Digitalization in a Lean Constructing Project: *A case study of the new life Science building project*

TDT4501 - Project Thesis

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Abstract

This project is a case study of the new life science building of the University of Oslo. When finished, the life science building will become Norway's most complex educational building and in the course of the construction employ over 2000 employees. On average, an employee in the construction business conducts 90,4% productivity, compared to an average of 129,8% work productivity in all on land work in Norway [1]. The goal of this project is to identify critical factors why there is this considerable gap in labor productivity in the construction business, compared to other on land industries. Not only is the problem of labor productivity, but it also fails to deliver on time, or even deliver at all. A problem that was known to occur in the IT industry. The study conducts an analysis of several topics, which includes working methodology, by some is said to be the critical factor of the rise in productivity and the ability to deliver in IT business. Comparing the use of the methodology in IT and constructing, the project discusses the importance of agile methods to overcome the matter of productivity in the constructing business. Other topics examined is organization structure, and the use of technical tools to streamline productivity and communication in organizations. All these topics will be analyzed first as a litterateur study and then an empirical study, with interviews and observations, of what the employees in The Life Science Project experience concerning the aspects mentioned.

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Chapter 1

Introduction

This chapter introduce the project, and will give overview over topics and deliveries of this project. The Background and Motivation section will give an introduction to why this research is usefull, as well as the motivation. Next, the Research and Question section introduce questions to be answered in this question. The Deliverables section describes what this project is to deliver. Last, the Thesis structure section describe the outline of this project.

1.1 Background and Motivation

The domain of this project consists of several different subjects. The Case chosen is a construction project. The researcher's origin is software development, and the problem discussed is also compared with the ICT-industry. The reason for this comparison is the use of APM in both industries. When comparing the two industries, the comparison is justified; Both have experienced problems in meeting budgets and delivering at the planned deadline and function, as well as experienced increased complexity. This problem is materialized in extensive documentation, change of requirements during production, failing to fix errors, and problems delivering a product that meets the requirements of the users. APM is mainly a structured way for the managers to direct the interaction between actors and participants in the project; thus, cooperation and interaction are a part of the problem space. In addition to using APM, the case object is also utilizing software supporting both management and cooperation.

The variety in problem space makes this research important, not only for the CI-industry and the ICT-industry. Other industries utilizing digital tools or Agile solving complex engineering problems or interaction, will find this research relevant.

Prior research relevant for this project is mainly the paper describing the construction of the Peter B. Lewis Building (PLB), where 3-D modeling was first introduced [2]. 3-D modeling was used both to manage the complexity of the installation, but also led to increased cooperation between different parties within the project. Even though the PLB-project showed promising results in means of cooperation and interaction, the introduction of 3-D modeling was not a single solution to the problem.

Relevant is also the book *Lean methodology in design and construction* [3] describes the making of the Bergen Academy of Art and Design-building, where Lean was one of the essential strategies. The managers of the project wrote this book; hence, the descriptions given are sufficient critical but still relevant as a cite for the project.

Notable literature relevant in this research is, among others, the research in the topic of contractors, and how different aspects of contracts influence cooperation [4, 5]. The Rolfsen & Bruvik paper is discussing the trust in construction project teams [6]. Common for these three papers is that they do not consider the complete problem domain; they lack the inclusion of APM and digitalization. Moreover, the Monplaisir paper concerning CSCW in Agile Manufacturing [7] is, therefore, more relevant but lack the problem domain of the CI.

The motivation for this rearch is to examine a project utilizing Lean in project management, to face the problems mentioned. Furthermore, looking at how a project make use of digital tools, aiding Lean has not been examined before. Taking experience from the ICT-industry, and the use of computer-aided agile development management is also desirable, as well as looking at the problem from a different perspective.

The Construction Industry (CI) has been a significant part of engineering throughout history. Over the past century, the requirements of constructions have become more and more complex. The buildings are getting higher, the tunnels are getting longer, and the roads are getting wider. Sure, the size of things is not equal to the complexity of the construction; however, when considering automated systems, multipurpose functionality, and multiple communication platforms – the complexity is increasing. The increased complexity leads to a significant decline in labor productivity (LP), seen over the past two centuries, mentioned in the article written by SSB [8]. As well, managing these projects is much more intricate then it used to, because of the increased numbers of actors participating in the project.

One can argue that the negative progress in LP in the CI has to do with the increasing complexity, and therefore not a number to consider. Even so, better productivity and efficiency are always something management dicier, simply because of improved marginal cost.

The challenges the CI is experiencing, as well as the process used, are highly similar to what the ICT-industry was facing in the late '80s. The ICT-industry, using the waterfall process [9], often faced the challenge of meeting the budgets and timelines. This breach had the origin in change of requirements during production, challenges in testing, and resultingly failing to deliver a finished product without bugs. These problems have been frequently present when creating large and highly user-interactive software — making for the introduction of agile software development to manage theses problems. Over the years, most of the process- and method-management in ICT is digitilized. Giving tools in which both the software developers and project managers use to aid project progression.

Frank Garry, in 1997, first introduced 3-D modeling in CI, when constructing the Peter B. Lewis Building (PLB). 3-D modeling was used both to manage the complexity of the installation, but also led to increased cooperation between different parties within the project. The paper, describing this project [2], is reporting a change in how actors in the construction react to using computer-aided constructions, in 3-D. Today 3-D modeling is used in almost all construction projects and is known as BiM. Even though the PLB-project showed promising results in means of cooperation and interaction, the introduction of 3-D modeling was not a single solution to the problem.

Furthermore, one has introduced Lean in the CI. The book [3] describes the making of the Bergen Academy of Art and Design-building, where Lean was one of the essential strategies. The object of the Case Study in this research are using experience from this book when managing the constructions.

