within the constraints of time, cost and quality?

Objective Achievement

Interviews: The CL explained that they have used resources to assist the contractor to improve the progress planning and scheduling (not the norm in design and build projects). The CL also invited the contractor to a Lean course, hoping to change the way they think about progress and how to plan in general, so they can finish the project on time. The CL noted that the CON needs to put more resources to management. The CL noted that they feel that their hands are tied due to the contract form. They would like to have greater impact on planning efficiency.

The CON's PMA explained that he was an extra resource added to the project afterwards but there are still barely enough executives on site. The CON's PM explained that there is great need for a person to control the logistics (almost no storage space) on site. This assignment has been added to the organizational chart but they have not hired a person for the job yet. The CON explained that they use a lot of resources to ensure their own profit from the project. They explained that they involve relevant stakeholders 2 and 4 weeks (sometimes also 8 weeks) before they start their work on site to give them the opportunity to influence the progress plan for construction.

The DT and the CL noted that the design meetings are way too long (5-6 hours) and both ineffective and very expensive (up to 20 participants). The DT noted that far distances between the different design agencies affects cooperation between the designers. More interdisciplinary cooperation was preferred by them. They noted that the design meetings are usually the only place where they all come together. Some of them have the chance to meet in between the meetings.

Observations: The investigator noticed during the observations that the meetings were often poorly structured with unclear agenda. The design meeting in particular was very long (4 hours) and included many participants (16 people), many of which only a few topics were relevant for. It was discussed during the design meeting that the efficiency of the meetings should be improved by applying more task meetings.

Documents: In the presentation on the project plan it is described that a drawback with design and build is that the CL doesn't have the ability to influence solutions in a great extent.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Improve Efficiency*.

Factor	Description	Source of evidence
Commitment to planning	Not enough resources have been allocated to planning by the CON. The CL has assisted them in the planning process.	Interviews, Observations
Tendering method	The CL is very restricted to the CON's expertise due to the contract form.	Interviews, Documents
Organization skills	The organization of meetings, design meetings in particular, is ineffective and expensive.	Interviews, Observations
Coordination skills	The DT is not well coordinated; too few occasions to discuss design matters.	Interviews, Observations

Table 29 - Factors Case 1: Improve Efficiency.

5.2.1.5 Establish Basis for Control

Do the planners establish a basis for monitoring and control?

Objective Achievement

Interviews: The interviewees explained that they use the progress plan as well as the decision plan and drawing delivery plan as a basis for monitoring and control. They also noted that it is the CON's responsibility to make the plans for design and construction.

The CL noted that the decision plan and the drawing delivery plan were not ready when the design process started and there still is no baseline for the design. The CL and the user have requested a more detailed decision plan from the CON, which looks further ahead in time. Also, the CL explained that they did not get the baseline for production until four months after the construction works started. They have used the last four months to get a satisfactory quality plan from the CON. The CL noted that they have still not gotten a progress plan which they are satisfied with. The CL can only point out what is missing in regard to the requirements listed in the contract.

The CL and the DT noted that the plans are not linked together and that the construction and design process are not integrated. The Engineers noted that to be able to control their man-hours and progress they have calculated and made their own progress plans for design and production (installing technical equipment).

Observations: The decision plan and action lists were applied during meetings. It happened several times during the meetings that participants asked "are those things clarified?" or intended to discuss tasks that were already clarified.

Documents: The main progress plan, made in Microsoft Project, shows the estimated start and finish dates for the main construction activities. It is based on the stages with in construction phase, e.g. groundwork, piling, concrete works and so on. The individual activities in the plan are very extensive, spanning over long time periods without further breakdown (often 40 days or more).

The only three parameters that the action list provided was *when* a task was first considered, who is *responsible* and a *deadline* for clarification. Within some tasks, comments such as *"very urgent"*, *"priority"* or *"OK"* were written in a chaotic way, within the same column where the deadlines are listed. The decision plan had more parameters but was lacking measurements such as priority, whether things are in progress or not and to summarize "clarified/not clarified".

Influencing Factors

The table below illustrates what factors influenced the achievement of *Establish Basis for Control*.

Factor	Description	Source of evidence
Commitment to planning	The basis for measuring and control was inadequate. Plans either insufficient or not existing at all.	Interviews, Observations, Documents
Planning skills	The CON struggled to establish a sufficient basis for monitoring and control. Plans not linked together. Design and construction not integrated. DT relied on own plans rather than the CON's plans.	Interviews, Observations, Documents
Tendering method	Again, the CL is very restricted to the CON's expertise due to the contract form (design and build). See section 5.2.1.4.	Interviews, Documents

Table 30 - Factors Case 1: Establish Basis for Control.

5.2.1.6 Determine Project Status

Are the planners able to measure and determine the current status of the project?

Objective Achievement

Interviews: The interviewees noted that they measure and determine the project status by comparing actual performance to the production progress plan for construction. They also noted that they have good control over their finances, by comparing actual costs to their budgets and financial estimates. The design progress is controlled by the drawing delivery plans; work drawings ready for the construction works. The interviewees noted that they use monthly reports to evaluate and update the projects status. The DT delivers their reports to the CON, the CON to the CL, and the CL to their upper management executives.

The DT's DM noted that he measures and determines performance by using his own progress plans.

The CL and the CON noted that they are 6 weeks behind schedule, by comparing actual performance to the production progress plan.

Observations: No relevant observation made on the subject.

Documents: The decision plans and action list do not have sufficient parameters to measure and determine the status of the project. The main progress plan, made in Microsoft Project, shows the estimated start and finish dates for the main construction activities. By reading the plan one can see that they are more than a month behind schedule in construction. No resources where measurable in the plan.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Determine Project Status*.

Factor	Description	Source of evidence
Commitment to planning	Compare actual performance to construction progress plan and budgets. Not able to measure the current status of the design.	Interviews, Documents
Planning skills	The CON explained that they were inexperienced and still learning how to apply the planning tools and methods.	Interviews
Control of subcontractors' works	The planners did not measure the performance of subcontractors works.	Interviews

Table 31 - Factors Case 1: Determine Project Status.

5.2.1.7 Evaluate Performance

Do the planners know the reason for delays and cost overruns? Do they have a plan of action?

Objective Achievement

Interviews: The CL explained that the CON blames the unforeseen circumstances in ground for the current delays. The CL on the other hand thinks that safeguards should have been made in the planning, since those "unforeseen" were described in the tender documents.

The CON's PM noted that there can be many and complicated reasons for delays. However, one must take into account that bad decisions and/or poor planning are often among those reasons. He noted that if one is behind schedule it usually also means that one has to spend more resources. The CON noted that the subcontractors control their own workers and resources. The CON explained that they do not have much experience using the planning tool *Microsoft Project* and now understand the importance of defining the critical path to be able to locate slack in the plans. They also noted that they don't use features such as assigning resources or man-hours to the progress plans in Microsoft Project. They use separate worksheet in Excel for calculating and controlling their resources and man-hours for their own workers.

The CL has requested a plan of action form the CON in regard to how they are going to get back on track. The CON noted that they will gather forces with their subcontractors to try find a solution to the problems. They were also trying to locate slack in the progress plans.

Observations: During the Clients meeting The CON was not able to answer the CL in regard to how they were going to get back on schedule. They were having trouble finding slack in the plans and noted during the meeting that they felt that they were tight on resources.

Documents: There are no parameters in the decision plan, action list or progress plan that can determine the reason for something not taking place on time. No resources are being managed in the main progress plan.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Evaluate Performance*.

Factor	Description	Source of evidence
Commitment to planning	Due to the lack of basis for monitoring and control the planners were not able to determine the reason for delays.	Interviews, Observations, Documents
Planning skills	The CON had problems finding the critical line and slack in the plans.	Interviews, Observations, Documents

Table 32 - Factors Case 1: Evaluate Performance.