The motivation for this rearch is to examine a project utilizing Lean in project management, to face the problems mentioned. Furthermore, looking at how a project make use of digital tools, aiding Lean has not been examined before. Taking experience from the ICT-industry, and the use of computer-aided agile development management is also desirable, as well as looking at the problem from a different perspective.

1.2 Research and Question

Under following a list of questions this project aims to answer, using The Life Science Building project as a Case Study.

$RQ1$**: How and why are the project utilizing agile and lean methodology?**

$RQ1.1$**: If any, what challenges is there using these methodologies?**

$RQ2$**: Which digital tools are deployed in this project, aiding Lean Constructing, and how are they being used?**

$RQ2.1$**: Are there any challenges making use of these digital tools?**

$RQ3$**: Are there other factors that influence the use of project methodology or the digital tools used?**

1.3 Deliverables

There will be two main deliverables in this thesis.

Literature review: The first part of this research is a literature review on graphical passwords. A literature review is providing the information needed to decide on the main research hypothesis for my master thesis, and the aim is to fill the gap in research on graphical passwords on mobile devices.

Empirical review: Forklar

1.4 Thesis structure

Chapter 2: Literature Review provides a context for the project thesis and support the discussion as well as the case.

Chapter 3: Empirical Review gives an introduction of the case, and impede how they make use of digitalization in their Lean Strategy, as well as how this support cooperation and knowledge sharing in the organization.

Chapter 4: Analysis and Discussion present the findings from the case study and discuss these. Furthermore, further work is proposed.

Chapter 2

Literature Review

This project's objective is to look at how the construction industry, or precisely how the LSB-project, make use of agile project management methods and digital tools to aid project management. The CI's lust for digitalization is ever-present, and often projects consist of entire departments responsible for digitalization. This chapter is using ICT as a successful case of utilization of digitalization in the context of agile project management.

First, the chapter takes a historical look at ICT and CI, and which factors made both utilize agile project management in the first place – what were the symptoms needed to be fixed? This comparison gives a surprisingly similar line of arguments, where productivity, complexity, failing to meet budgets, and requirements change during project implementation are some — additionally, similarities between the project process makes for comparison.

Secondly, the chapter discussing organizational cooperation, where one looks at software as a tool aiding organizational interaction and interaction. Furthermore, the chapter gives a brief overview of a traditional CI project, as well as a short overview of different agile project management methods as a context for the project.

2.1 A Brief History of Software Engineering

Software engineering is considered one of the newer disciplines of engineering. From 1842, when Ada Lovelace first described the advantages of the Analytical Engine, up to the 1968 NATO Garmisch conference, computer science was not considered an engineering field at all. Back then, engineers found writing code a handcraft, done by the specialists, that could be applied in several disciplines of engineering.

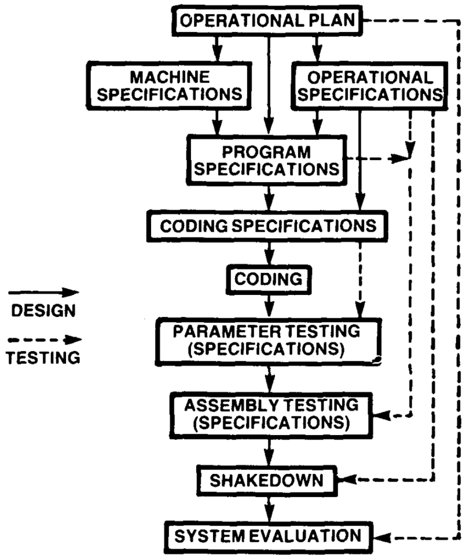

Figure 2.1: Production of a large-program system as presented of Bennington in 1956.

By the 1950s, military initiatives had seen the need for some structure or process that could aid large-scale development. Because there was no standard procedures the industry suffered significant productivity issues. The process used back then is now known as the code-and-fix method. Problems using this method was: (a) products not hitting the needs of the user, (b) code that was barely readable, and (c) not testable. Also, producing software with a team was shown difficult because of a lack of documentation and inexperienced team members.

In 1956 H.D. Bennington wrote a paper: "Production of Large scale Programs." Bennington proposes, among other things, an operational plan. The operational plan included nine phases to prepare a large system program, seen in figure 2.1. The plan is considered the precursor of the waterfall model, introduced by W.W. Royce, with the "Managing the Development of Large Software Systems"-paper, from 1970. What Royce is describing is a way of managing large-scale software development within both cost and time. The Waterfall has since become the dominant software development method used in the industry. The problems both Bennington and Royce saw was the need for process management. The reason for the need for process management was that programs did not meet cost- and time schedule, as well as requirements set. The industry suffered major productivity issues. The resulting product did not meet the expectation of the user, and the requirements needed to be modified, or the development process had to return to the origin. The issues had the source of poorly designed and documented requirements. The need for documentation and requirement specification features that come in to play in more complex software developments, because one could not see the bigger picture when the complexity of the program increased to a certain level.