5.2.1.8 Manage Actual Changes

Do the planners correct and update the plans? Is the plan of actions activated?

Objective Achievement

Interviews: The interviewees explained that they constantly update the project plans, via meetings, e-mails and other communication forms. Additions and changes are managed through change notifications.

Both the CL and the CON noted that a drawback with a design and build project is that additions and change notifications can easily create a small war between the two parties. In fact, the CL noted that it felt as if they had been fighting from day one. They see a difficult process ahead for solving several problems in terms of the contract with the CON. The CON explained that additional cost falls either on them, the CL, or the subcontractors. How to split the cost depends on who is responsible for the delays or cost overruns.

The CON's plan of action to get back on track was not ready and could therefore not be activated.

Observations: During the clients meeting the CL frequently asked the CON if they understood what was requested of them. The CL also asked about the plan of action and noted that the CON needs to update the progress plans. The decision plan and action list were updated during some of the meetings.

Documents: No relevant documentation on the subject.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Manage Actual Changes*.

Factor	Description	Source of evidence
Commitment to planning	The progress plan was not updated frequently enough. No real plan of action yet to get back on track.	Interviews, Observation
Communication	The communication between the CL and the CON been difficult from the start.	Interviews
Cooperation	Cooperation not based on trust and understanding	Interviews, Observation
Tendering method	The CL and CON have been "fighting" from the start regarding changes and additions to the contracts.	Interviews

Table 33 - Factors Case 1: Manage Actual Changes.

5.2.1.9 Summary

The table below shows the main results regarding how well the objectives were met at case 1 and what influencing factors affected the achievement of the objectives for planning, scheduling and control.

Objective	Objective Achievement	Influencing Factors
Understand the Goals	- Effort to clarify project goals. - CL motivated planning commitment. - CON and DT focused on own goals. - CL's basis for design misleading. - Roles unclear (user, operator, client)	- Commitment to planning. - Motivation: success perspectives. - Tendering method. - Organizing skills. - Client's ability to define roles.
Reduce Uncertainty	- Effort made to reduce uncertainty. - Regular uncertainty analyses.	- Commitment to planning. - Project-related factors. - Political Environment.
Apply Realistic Estimates	- The CON got too short time to prepare the schedules and project documents. - The DT will use more time than planned. Much rework.	- Commitment to planning. - Feedback capabilities. - Project-related factors.
Improve Efficiency	- CL uses resource to assist the CON. - CON has not prioritized planning. - Ineffective and expensive meetings.	- Commitment to planning. - Tendering method. - Organization skills. - Coordination skills.
Establish Basis for Control	- There is no baseline for design. - No baseline for construction until four months after the construction works started. - Decision and drawing delivery plans not ready on forehand. - The CON's quality plan was insufficient (needed adjustment). - The plans are not linked together. - Design and construction not integrated. - DT established their own plans.	- Commitment to planning. - Planning skills. - Tendering method.
Determine Project Status	- Compare actual performance to plans. - Limited design progress measurements. - They are 6 weeks behind schedule according to progress plan.	- Commitment to planning. - Planning skills. - Control of subcontractors' works.
Evaluate Performance	- Not able to define reasons for delays. - Don't measure productivity of workers. - The CL has requested a plan of action from the CON. - The CON does not have a plan of action to get back on track.	- Commitment to planning. - Planning skills.
Manage Actual Changes	- Plans are updated on a daily basis. - Difficult process ahead to solve the issues between CON and CL. - The plan of action not ready yet; not activated.	- Commitment to planning. - Communication. - Cooperation. - Tendering method.

Table 34 - Results Case 1: Objective Achievement and Influencing Factors.

5.2.2 Case 2: Norwegian University of Life Sciences

In this section the objective achievements and influencing factors of this case study are presented.

5.2.2.1 Understand the Goals

Do the planners know what needs to be done to accomplish the project goals?

Objective Achievement

Interviews: The planners emphasized the operational project goals and had clear plans on how to accomplish those goals. Time was a priority of most interviewees due to tight schedules.

The interviews explained that the CL, CON and DT had a three months interaction phase before the construction work started, reviewing critical areas and trying to locate the optimal solutions. However, some of the interviewees noted that they didn't think that this opportunity was fully utilized.

The CL noted that they included the user, operator and owner as well as The Directorate for Cultural Heritage throughout the project to make sure that their needs were met. The CL also noted that to achieve the shortest possible construction time and to do work in a rational order they insisted that the CON and DT applied a Lean methodology for both design and construction.

The PPM noted that to achieve the operational goals the CON focuses on reducing waste during production by doing the activities in a rational order and by removing obstacles before they occur.

The DT explained that to achieve the operational goals they must follow the drawing delivery plans and try to stay within their budgets.

Also see section *5.1.2.1*.

Observations: See section *5.1.2.2.*

Documents: See section *5.1.2.3.* The interaction phase is described in the *Lean Interaction* document as well as in the *Invitation to Bids* document. The purpose of the interaction phase was to form the final meeting structures for the project as well as the communication lines, organization and production progress.

The intention of applying Lean is described in the *Lean Interaction* document as to clarify contract terms, descriptions and project phases, but also the will, objectives and intention of all the parties involved within the project. In that same document success criteria for project management were defined, for example: *Proper and rational organization, adequate staffing and expertise at all organizational levels.*

In the project plan a list of CSFs were defined as follows: *Scope clarification, contract with the DT, clarification on cultural heritage matters, good user communication, meeting user needs, replacement property (during construction), good knowledge of the building's condition, organizing and control, progress planning and coordination, interdisciplinary control, roles and responsibilities and how to handle change.*

It is described in the *Invitation to Bids* document that the contract with the DT and CON are evaluated on both price (65%) and expertise of key personnel (35%).

Influencing Factors

The table below illustrates what factors influenced the achievement of *Understand the Goals*.

Factor	Description	Source of evidence
Commitment to planning	The participants were committed to planning.	Interviews, Observations, Documents
Motivation	Different success perspectives among planners. However, they aimed at the same project goals.	Interviews, Observations, Documents
Tendering Method	Ensures expertise of key personnel.	Documents

Table 35 - Factors Case 2: Understand the Goals

5.2.2.2 Reduce Uncertainty

Do the planners take actions to reduce and reveal uncertainty?

Objective Achievement

Interviews: The CL and the CON explained that before the detailed design and construction phase they implemented a demolishing phase to reveal and remove uncertainties. They now see that they failed to reveal many critical design features of the old building. The PPM noted that many interfaces between demolish contractor and general contractor were not clarified and they did not involve a person with construction expertise in the demolition phase, as he had recommended on forehand. Due to this the uncertainties are reveled in the construction phase instead which then causes rework for the designers and delays in construction. The PPM noted that this is a very expensive way to produce. In his mind the construction works started too early, before the uncertainties were revealed and the design was ready. The interviews explained that due to the long project lifetime modernization of the project was needed, causing rework for them.

The DT noted that the unforeseen events from the construction site affected them a great deal and caused much rework for them.

The interviewees noted that they use BIM modeling to reveal and reduce uncertainty during design and construction.

Observations: During the Construction site tour the investigator was shown some unexpected design features of the old building which had been revealed during the demolishing phase and/or the construction phase, e.g. the roof structure and aspects of the basement/groundwork. The construction workers had access to 50” led screens at each floor of the building, where they could access the BIM Model to view specific design features.