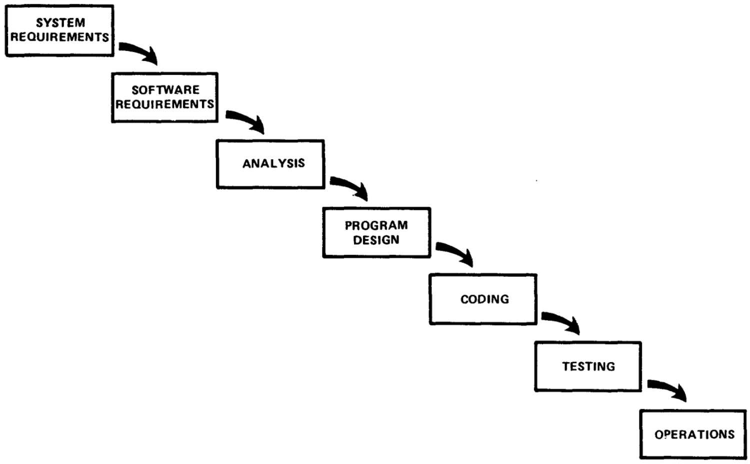

Figure 2.2: Waterfall method as proposed by Royce in 1970. Visualizing implementation steps to develop a large computer program for delivery to a customer.

Further, one wanted to make sure that the code written was performing as intended, which introduced the need for testing. The waterfall model, presented by Royce, seen in figure 2.2, has some modifications to Bennington's Program production, but one can identify notable similarities between the two. A feature for them both is that, to some extent, they proclaim the use of an iterative design process, which has shown to be forgotten in recent years, using the waterfall model. Royce shows the prototype in a illustration, seen in figure 2.3, while in Bennington's paper the iteration is not mentioned, but he does indicate the use of iterations in the later applied foreword.

In 1987 Barry W. Bohem wrote a paper comparing three papers from the past, with how the software industry treats process management of the time. The papers compared includes both Royce's and Bennington's paper. Bohem starts the paper with a quote:

> *"Those who cannot remember the past are condemned to repeat it."* - George Santayana

Even after Royce, the industry still struggled with requirements, documentation, staffing, and testing. Following the process, but forgetting the details resulting in some of the same problems previously recorded, thus the Santayana quote. An interesting detail is Bohem's discovery of the lack of prototyping and iteration, in the interpretation and use of the waterfall model; though both Royce and Bennington promote prototyping in the design phase

> *"Thou shalt not write one line of code until every detailed design specification is completed."* - Software Developer

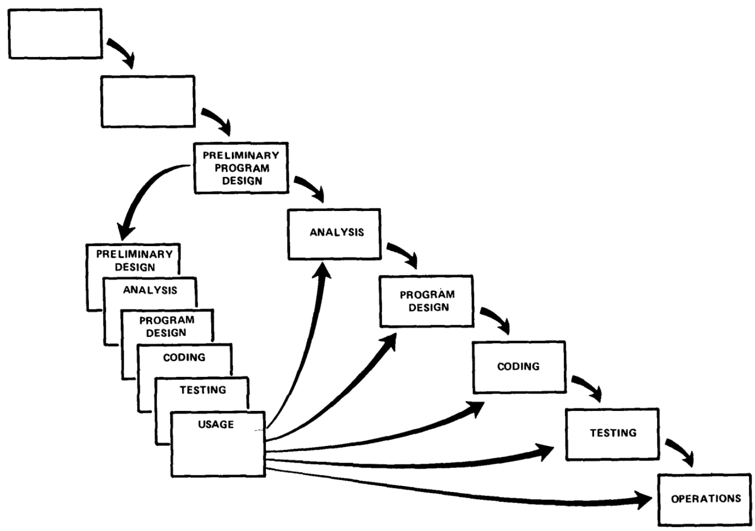

Figure 2.3: Waterfall method as proposed by Royce in 1970, including an iterative process using prototype. Attempting to do the job twice - the first result provides an early simulation of the final product.

The industry, entering the 90s and the 21 century, had a set of structures, processes, and models. Furthermore, it had become a known and highly valued field of engineering. Still, the discussion of productivity- and efficiency was present. Large software developments failed to deliver at the time and cost initially planned, sometimes failing to deliver at all. Some of the repeating problems were: (1) the initial requirements often changed during the development process: forcing the development going back to the origin, costing both time and money; (2) the need of project management during a stage of the process: making sure developers working in parallel being exploited at an accepted level, and knowing what to implement at all times. The process models, such as Waterfall, structure the order of stages, and when to proceed to the next stage, while process methods are more concerned about guidance through each phase. Thus the need for software management methods was present and the introduction of Agile Development as a means to overcome, among others, the two problems mentioned.

One can argue that productivity is an ever fighting battle, but after the introduction of agile development, productivity is shown to have a definite increase in Norwegian ICT-industry. Looking at figure 2.4, comparing ICT and CI, the difference is substantial. Yes, the productivity of CI is not good, but a productivity gain of 478,9% from 1972 until 2017 is to be considered satisfactory. One can see a big leap from the middle of the 90s. Using Labor Productivity measuring how a industry is discussed later in this chapter.

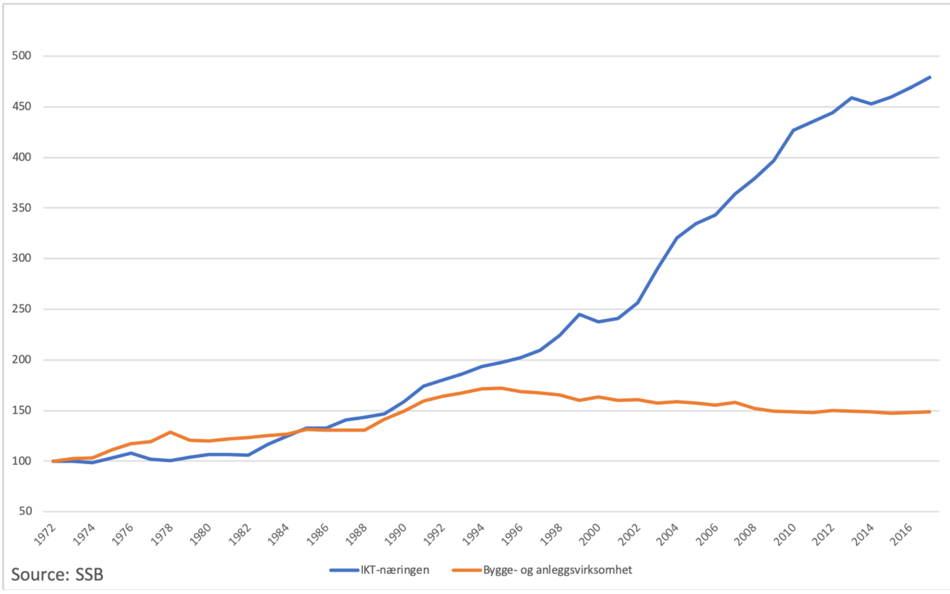

Figure 2.4: Labor productivity; ICT and CI compared from 1972 up to 2017.

2.2 Construction Engineering

This section will introduce the CI as a context for the project, as well som implications and motivation forcing a change in the way CI-projects are managed.

Construction Engineering has been a significant field of engineering throughout history. Originates from the construction of the pyramids. Continuing with Da Vinci, and some of the most skilled people, in the middle ages, forming some of the most known structures of today. In the raging of wars and through the industrial revolution, one could witness the rapid development of both civil and military engineering; as a result, one could now construct both faster and better than ever before.

Over the last century, the requirements of constructions have become more and more complex. The buildings are getting higher, the tunnels are getting longer, and the roads are getting wider. The size of things is not equal to the complexity of the construction. Adding automated systems, multipurpose functionality, and multiple communication platforms, the complexity is ever so present. Take for example a university building, which is no longer simply a place where one can lecture and read. A university building now requires to host highly sophisticated labs for various purposes, as well as several other rooms for different kinds of purposes, and some also multipurpose. Besides, that is just the requirement of the rooms; one needs to consider all the systems added in regards to, among others, ventilation, electricity, sewage treatment, internet, and telecommunication. All these systems- and room requirements, as well as other requirements, makes the construction of the modern building way more complicated than it used to be.

Even though the complexity of the construction is increasing, the process management has, for the most part, been the same — resulting in an unfortunate progress of productivity in CI.

2.2.1 Construction Industry Project as a Context for the Project

The process of constructing, in Norway, follows a pattern described by The Norwegian standard agreements (SSA). The construction process divides into five steps: (1) the early phase: where deciding both the vision of the project and process of project conduction; (2) the procuring of architect or adviser: starting by publishing the project and at the end awarding the best actor with a contract; (3) the design phase: where one produces different levels of design; (4) the procuring of entrepreneur(s): includes deciding on contracts, and choosing the correct contractors for the job; and (5) realization: where conducting the substantive implementation.

The third phase, designing, is typically conducted in three levels of granularity. First, the architect is sketching the over-all concept of the construction and delivering the concept as a set of drawings, models, and specifications. Furthermore, the concept is to realize the intention and vision of the project. Second, often called the pre-project, a team often consisting of architects, project managers, and engineers, is to define the project. The definition results in a set of user- and technical requirements, as well as further developing the functional and physical structure of the project. It is here one sets the budget and goals of the project. The pre-project is ending by handing the result and a proposal of decision for political treatment. The political treatment is known to be time-consuming, often spanning a one-to-two year period. Given the political decision, the requirements and budget set, limits and sets the basis for the rest of the project, as well as the goals used to measure. Third and finally, the detailed design is happening. The result of the detail design is the sketches used in the procurement of contractors — plus, an outline of the awarding strategy used in the next phase. Because of the time-consuming political decision, a new team is often responsible for the detailed design. Documentation of the pre-project is therefore vital. When going into the realization, it is the detail-design-team that is responsible for the project to keep the budget and achieving the goals set by the political decision, which can seem unfair if the pre-project requirements are not manageable.

A typical case is a change of requirements, required by a stakeholder, either during detailed planning or the production-phase. A change often leads to budget-breach, or if not feasible, dissatisfied stakeholders.

2.2.2 The problem of Labor Productivity in the Construction Industry

The Norwegian CI is, as mentioned, accused of having a decline in Labor Productivity (LP). An Industry that is one of the most significant industries in On-Land Norway, with 466 billion Norwegian Kroner accumulated in 2017. A common fact shared among the industry stating that CI is facing an LP decline of 10%, since the year of 2000. Often

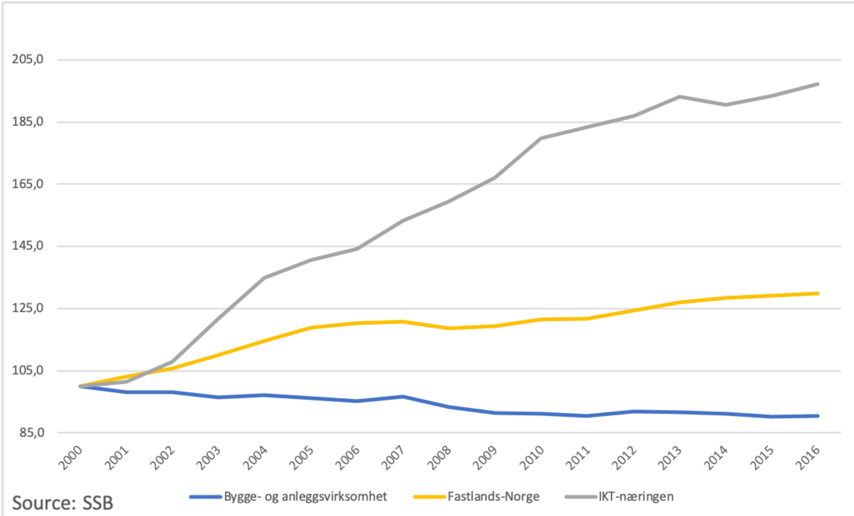

Figure 2.5: Labor productivity in the constructing industry, compared to average on-land industries in Norway, from 2000 to 2016.

these numbers are justified by a complex and ever-changing industry and considered not representative of the industry of today. Sure the numbers are correct, but do these numbers show us the big picture?