Documents: It is described in the project plan that the demolishing phase should take place as early as possible in parallel with detailed design phase to identify and remove uncertainties regarding the building's condition and hidden elements. The main uncertainties identified in the project plan as: *Ground conditions and foundations, market uncertainty, roof insulation, Lean in the construction phase, shifting project managers,* and *delays with recruitment of contractors.*

Regular uncertainty analysis throughout the project described in the project plan. It is explained that they apply tornado diagrams and uncertainty matrix among other tools in their uncertainty analysis.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Reduce Uncertainty*.

Factor	Description	Source of evidence
Commitment to planning	The CL and CON showed effort to reveal and reduce uncertainties. The CL failed to follow PPM recommendations, some critical elements not revealed.	Interviews, Observations, Documents
Project-related factors	The old building's design features were unpredictable.	Interviews, Observations, Documents.
Political environment	Political environment affected the long project lifetime and the need for modernizing the project; rework and scope changes.	Interviews

Table 36 - Factors Case 2: Reduce Uncertainty

5.2.2.3 Apply Realistic Estimates

Do the planners apply realistic schedule and budget estimates?

Objective Achievement

Interviews: The CL's PM explained that their initial progress estimates for the construction phase were mainly based on their own experience, but with indications form a Porsche Consulting seminar, where the project was planned on forehand. They now see that those estimates were too optimistic. The PM intends to include a professional progress planner in his next project in the detailed design phase to get more realistic estimates for the construction duration.

The interviewees noted that the CON has set up a very good progress plan, but the CL has been pushing the time limits and tolerates too little slack which is necessary to include in this kind of project.

The DT explained that they give the DTC feedback on the time estimates for the drawing delivery plan. They have however failed to predict many (unforeseen) events and have more often than not established unrealistic time estimates, resulting in additional costs. The DTC noted that it was a concern of his how unrealistic the designer's estimates were, especially the ARC's estimates. The ARC noted the exact same thing, that their estimates had unfortunately always been wrong during this project. The ELE noted that they apply figures based on experience to calculate their schedule and budget estimates.

Observations: No relevant observation made on the subject.

Documents: By reviewing the meeting minutes the investigator noted that some decisions and actions exceeded the original deadlines listed in the minutes.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Apply Realistic Estimates*.

Factor	Description	Source of evidence
Commitment to planning	To optimistic estimates.	Interview, Documents
Feedback capabilities	The DT's feedback was not something the DTC could rely on.	Interview
Project-related factors	Unforeseen events affected the planner's estimates.	Interview

Table 37 - Factors Case 2: Apply Realistic Estimates.

5.2.2.4 Improve Efficiency

Are resources coordinated to get work done within the constraints of time, cost and quality?

Objective Achievement

Interviews: The interviewees explained that they use a meeting series of 14, 10, 8, 4, and 1 week meetings to integrate the design and construction process. These meetings are based on the progress plan which also serves as the basis for the DTC to form a detailed delivery plan for the DT. The drawing delivery plan describes what to design and when to deliver the drawings and thus coordinates the designers. The progress plan serves as the basis to coordinate the construction works, by involving subcontractors and suppliers 4 weeks in advance to make sure that everything is ready when the construction works starts in a given area in "week 0".

The DT noted that it is mainly the DTC that participates in the meetings, but they are at the office in case there is something which only they can clarify. It saves them much time; they can work instead of sitting in the meetings.

The DT noted that the drawing delivery process has been very tight, but they have still not missed a single deadline. They work much overtime to stay on track (also due to low staffing), resulting in increased design costs. They explained that exceeding their budget estimates is better than delivering the drawings too late, since that affects (stops) the construction process which is much more expensive than the design process.

Observations: The meetings were well structured, right to the point, with clear agenda, usually based on an action list. An example of a very productive meeting was the 8 weeks meeting: The DT started with a brief presentation on the main meeting topics. Then the meeting participants (17 in total) were spread out into relevant workgroups to solve specific tasks. In the end all participants came together again and a member from each group presented the main decisions or actions to be taken.

Documents: In the *Lean Interaction* document it is explained that the implementation of the building will be in takt/flow within predefined control areas. The DT, in cooperation with the CON, should make a delivery plan in regard to the startup of these control areas. It is described that the 14-10-8-4 and 1 weeks meeting series are intended to coordinate the DT and the CON to ensure the best use of design and construction resources.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Improve Efficiency*.

Factor	Description	Source of evidence
Commitment to planning	The participants were committed to planning.	Interviews, Observations, Documents.
Organization skills	The organization was excellent.	Interviews, Observations, Documents.
Coordination skills	Recourses were coordinated to get work done within the constraints of time, cost and quality	Interviews, Observations, Documents.

Table 38 - Factors Case 2: Improve Efficiency.

5.2.2.5 Establish Basis for Control

Do the planners establish a sufficient basis for monitoring and control?

Objective Achievement

Interviews: The interviewees explained that the whole planning process is integrated by linking action and decision lists, as well as the drawing delivery plan, to the main production progress plan made by the CON. This establishes an adequate basis for monitoring and control, both for the design and construction process.

The CL explained that decision lists are used to clarify important decisions in regard to interfaces between the CON and CL, whereas the action lists are applied to design. The action lists cover issues that must be resolved, someone is made responsible, a deadline is set, and it is determined whether tasks are resolved or not, "finished"/"not finished".

The interviewees explained that the main production progress plan is very clear and readable (made in Excel). The building is divided into control areas which the designers and builders must adapt to. The DT noted that due to a clear production progress and drawing delivery plan they always know *what* drawing to deliver *when*.

Observations: The meeting room was covered with readable progress plans that displayed the main progress for each floor of the building. Also, the tables in the meeting room were covered with drawings of the building. This made the planning more visible.

Documents: The main progress plan provides a basis for monitoring and control, from monitoring an individual construction worker to determine the whole project status.

The action lists included parameters that could determine: *responsibility*, *registered by whom/when*, *priority of task* (high, moderate low), *deadline*, *status* (closed, ongoing, open), *delays* (how many task behind schedule), *the date of closing* (finished/not finished) and *who closed the task*.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Establish Basis for Control*.

Factor	Description	Source of evidence
Commitment to planning	The basis for monitoring and control was very clear.	Interviews, Observations, Documents
Planning skills	The planners had established a sufficient basis for monitoring and control. Good tool for monitoring and control.	Interviews, Observations, Documents

Table 39 - Factors Case 2: Establish Basis for Control.

5.2.2.6 Determine Project Status

Are the planners able to measure and determine the current status of the project?

Objective Achievement

Interviews: The interviewees noted that they can determine the current status of the project by comparing actual performance to the production progress plan for construction, since the plans are all linked together. The progress plan, which is very clear and readable, is divided into small batches controlled by "finished"/"not finished", so they can easily see the status of the construction works. The action lists and the drawing delivery plan also provide similar measurement where the planners can determine what is done and what is not; "delivered"/"not delivered". The interviewees also noted that they compare actual costs to their budgets to see the financial status of the project.

The CL noted that the production progress plan shows that they will deliver the project 6 months after the original finish date.

The DT noted that they keep the delivery besides them at all times to keep track on the progress.

Observations: During the meetings the planners were constantly evaluating which activities must be prioritized to be able to keep progress. The plans provided the necessary basis for decision making and to determine the status of the project.

Documents: The decision plans, action list and the progress plans all provide sufficient parameters to measure and determine the status of the project, both for design and construction. The progress plan, made in Excel, shows the progress for the whole building, but also for each floor, production line and individual activities on a daily basis. The progress plan applies 7 assumptions for controlling construction works in regard to HSE, quality assurance, preceding activities, work space, equipment, drawings and materials. It determines whether each activity is on track or not. It calculates how many man-hours are productive and can tell how many workers are working on site at any given time.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Determine Project Status*.

Factor	Description	Source of evidence
Commitment to planning	The basis for monitoring and control was very clear; able to measure and determine current project status.	Interviews, Observations, Documents
Planning skills	The planners had established a sufficient basis for monitoring and control	Interviews, Observations, Documents
Control of subcontractors' works	Good overview of all construction works (also subcontractors works) and designers.	Interviews, Observations, Documents

Table 40 - Factors Case 2: Determine Project Status.

5.2.2.7 Evaluate Performance

Do the planners know the reason for delays and cost overruns? Do they have a plan of action?

Objective Achievement

Interviews: The CL and the DT noted that the delays are due to unrealistic initial progress estimates, unforeseen circumstances in the old building's design and unfortunate design changes and demands from the user, operator and The Cultural Heritage. The DT noted that the design costs are higher due to much rework and working much overtime to be able to deliver the drawings on time.

The PPM explained that they do a variance analysis to find the cause of delays: *"Why can't we start now? What is the reason?".* He explained that they apply seven assumptions/requirements to control the construction works (see documents below). If these requirements are not fulfilled for a given construction activity, it is postponed until they have resolved the issue. With other words, they stop the production if these requirements are not met. The CON also uses these assumptions to identify the reason for delays and/or cost overruns. The PPM noted that insufficient drawings and description have been the main reason for delays in construction, wherein the reality differs from what is described in the drawings (due to unrevealed conditions of the old building). He explained that they can measure the amount of productive man-hours in the construction works (*PPC*, see section *2.5.2.3*). He noted that almost none of the production lines had gone as planned. In September they sow (ca. 9 weeks after the production started) that there were more man-hours left than originally planned.

The plan of action is to postpone the project's delivery date according to the production progress plan's time estimates. The CL and the CON want to implement the project in a rational way without much rework and extra costs. Their plan of action is to stop the production lines when obstacles occur to prevent more unproductive work.

Observations: During the meetings it was often brought up that either designers or construction workers were unsure how to perform their work due to unrevealed (or recently revealed) conditions of the old building.

Documents: The progress plan applies seven assumptions/requirements which the CON uses to control the construction works. These assumptions are as previously mentioned defined as: *HSE*,

quality assurance, *preceding activities*, *work space*, *equipment*, *drawings* and *materials*. If any of these assumptions are not fulfilled the planners mark the relevant requirement as insufficient (e.g. drawings) and write a short description of what is missing (e.g. drawing incorrect, needs modification).

Influencing Factors

The table below illustrates what factors influenced the achievement of *Evaluate Performance*.

Factor	Description	Source of evidence
Commitment to planning	Due to clear basis for monitoring and control they were able to define the reason for delays.	Interviews, Observations, Documents
Planning skills	The planners knew how to use the methods and tools to determine reason for delays.	Interviews, Observations, Documents
Control of subcontractors' works	Good control of construction and design works: PPC, 7 assumptions, drawing delivery, budgets.	Interviews, Observations, Documents

Table 41 - Factors Case 2: Evaluate Performance.

5.2.2.8 Manage Actual Changes

Do the planners correct and update the plans? Is the plan of actions activated?

Objective Achievement

Interviews: The interviewees noted that they are constantly correcting and updating the project plans, via meetings, e-mails and other communication forms. They noted that they apply monthly reports to update the project status. The CL's PM noted that they have a weekly status meeting, but he would like to change it to brief daily status meetings instead. The CL explained that they have set a new finish date for the project, which is relevant to the updated production progress plan. They aim to deliver the building ready for use in the 1st of January 2016 (originally in the fall of 2015). Additions and changes are managed through change notifications. Additions and changes are managed through change notifications.

The PPM noted that they have a daily discussion with the CL to resolve how to divide additional costs between them. He explained that they push the disagreements and problems to the surface right away to prevent major problems and potential lawsuits when closing the project.

Observations: The decision plan and action lists were updated during meetings.

Documents: In the project plan it is stated that the rehabilitation project should be ready for use in the fall of 2015. However, it is also noted that an alternative is to deliver the project in January 2016, if that ensures better project results in regard to cost and quality. Parts of the project plan had been updated (not the part previously mentioned, about the finish date). By examining the progress plans in Excel it was evident that daily updates were done to keep an overview of the 7 assumptions and the PPC.

Influencing Factors

The table below illustrates what factors influenced the achievement of *Manage Actual Changes*.

Factor	Description	Source of evidence
Commitment to planning	Constantly correcting and updating the plans. Plan B described in the project management plan on forehand.	Interviews, Observations, Documents
Communication	The communication between the CL, DT and CON was good.	Interviews
Cooperation	Trust among CL and CON.	Interviews

Table 42 - Factors Case 2: Manage Actual Changes.

5.2.2.9 Summary

The table below shows the main results regarding how well the objectives were met at case 2 and what influencing factors affected the achievement of the objectives for planning, scheduling and control.

Objective	Objective Achievement	Influencing Factors
Understand the Goals	- Effort to clarify project goals. - Following clear progress plans. - Planning commitment. - Applying Lean thinking: Reduce waste.	- Commitment to planning. - Motivation: success perspectives. - Tendering method.
Reduce Uncertainty	- Effort made to reduced uncertainty: demolishing phase; failed to reveal many critical conditions in old building. - Regular uncertainty analyses.	- Commitment to planning. - Project-related factors. - Political environment.
Apply Realistic Estimates	- Planning effort on forehand optimistic. - Progress plan good, but too little slack. - The DT's estimates too optimistic.	- Commitment to planning. - Feedback capabilities. - Project-related factors.
Improve Efficiency	- Coordinating efforts; design and construction. - Meetings well organized. - scheduling compression: overtime.	- Coordination skills. - Commitment to planning. - Organization skills.
Establish Basis for Control	- Clear basis for monitoring and control. - Design and construction integrated. - Plans linked together.	- Commitment to planning. - Planning skills.
Determine Project Status	- Compare actual performance to plans. - Could measure project status in design and construction. - 6 months after initial finish date.	- Commitment to planning. - Planning skills. - Control of subcontractors' works.
Evaluate Performance	- Could identify reason for delays and cost overruns. - Could measure productivity. - Had a plan of actions.	- Commitment to planning. - Planning skills. - Control of subcontractors' works.
Manage Actual Changes	- Plans are updated on a daily basis. - Manage according to progress plan. - Deal with conflicts as they appear.	- Commitment to planning. - Cooperation. - Communication.

Table 43 - Results Case 2: Objective Achievement and Influencing Factors.

5.3 Comparing the Methods

This section addresses research question **2 a)** and **b)**, where the planning methods are evaluated by applying a SWOT analysis. The evaluation is based on how capable the methods are to achieve the objectives of planning, scheduling and control, as well as their ability to deal with the influencing factors that contribute to the achievement of those objectives. As previously stated, the two methods examined in this study are:

a) The traditional project management planning method.

b) The Lean construction planning system.

The objectives for planning, scheduling and control are defined in section *5.2*.

5.3.1 SWOT Analysis

The SWOT analysis is based on the research data collected for this study (interviews, observation and documents), with focus on the main findings from research question 1 presented in section *5.1.2.9* and *5.2.2.9*.

As previously explained, the strengths and weaknesses are internal aspects (e.g. capabilities, resources and processes), whereas opportunities and threats are external aspects (e.g. environment and industry). One should build on the strengths, eliminate the weaknesses, invest in the opportunities, and identify the threats. Strengths and weakness are items which one can control, whereas opportunities and threats are items which one can impact, but not control.

The table below shows the strengths (S), weaknesses (W), opportunities (O) and threats (T) for the two approaches examined in this study.