In this section, the question of declined LP in Norwegian CI will be discussed, and if LP is in fact *not* declining.

Labor productivity(LP) is a description of the value created relative to the resources used, as seen in equation 2.1. Practically speaking, a company or business achieving a high degree of LP, work less, and achieve more.

$$LaborProductivity = \frac{\textit{Labor dividends in quantity or value}}{\textit{Labor effort in hours or count of employees}} \tag{2.1}$$

Having increased productivity, make sure that a company gets the right turn on investment, rather than barely be able to endure. There are lots of different factors that come in to play why some industries have a positive LP-rate, and some have a negative LP-rate, but how can this decline be, when the Industry see turnover growth?

By Statistics Norway (SSB) the constructing Industry (CI) suffer a substantial decline of 10%, since the year of 2000. This trend is also present in both Sweden and Finland. Comparing these numbers, seen in figure 2.5 with the same statistics in LP in all on-land private sector businesses, where there has been an overall increase, by 30%, one can

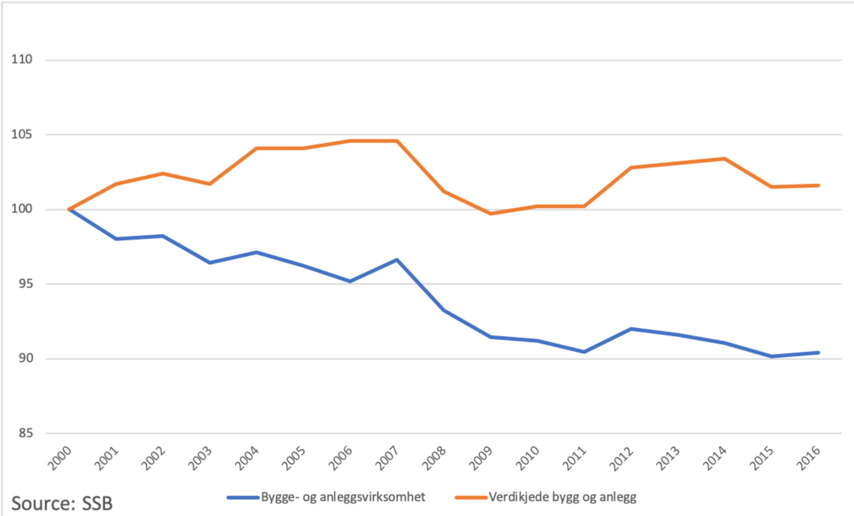

Figure 2.6: Labor productivity in the constructing industry supply chain, from 2000 to 2016.

arguably state that the decline is a fact. What do these statistics represent? SSB' definition of CI used in this calculation is labor that is directly involved in the on-site constructing, which is not representative of what is considered CI of 2019. Much of the work done on today's building site is prefabricated, and to get construction completed, one has to cooperate with a lot of businesses and industries. SSB explains that the reason for the small definition of CI is because of an EU-standard; hence, the comparison of the northern countries. If we consider the entire supply chain, there is a minor, in fact, increase in productivity of about 2% from 2000 to 2016, as seen in figure 2.6.

An issue paper posted by Sintef in 2013 raises the discussion about this topic. The issue paper states three central observations: (1) The numbers does not tell the whole story about productivity, (2) the numbers can't be used in scientific research and (3) the numbers can not be used in comparing businesses, projects or corporations, because each project is so vastly different from one another.

Looking at observation two, stating that the numbers are not to be used, measuring increased productivity in CI overall. We need, therefore, to look at a process, a specific project, or a corporation to conduct a sufficient scientific analysis. This holds for a case study, where one looks at an individual project, analyzing the internal processes and project management to identify the measurements taken to boost internal productivity. Moreover, complexity makes for no comparison between different projects, because when creating a complicated construction, sometimes new invention needs to happen, and this is not something to be compared. In the same way, comparing productivity in different software development projects is not relevant. If one is to construct the same house, or the same piece of software, time after time, then a comparison is very legit. Then again, in this case, the ingenuity is discussable.

Stating that CI has declining Labor Productivity is therefore not unilaterally correct - still, if we consider the total value chain, the result is considered poor. The industry is taking action to get labor productivity closer to the average rate. The focus is to make each project as efficient and productive as possible, but that is always the case. Simply because of the marginal cost gained.

Thus yields for a bottom-up approach: Starting with a process in a project and perfecting it, continuing with each process will eventually lead to a resulting better efficiency and productivity in the entire project. Which, if done in the entire constructing industry, will lead to increased LP overall. Therefore, the industry needs to overcome the challenges, mentioned earlier, (starting with a breach of planned timeline and budget, with symptoms such as requirements change during design, increased complexity, and struggling to complete the products,) were digitalization, Agile (hereunder Lean), is promising and populare solutions to the problem.