SWOT analysis			
Objective	**Traditional approach**	**Lean approach**	**Lessons learned**
Understand the Goals	**S**: Resources assigned to clarify goals. **W**: Stakeholders emphasize own goals. **W**: Only few participants assign resources to planning.	**S**: Resources assigned to clarify goals. **S**: Mutual goals; eliminate waste. **S**: Everyone assign resources to planning.	Lean more favorable.
Reduce Uncertainty	**S**: CL assigned resources to reduce uncertainty. **W**: CON not as committed to planning (additional funding). **T**: Politics (project life time).	**S**: Resources assigned to reduce uncertainty. **W**: Capabilities and Process; failed to reveal uncertainty. **T**: Politics (project life time).	Similar performance. Great effort by CL at both projects.
Apply Realistic Estimates	**S**: Feedback opportunity. **W**: Capabilities: poor estimates.	**S**: Feedback opportunity. **S**: PPM's capabilities: good progress estimates. **W**: CL and DT capabilities: poor estimates.	Lean more favorable.
Improve Efficiency	**W**: Coordinating resource: not showing efficient results. **W**: Planning process. **W**: CON: Capabilities and/or commitment lacking.	**S**: Coordinating resources: overtime, deliver on time. **S**: Planning process. **S**: Capabilities; organization.	Lean more favorable.
Establish Basis for Control	**W**: Capabilities/commitment to planning: plans inadequate. **W**: Planning process: design and construction not integrated.	**S**: Capabilities/commitment to planning: clear control basis. **S**: Planning process: design and construction integrated.	Lean more favorable.
Determine Project Status	**S**: Capabilities: can determine construction status. **W**: Capabilities: cannot determine design status.	**S**: Capabilities: can determine project status.	Lean more favorable.
Evaluate Performance	**W**: Capabilities: don't know reason for delays. **W**: Capabilities: Don't measure productivity. **W**: Capabilities: No plan of action.	**S**: Capabilities: know reason for delays. **S**: Capabilities and processes: Measure productivity. **S**: Capabilities: Plan of action.	Lean more favorable.
Manage Actual Changes	**S**: Process: Daily updates. **W**: Capabilities and process: issues between CON and CL.	**S**: Process: Daily updates. **S**: Capabilities: issues resolved right away.	Lean more favorable.

Table 44 - SWOT analysis: comparing the methods

5.3.2 Lessons Learned

The SWOT analysis clearly shows that the Lean approach was more successful in regard to meeting the objectives for planning, scheduling and control in this study. The only objective which the Lean approach did not exceed the traditional approach was *Reduce Uncertainty*. However, it should be noted that the Lean planners showed extensive effort to reduce uncertainty, but the 115 year old building was very unpredictable and full of surprises, making the planners look bad.

Since this study only compares two projects one must take into account that the results could have been the other way around, for example if the planners applying the traditional approach had great planning skills and the planners applying the Lean approach had little or no planning skills. This means that one cannot conclude that the Lean approach is more successful that the traditional approach in meeting the objectives for planning, scheduling and control based on this study alone. However, one clearly sees the alignment of the study findings to the teachings of e.g. Koskela, Ballard and Howell, in regard to the weaknesses of the traditional approach and the strengths of Lean Construction.

Every individual who had tried Lean construction stated that they were not interested in going back to applying the traditional approach of planning, scheduling and control.

In the following sections areas of improvement and possible reason for failure is briefly addressed for each method.

5.3.2.1 The Traditional Approach

This method's failure to meet the criteria for successful planning, scheduling and control is in the investigator's mind mainly due to the CON's lack of commitment to planning as well as lack of tool understanding. The chosen tendering method in this particular project made matters even worse since the CL did not have the opportunity to influence the planning process as much as they felt was necessary to improve the efficiency and progress in general. In the investigators mind the evaluation criteria for the contract, only based on price, was unfortunate as well, due to how restricted the CL is to the CON's ability to plan and implement the project.

The CL's PM explained that she took over the project from another PM in the summer of 2013. Also the original DT replaced by another due to the interests of the main CON. It came as a surprise to the investigator that many of the interviews noted that they did not feel that they were missing any techniques or tools to maintain sufficient control of the project.

Of Kerzner's typical reasons for planning failure (see section *2.2.1.4*) the following reasons are relevant for case 1:

- Plans are based on insufficient data.
- People are not working toward the same specifications.
- Financial estimates are poor.
- Little attempt is being made to systematize the planning process.
- The ultimate objective is not in focus by everyone.
- The staffing requirements were not a priority.
- Not enough time has been given for proper estimating.
- Failed to ensure that personnel with the necessary skills were available.
- People are consistently shuffled in and out of the project with little regard for the schedule.

5.3.2.2 The Lean Approach

Even though the SWOT analysis showed promising results for the Lean approach to build on, many of the planners noted during the interviews that they were unsatisfied with their performance and did not feel that they had achieved Lean to the extent they had hoped for. However, in the investigators mind, this should be viewed differently. In the investigators opinion, it was due to good planning methods and tools, commitment to planning and sufficient planning skills that the planners were able to identify the reason for delays and cost overruns. Hypothetically, if they would have applied a more traditional approach it is likely that they would have achieved an even worse outcome and definitely not been able to identify the reasons for the delays as precisely as they did by applying Lean, simply because many of the Lean measuring parameters are not provided in the traditional techniques and tools (even though the tools are applied correctly). The ELE similarly stated that if they had used a traditional approach to progress planning and control they would have failed to keep progress.

It was noted by the interviewees that managers had shuffled in and out of the project due to burnout. The CL's first PM had resigned as well as the head ARC. The DT noted that they had been working 2-3 weekends and most evenings for the past months to be able to stay on track. In the investigators mind this should be a concern of the executives to prevent further physical or mental collapse caused by overwork and stress.

Of Kerzner's typical reasons for planning failure the following reasons are relevant for case 2 (Kerzner, 2013)

- Plans encompass too much in too little time.
- Financial estimates are poor.
- Plans are based on insufficient data.
- Project estimates are best guesses, and are not based on standards or history.
- People are consistently shuffled in and out of the project with little regard for schedule.

6 Conclusions

In this chapter the main findings are presented as well as discussing relevant research topics for further research.

6.1 Main Findings

The main findings from the study are presented in the order of the research questions.

6.1.1 Main Findings: Research Question 1

The literature review revealed that to be able to define the CSFs for planning, scheduling and control one must first understand and define the concept of success and the difference between criteria and factors.

Since scheduling is just one part of the planning effort the two aspects have been merged and will be referred to as *planning* in the following presentation. The figure below illustrates the objectives (criteria) by which planning success can be judged (see description of the objectives in section *5.2*). If these objectives are fulfilled, planning can be viewed as successful. The figure also illustrates what influencing factors were of most importance for the achievement of these objectives, according to the study findings.

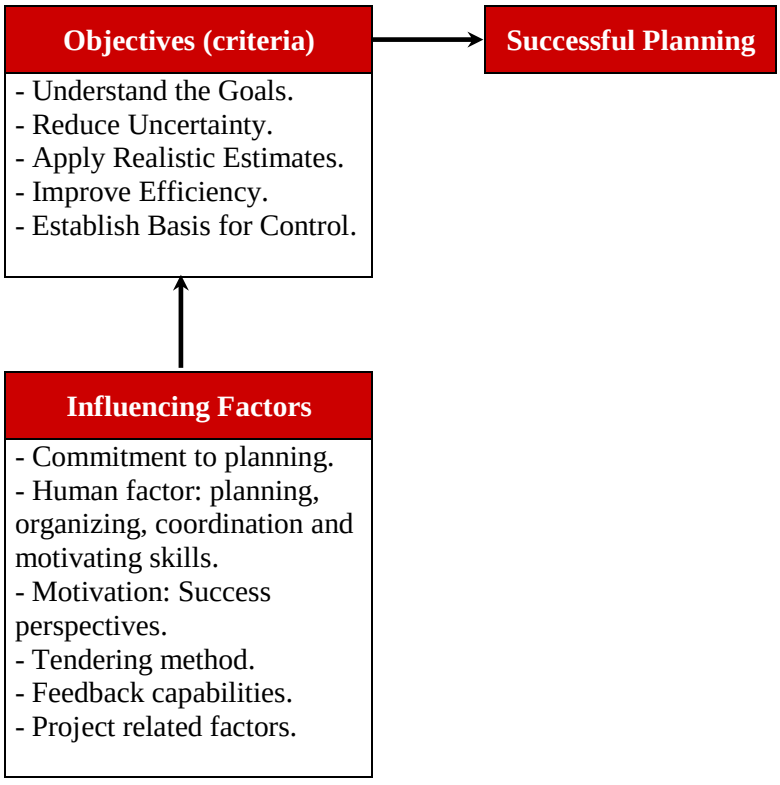


Figure 26 - Successful Planning: Criteria and factors.

The figure below illustrates the objectives (criteria) by which successful control can be judged. If these objectives are fulfilled, control can be viewed as successful. The figure also illustrates what influencing factors were of most importance for the achievement of these objectives, according to the study findings.

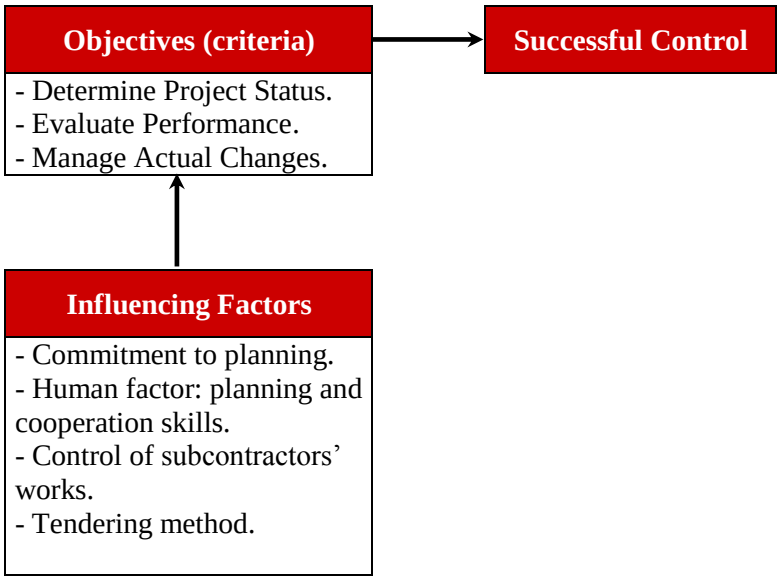


Figure 27 - Successful Control: Criteria and factors.

Of the factors which influenced the achievement of the planning and control objectives studied, *commitment to planning* can be assessed as a CSF, based on the literature review as well as the study findings.

One of the main findings of this study is that successful planning, scheduling and control, in the construction and design phase of construction projects, does not necessarily equal project management success. With other words, planning, scheduling and control can be sufficient during this phase without the project being completed on time and within cost. This can also be the other way round, when planning, scheduling and control is insufficient but the project is still delivered on time and within cost.

6.1.2 Main Findings: Research Question 2

Both methods applied to the projects examined in this study failed to achieve project management success during the time period of this research, meaning that they failed to fulfill the success criteria of completing tasks within the constraints of time, cost and quality. However, the study findings showed that the Lean approach achieved more successful planning and control than the traditional approach. This study by itself can however not conclude the ultimate capabilities of these methods since it only examined two projects.

6.2 Further Research

This research mainly focused on the success factors for planning, scheduling and control and not on the measurement itself, namely the key performance indicators (KPI's). To better assess the capabilities of the managements methods further research could focus on identifying the KPI's for planning, scheduling and control and linking them to the influencing factors. If sufficient relationships between the KPI's and the influencing factors can be identified, useful information in regard to successful planning, scheduling and control could be provided. This could help clients to select appropriate methods for planning, scheduling and control in their design and construction projects.

7 References

Aasland, K., & Blankenburg, D. (2012). An analysis of the uses and properties of the Obeya. In *2012 18th International ICE Conference on Engineering, Technology and Innovation*, 1–10.

Alarcón, L. (1997). *Lean Construction*. Netherlands: CRC Press.

Anumba, C., Kamara, J. M., & Cutting-Decelle, A.-F. (2006). *Concurrent Engineering in Construction Projects*. New York: Taylor & Francis

Ballard, G. (2000a). Lean Project Delivery System. *LCI White Paper*, *8*, 1-7.

Ballard, G., & Howell, G. (1998). Implementing Lean Construction: Understanding and Action. *Proceedings IGLC '98, Brazil.*

Ballard, G., & Howell, G. (2003). Lean project management. *Building Research & Information*, *31*(2), 119.

Ballard, G. (2000b). *The Last Planner System of Production Control.* Birmingham: The University of Birmingham.

Best, R., & Valence, G. de. (2007). *Design and Construction*. United Kingdom: Elsevier Science Ltd.

Borrego, M., Douglas, E., & Amelink, C. (2009). Quantitative, Qualitative, and Mixed Research Methods in Engineering Education. *Journal of Engineering Education*, *98*(1), 53–66.

Bowen, P. A., Cattel, K. S., Hall, K. A., Edwards, P. J., & Pearl, R. G. (2012). Perceptions of Time, Cost and Quality Management on Building Projects. *Australasian Journal of Construction Economics and Building*, *2*(2), 48–56.

Chan, A. P. C., Scott, D., & Chan, A. P. L. (2004). Factors affecting the success of a construction project. *Journal Of Construction Engineering And Management-Asce*, *130*(1), 153–155.

Chitkara, K. K. (1998). *Construction Project Management*. New Delhi: Tata McGraw-Hill Education.

Christensen, C. R., Andrews, K. R., Bower, J. L., & Learned, E. P. (1973). *Business policy: text and cases*. Location unknown. R. D. Irwin.

Cooke-Davies, T. (2002). The "real" success factors on projects. *International Journal of Project Management*, *20*(3), 185-190.

Creswell, J. W. (2013). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. United States of America: SAGE Publications.

De Wit, A. (1988). Measurement of project success. *International Journal of Project Management, 6*(3), 164-170.

Dyson, R. G. (2004). Strategic development and SWOT analysis at the University of Warwick. *European Journal of Operational Research*, *152*(3), 631–640.

Eisenhardt, K. (1989). Building Theories from Case-Study Research. *Academy Of Management Review*, *14*(4), 532–550.

Forbes, L. H., & Ahmed, S. M. (2010). *Modern Construction: Lean Project Delivery and Integrated Practices*. Florida: CRC Press.

Herriott, R. E., & Firestone, W. A. (1983). Multisite Qualitative Policy Research: Optimizing Description and Generalizability. *Educational Researcher*, *12*(2), 14–19.

Hill, T., & Westbrook, R. (1997). SWOT analysis: It's time for a product recall. *Long Range Planning*, *30*(1), 46–52.

Hornby, A. S. (2011). *Oxford Advanced Learner's Dictionary of Current English*. Oxford: Oxford University Press.

Johnson, S. B. (2006). *The Secret of Apollo: Systems Management in American and European Space Programs*. United States of America: JHU Press.

Jugdev, K., & Müller, R. (2005). A Retrospective Look at Our Evolving Understanding of Project Success. *Project Management Journal*, *36*(4), 19-31.

Kerzner, H. (1998). *In search of excellence in project management: successful practices in high performance organizations*. Location unknown. Van Nostrand Reinhold.

Kerzner, H. (2013). *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*. New York: John Wiley & Sons.