Measuring productivity on project-, process- and process level

Practicing the bottom-up approach and implementing Lean Constructing, explained in section 2.3.5, in the design- and implementation phase, increasing productivity, and overcome difficulties (such as requirements change during design, increased complexity, and breach of planned timeline and budget) within the particular project phases. Lean is an excellent method but offers no mechanism measuring the achieved improvements. Using KPI's measuring could be a solution. Skappel [10] suggests in her master thesis, ten KPIs ensuring continuous flow improvement in Lean design process:

1. Number of work packages (deliveries) completed and delivered within a takt time

2. Number of decisions made on the wrong basis

3. Number of revisions after products in a common BIM are frozen

4. Number of unresolved questions in the dialog matrix

5. Intensity Curve - Number of questions asked in the dialog matrix and how fast these are resolved

6. Number of approved functional descriptions prepared at the right time

7. Number of correct functional descriptions revealed during table testing

8. Number of systems with developed test procedures before sending contract to contractors

9. Number of change requests due to errors and misunderstandings

10. Percentage of project material delivered to the contractors at the right time

These KPIs are yet to be tested, but still promising ensuring LP in the first phase of a traditional CI-project evolve in the appropriate direction.

In addition, by recommendation of the issue paper a project, started in 2015, establishing a state-of-the-art performance measurement tool. In 2017 the resulting Nordic 10-10 [11] program was finished. Nordic 10-10 is a version of the CII 10-10 program[12], designed and translated for the Nordic countries. The CII 10-10 program is a survey-based measurement tool based on the concept of anonymously surveying members of a project, regarding their project's performance, team dynamic, and organizational relationship. The surveying is done at the end of each of the five faces of the constructing project. Opposite to a standard approach, where such analysis is done only one time; at the end of the project. Using Nordic 10-10 results in more agile project management, where changes are implemented throughout the project. In some projects, they even do the analysis even more often, allowing the project manager to make changes also within each phase of the project.

As mentioned, the use of process management and method management has helped ICT and software development. If not directly increasing LP, although structuring projects, increasing interactions, and overcome the challenges in SD and curing the symptoms seen both in ICT-industry and the CI.

Since the introduction of SCRUM [13], in 1995, the use of it, and other SDM, has been wastly spread throughout the majority of software development projects in the world, and Norway as well. It is, therefore, fascinating looking at the figure 2.4. Comparing LP in ICT and CI from 1972, up to the beginning of the '90s. Sky-rocketing after dot com, at the beginning of this century, while CI has a slight declining graph after breaking the millennia. Knowing the Agile manifesto was published in 2001 makes for a promising correlation. Though, one can not use LP as a single source of indication, nor stating that SDM is the single reason for the progress; this result yields for implementing agile project management in other industries. The next section will, accordingly, introduce different agile project methods.

2.3 Agile Project Management

This section will give an overview of Agile in the context of project management, as well as provide an introduction of different Agile management methods as context for the reader. Furtheremore, a discussion of Agile as a management method, and if the introduction of Lean is in fact just a hype.

First, when discussing this topic, project methods need to be defined. Different from the *process*, which is more concerned about the different phases of the project, the *method* is about how one can manage within a given stage of a project. Thus, project management

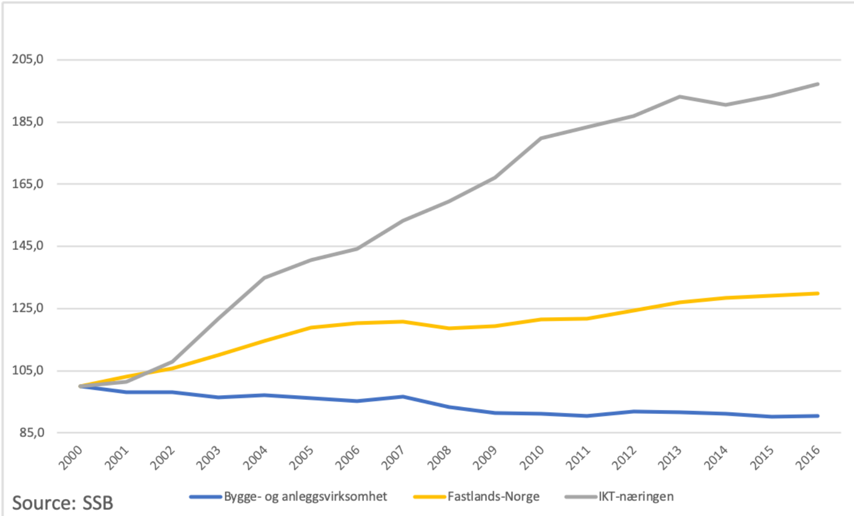

Figure 2.7: Labor productivity in ICT, compared to constructing industry and average on-land businesses in Norway, from 2000 to 2016.

methods are about making the most effective utilization of resources within a given phase.

2.3.1 The Motivation for Agile Project Management

In the ICT-industry the urge for change in project management within distinct phases of projects led to the introduction of agile software development. The move was motivated by having a way of handling late requirements and the growing amount of documentation needed in the ever-more-complex projects. Furthermore, utilizing testing, that way, bugs can be fixed during production, when most uncomplicated. Pushing was also the headlines describing yet another software project failing to meet the schedule. All these symptoms made the software industry move into using agile software development methods as a basis for their project management, starting at the beginning of the '90s and has since been introduced in most software development developments, where needed.

As we have mentioned increasing productivity and efficiency in a project is desirable for every project, hence marginal cost. This added to the fact that LP in the CI is decreasing made the industry wanting to take action. This project is, therefore, concerned about the bottom-up approach securing more cost-effective and labor-productive management, leading to a more solid industry in the end. The LP-problem is not the only motivation for CI to utilize Agile project management methods. One can identify most of the same issues ICT had when introducing Agile. Most present, as mentioned, is: (a) increased complexity, (b) extensive documentation, (c) reporting of issues leading to change of design during production, and last (d) delivering a construction without errors.