Kidder, L. H., & Smith, E. R. (1986). *Research Methods in Social Relations* (5th Ed.). Location unknown. Holt, Rinehart, and Winston.

Koontz, H. (2010). *Essentials of Management*. New Delhi: Tata McGraw-Hill Education.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*. Stanford: Stanford University.

Koskela, L. (2000). *An exploration towards a production theory and its application to construction*. Finland: VTT Technical Research Centre of Finland.

Lean Construction Institute. (2013). Lean Construction Institute: Report from LCI-Peru. *Lean Construction Institute*, 1-5.

Lichtig, W. A. (2005). Sutter Health: Developing a Contracting Model to Support Lean Project Delivery. *Lean Construction Journal*, *2*, 105–112.

Lim, C. S., & Mohamed, M. Z. (1999). Criteria of project success: an exploratory re-examination. *International Journal of Project Management*, *17*(4), 243–248.

McCarthy, J. F. (2010). *Construction Project Management*. Westchester: Pareto.

Morris, P. W. G., Pinto, J. K., & Söderlund, J. (2011). *The Oxford Handbook of Project Management*. Oxford: Oxford University Press.

Mubarak, S. A. (2010). *Construction Project Scheduling and Control*. New Jersey: John Wiley & Sons.

Munns, A. K., & Bjeirmi, B. F. (1996). The role of project management in achieving project success. *International Journal of Project Management*, *14*(2), 81–87.

Office of Government Commerce. (2002). Contract management guidelines: Principles for service contracts. *Crown Copyright*, 1-57.

Office of Government Commerce. (2007). Achieving Excellence Guide 6: Procurement and Contract Strategies. *Crown Copyright*, 1-24.

Olsson, H., & Sörensen, S. (2003). *Forskningsprosessen: kvalitative og kvantitative perspektiver*. Norway: Gyldendal Akademisk.

Philliber, S. G., Schwab, M. R., & Sloss, G. S. (1980). *Social research: Guides to a Decision-making Process*. Location unknown. Peacock.

Pierce Jr., D. R. (2013). *Project Scheduling and Management for Construction*. New Jersey: John Wiley & Sons.

Pinto, J. K., & Slevin, D. P. (1988). Critical Success Factors Across the Project Life Cycle. *Project Management Journal*, *19*, 67.

Pinto, J. K., & Prescott, J. E. (1990). Planning and Tactical Factors in the Project Implementation Process. *Journal of Management Studies*, *27*(3), 305–327.

Project Management Institute, Inc. (2013). *A Guide to the Project Management Body of Knowledge* (4th Ed.). United States of America: Author.

Popescu, C. M. (1995). *Project Planning, Scheduling, and Control in Construction: An Encyclopedia of Terms and Applications*. New Jersey: John Wiley & Sons.

Project Management Institute. (2007). *Practice Standard for Scheduling*. Newtown Square: Project Management Inst.

Robson, C. (1993). *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*. United Kingdom: Blackwell Publishing.

Rockart, J. F. (1979). Chief executives define their own data needs. *Harvard Business Review*, *57*(2), 81–93.

Rundell, M. (2005). *Macmillan English Dictionary: For Advanced Learners of American English*. Oxford: Palgrave Macmillan.

Samset, K. (1998). *Project management in a high-uncertain situation*. Norway: Norwegian University of Science and Technology.

Sinclair, J. M. (2001). *Collins Concise Dictionary*. United Kingdom: HarperCollins.

Statsbygg. (2014). *About Statsbygg*. Retrieved May 2, 2015, from http://www.statsbygg.no/Om-Statsbygg/About-Statsbygg/

Statsbygg. (2015). *NMBU, Urbygningen*. Retrieved May 3, 2015, from http://www.statsbygg.no/Prosjekter-og-eiendommer/Byggeprosjekter/NMBU-Urbygningen/

Stevenson, A. (2010). *Oxford Dictionary of English*. Oxford: Oxford University Press.

Suzaki, K. (1987). *New Manufacturing Challenge: Techniques for Continuous Improvement.* New York: Simon and Schuster.

Tuckman, B. W., & Harper, B. E. (2012). *Conducting Educational Research*. United Kingdom: Rowman & Littlefield Publishers.

Turner, J. R., & Müller, R. (2003). On the nature of the project as a temporary organization. *International Journal of Project Management*, *21*(1), 1–8.

Walter, E. (2008). *Cambridge Advanced Learner's Dictionary*. United Kingdom: Cambridge University Press.

Womack, J. P., & Jones, D. T. (2010). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. United Kingdom: Simon and Schuster.

Wysocki, R. K. (2011). *Effective Project Management: Traditional, Agile, Extreme*. New York: John Wiley & Sons.

Yin, R. K. (2009). *Case Study Research: Design and Methods* (4th Ed). United States of America: SAGE Publications.

8 Appendixes

8.1. Appendix A

The interview guide applied during the interviews.

Interview Guide

Project name:			
Interviewee:			
Date of meeting:	**Time:**	**Location:**	**Minutes written by:**

Meeting attendees:	**Minutes sent to:**

Comment:

This interview guide is made for a case study research where the aim is to identify the CSFs in planning, scheduling and control for design and construction projects using either Lean construction planning systems or traditional project management planning methods. The research focuses on to demonstration projects provided by Statsbygg, one project that uses Lean construction planning system and one that use traditional project management planning method. The case study is part of a master thesis. The following questions were formed to highlight relevant issues. The interview will be transcribed and sent to the interviewee for approval.

	Project strategy:	

	- How was the project strategy developed?
	  o What is the main focus?
	- Were there made any changes to the project strategy?
	  o If, yes, what is the main focus?	

	Objectives and goals in planning, scheduling and control:	
	- How are the objectives and goals identified? - How are the objectives and goals managed and achieved? - How is the next milestone and project phase reached? - How are the opportunities and options identified and managed? - How do you measure performance?	

Effectiveness:
- How do you measure effectiveness in planning, scheduling and control?
Stakeholders:

- How do the different stakeholders affect the planning, scheduling and control?
  o Internal/External stakeholders
- What stakeholders are involved in the planning phase?
  o How are they involved?
- How are the needs and requirements of the stakeholder met?
- What is done to make sure that the right stakeholders are included?

Tools:

- What tools do you use for planning, scheduling and control at the stage you in are now?
- How do the tools for planning, scheduling and control help you in this phase?
- What do the tools plan and/or observe?
  o What factors are important for effectiveness when using the tools?
  o What factors are likely to cause delays, cost overrun and/or other errors?
- Who uses and manages the tools?

Meetings:

- How do you manage your meetings?
  o What are the different meeting types?
  o How frequently are the meetings?
  o How do you handle the minutes from the meetings?
  ▪ How do document your data?

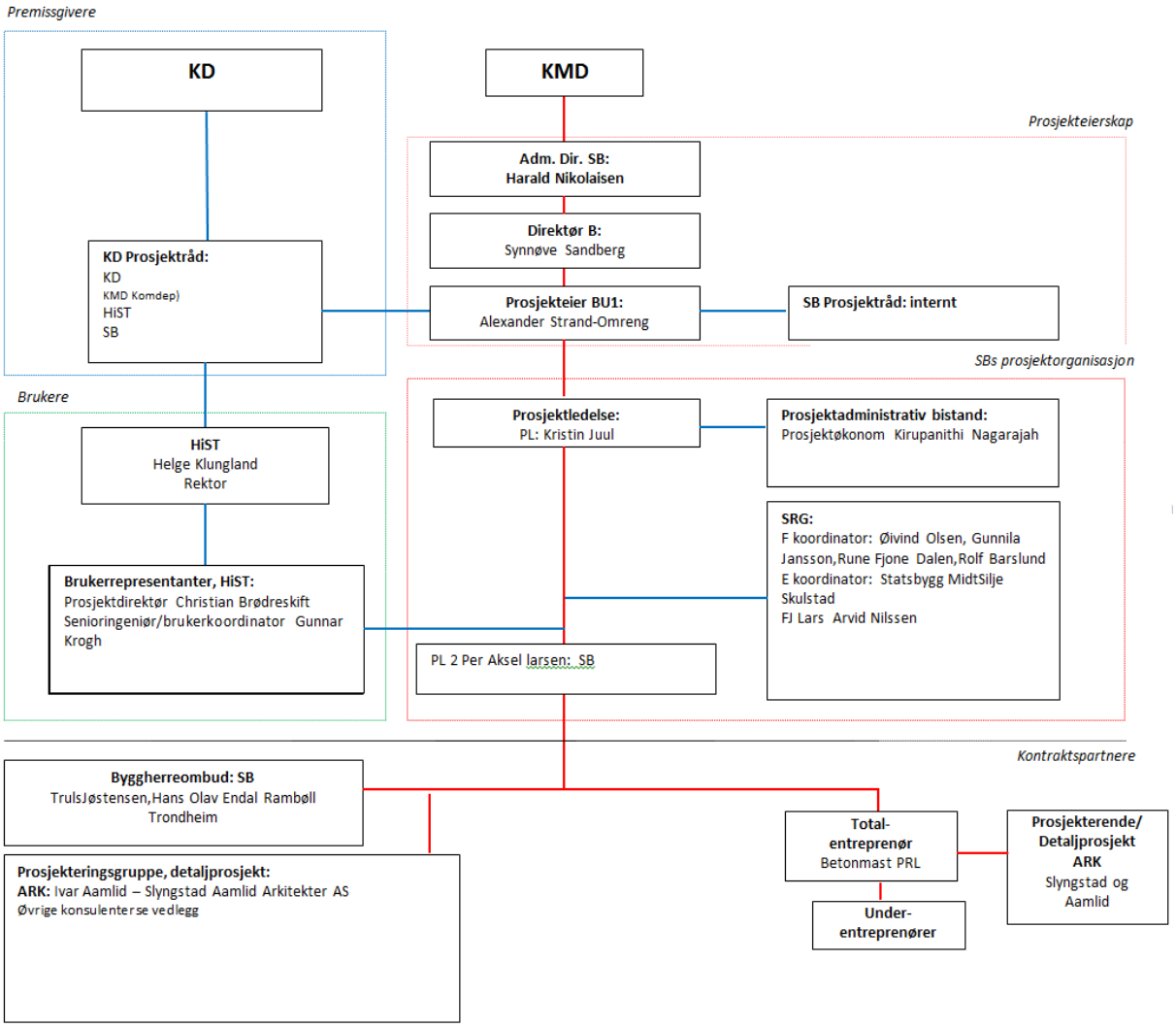
Motivations:

- Are there any rewards in case of successful planning, scheduling and control?
  o If yes, what are they?
- Are there any penalties in case of delays?
  o If yes, what are they?
- What happens if the project goes over budget?
- Are there any other forms of incentives in this phase?
  o If yes, what are they?
- What suggestions do you have for incentives that could lead to more successful project planning, scheduling and control?

Professional experience:
- What factors are critical for success for planning in this phase? - What factors are critical for success for scheduling in this phase? - What factors are critical for success for control in this phase?
Lean vs. traditional approach:
- What are the strengths, weaknesses, opportunities and threats of the different planning methods?
The Project:
- How long have you been involved in this project? - Do you have the knowledge you need about the project?
Other topics?

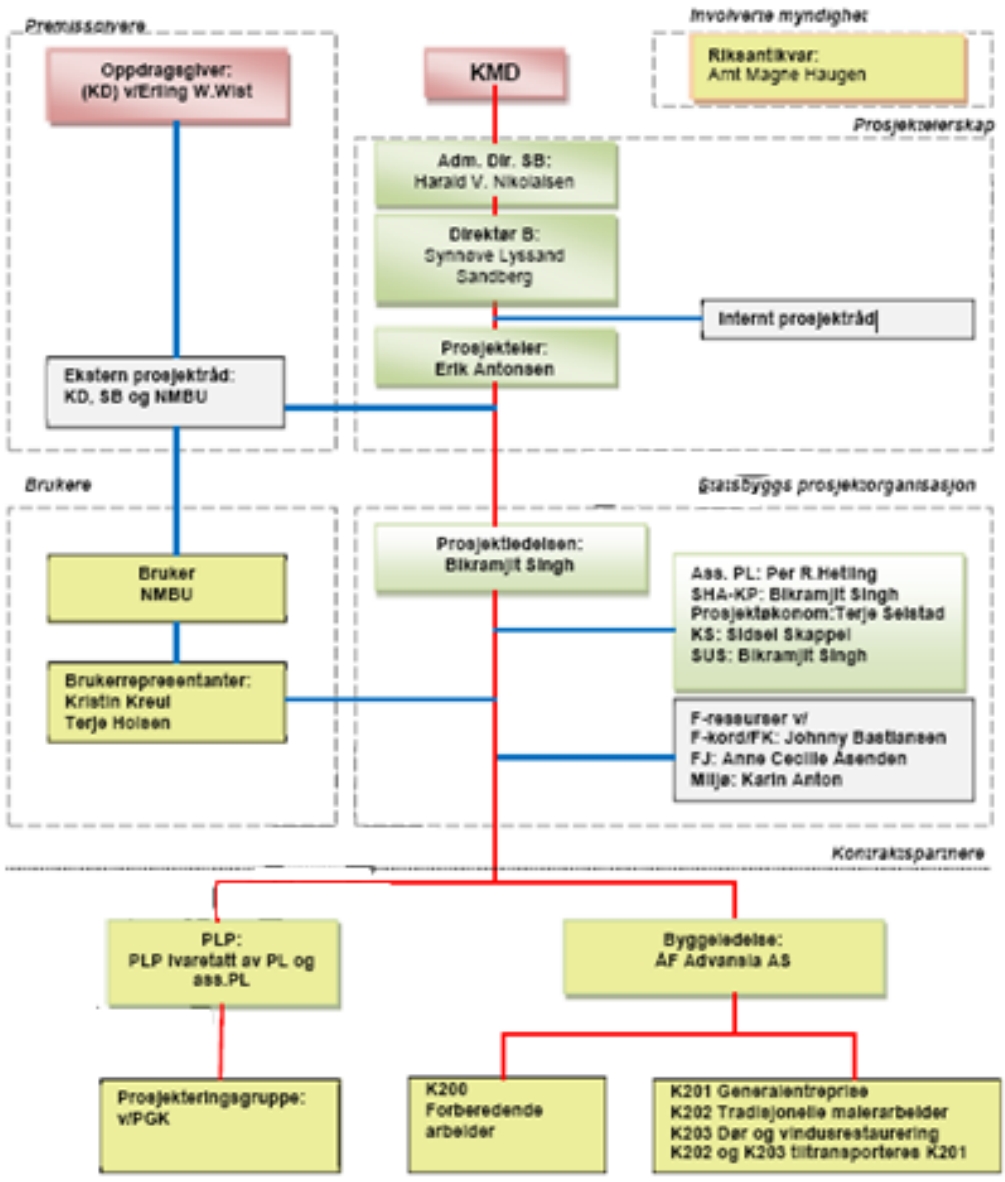
8.2 Appendix B

Organizational chart at Sør-Trøndelag University College (not updated).



8.3 Appendix C

Organizational chart at The Norwegian University of Life Sciences (not updated).



8.4 Appendix D

Statsbygg´s lifecycle model.