2.3.2 Agile Project management

Seen the motivation for both the ICT and CI to make changes and introduce APM. This section will give a short introduction to APM: the bases as well as some disussion of the use. Furtheremore, the section will introduce some known ASDs, as context for the reader. These methods promote smaller teams of 5-12 people; therefore, included is also an elaboration of ASD in large scale corporations, as well as, Lean, which encourages comparison between SD and Construction.

APM diverse from linear processes; by the way, a project, or the workers, can rapidly adapt to circumstances. This lines with the problem of requirement change in SD. Moreover, it corresponds to the reporting of issues during production in the CI. The initiatives done since the adaptation of agile in SD was expressed in the Agile Manifesto [14], when published in 2001. The manifesto gave a tangible reference for project leaders, as well as developers, to steer the project with the correct mindset and focus. Moreover, the manifesto gave a baseline for creating new and potentially better APM methods. The Agile Manifesto says:

> **Individuals and interactions** over processes and tools
> **Working software** over comprehensive documentation
> **Customer collaboration** over contract negotiation
> **Responding to change** over following a plan

Including these four sentences, the manifesto also includes a set of twelve principles. Theses principles emphasize always having a working product, an enjoyable working environment, and a proper dialog with the customer. Wich eventually results in a team able to adapt to change, also late in the development. The manifesto emphasize that face-to-face conversation is the best way of proper conversation, even though much of the interaction can be supported by software.

2.3.3 Agile software development in smaller teams

The above mentioned agile manifesto, says a lot about principals and values when conducting APM and ASD. The manifesto says nothing about the actual process, that is for the different agile methods to explain. Known methods such as SCRUM [13], Extreme Development (XP) [15], and Feature-Driven Development[16] are among other descriptions and practices on how to implement scrum as a work method. Abrahamsson, identify that common for all is that they are incremental, straightforward, cooperative, and adaptive [17]. Different from the waterfall process, Abrahamsson concludes, agile emphasizes on being people-centric.

A generic view of the agile method is iterative development, seen in figure 2.8. Using the example of SCRUM, the iteration involves sprint-planning, implementation, and review. The method emphasizes growing the team, and after every iteration, a retrospective meeting is being held. Also, worth mentioning is the daily scrum, a meeting where the

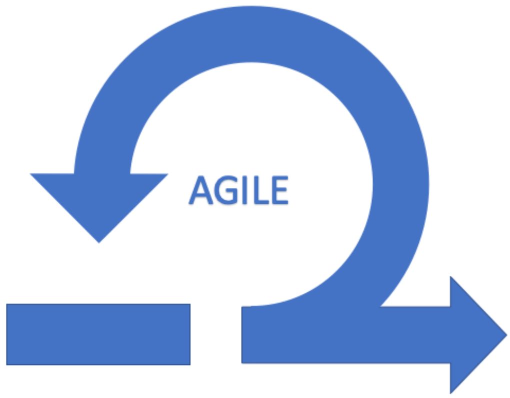

Figure 2.8: Illustration of the generic agile loop.

team discusses the progress, and issues can be raised. Most of the artifacts and events applied in SCRUM has comparable ceremonies in other ASDs.

Still, the process of creating a product has to involve more than just sprint planning. Most of the agile methods also include prior planning before the iterations start. This planning is to be found both in XP and SCRUM. When agile development methods are applied, a problem with estimation often occurs [18]. This problem is very present for the managers [19]. Traditional project managers utilize a Gantt chart, scheduling project tasks. Sutherland, on the other hand, argues the use of Gantt is mostly a waste of time:

> *The only problem with them is that they are always, always wrong.*

Even though most of the methods encapsulate planning in the process, Abrahamsson, in his paper [17], discovers that there are only two of the methods implementing concept creation in the process. This is an essential part of the CI project process. Still, one can argue that this is not a part of the development and is supported by the SSA e-procurement process [20].

Agile methods are, as the title of this sub-section implicates, planned for smaller teams. Challenges, when extending the team-size, of more than the recommended 5-12 people, are decision-making, communication, and control [21]. Also, when wanting to use the methodologies in large organizations, some adjustment is needen. This made for the introduction of large-scale agile organization methodologies discussed in the next sub-section.

2.3.4 Agile in Large Scale Organizations

As mentioned, most agile methodologies are designed for smaller teams. Challenges applying agile in large-organization are mostly communication and coordination [22]. These issues are well-known when considering large organizations, but are very present when the agile mindset emphasizes harmonization between different actors [4]. When considering large-scale agile, one often want the whole organization to utilize agile with diverse teams. Understanding the concept of agile methodology is problematic. This applies to the managers, and team-members not known to agile beforehand [23].

When considering large-scale agile organizations, one can divide between organizations using consultants and large in-house scale organizations. When considering projects and organizations of that size, the complexity of management is very present. Still, most of the problems are the same, including knowledge sharing, clear practices, and interacting [24]. In the case of Spotify, they promote continuously improving their practices, as well as communicating in a face-to-face fashion.

Often directors tend to employ old tools and practices not suited for agile, such as Gantt charts, detailed plans and documentation, and set-dates for production [25]. Both in the case of Spotify and the A-team-project, the discovery is that autonomous team is way more effective than typical teams managed by some leader. Thus, the managers and directors are to facilitate the best infrastructure for the teams.

2.3.5 Lean

As we know, the term agile was first introduced by Takeuchi and Nanaka in the article *The new new product development game*. They explained how Toyota utilized agile methodology in its construction line. Moreover, the systems used at Toyota are formally named Lean manufacturing and was developed by Ohno and Shingo [26]. The idea of the build-measure-learn loop has later been adopted by many other industries, especially after the international bestselling book: *the lean startup* [27]. The constant focus on added value to the product is a quintessential aspect of the methodology, which is yearned for many managers out there.

The lean startup was written by Eric Ries, which origin is software developer, and the approach explained in the book is, therefore, primarily suited for software startups. The act of creating a minimum viable product is not as applicable in the CI. Lean thinking, on the other hand, could still be beneficial for the CI [28], thus leading to the introduction of Lean Construction.

Lean Construction as a Context for the Project

Agile Construction origins from the Lean Manufacturing, and share many mutual ideas, despite operating on vastly different products [29]. While in manufacturing, one can move the product around, the physical size of a construction project induce other measures in Constructing. That is why Lean Construction has rejected many of the ideas from Laan Manufacturing [30]. The essential aspect of Agile Construction is flow. For the method to accomplish the perfect flow, it does, as in other Agile methodologies, stack each iteration with a clear set of objectives to be conducted in the planned timeframe, and the flow is kept by planning the correct amount of tasks before the set deadline. The Norwegian Lean

Construction translation uses a train as an image of the flow. Where the idea is for the train to move through the construction. The movement happens when every task within a specific area is completed. The train is represented with a set of cars, each a representation of a discipline. Alining the cars, so that the correct disciplines are in succeeding order.

The output of every flow is the percent planned completed (PPC). The managers can adjust the order of carts, or the number of tasks to make the production more efficient. When utilizing Lean Construction, a top-down approach recommended [3]. This emphasizes the problem raised by Ingvaldsen, in her article, that the teams lose autonomy when applying Lean in, which conflicts with the Norwegian working model.

Applying agile and lean has, for the most part, had a positive impact on the projects. The deployment is, as mentioned, a way for managers to control the production. Moreover, a tool to control a phase of the process, that has to do with designing and implementation. Added to the process management, the coordination of people in a complex organization is equally as important. The next section is going to discuss this multifaceted area of administration.

2.4 Cooperation in Large Organizations

The work of constructing a highly complex and costly structure is, as we have understood, difficult. There is no straightforward way of doing it, and the focus on project management is an essential part of it. Though, in the end, the act of design and project management is primarily making people work together. Make people interact, coordinate, and synchronize for them to create something that could not happen, if not cooperating. The challenge of making people meet and work together on a common goal, not being self-centered, is something the industry finds difficult. It is seen both in CI, in ICT, and most other industries that have to coordinate different domains of competence.

This section will discuss this challenge and examine what are the ground principals of cooperation and look at different measures one can make. How may computers support cooperative work? Furthermore, how do contracts influence the interest of different actors to cooperate?

First, a short introduction to cooperation: Cooperation is the act of communicating and share knowledge in a way that makes different actors coordinate, interact, and synchronize. The act of talking starts with a desire, or at least a reason, for various individuals to talk.

One must take for granted that the will is there, but in some cases, contracts, politics, or even physical barriers hamper this to happen. Regarding physical barriers, the internet and telecommunication have been a significant leap towards decreasing the boundaries. Computer-supported cooperative work (CSCW) is how technology supports teams cooperate in a project. CSCW will be discussed later in this section. Furthermore, this section will give a brief insight into Norwegian CI- contracts and politics as a context on how for the project, which is an import backdrop for why individuals and parties act the way they do.

2.4.1 Comunication and Knowledge sharing

The act of talking among project actors and team members is, in most cases, sharing knowledge. One often divides knowledge into tacit- and explicit knowledge. Tacit knowledge is something that is known to actors, but not written down, or otherwise, for somebody else to learn and understand. Where, on the other hand, explicit knowledge can be assimilated simply by reading a manual, or a document.

A known problem in the CI is knowledge sharing. The motivations for knowledge sharing is as Dainty describes mostly social [31]. The contractors do what others do, are following the leaders' example, and the feeling of taking part in something bigger than their problems is vital for making people share knowledge. Also, the fact that people need to get something in return when sharing [32]. They get a positive effect through feedback and the effectiveness of their work. Furthermore, Zhang and Ng note that the problem causing people not to share is the fear of losing face. For the managers to contribute to knowledge sharing, they have to create a strategy of capturing and distributing the knowledge [33], often tacit, created in each project.

Systemizing could help digest explicit knowledge because sometimes the information is there, but how to find it could be the impediment. In modern times computers are taken in to use, systemizing knowledge. Then again, the introduction of computers leads to new tacit knowledge, on how to use the systems. A platform for knowledge sharing could serve positive for the different CI-businesses [34].

Boundary Objects, introduced in the original paper [35], is a helpful tool when looking at complex situations. Defining objects where actors cooperate and exchange tacit- and explicit knowledge. A boundary object is part of the social world and is, in some way, a facilitator for communication between actors. Star and Greisemer argue that it has to be well-defined, as well as fluid, such that it can both adapt and maintain a collective identity between parties. An example in an engineering project would be documentation or a user manual, which contains explicit knowledge for different parties to share. Furthermore, a stand-up meeting in Lean Construction is a boundary object which emphasizes tacit knowledge sharing.

2.4.2 Computer-Supported Cooperative Work

Computer-Supported Cooperative Work, first defined by [36], is the theory of the technology's role in the work environment. Often considered in the same context is groupware. The artical *Computer-supported cooperative work: history and focus* [37] describe the motivation for groupware:

> *"The complexity of managing large government software contracts provided*

further incentive to apply technology to group work." - Jonathan Grundin

This motivation applies to Software development as much as for CI. Software and applications as boundary objects have aided complex working groups for centuries. One of the most known, and by Kraut in [38] described as the only successful, CSCW application is e-mail. Groupware has been an essential part of collaborative work, but what makes good groupware?

To make groupware work, first, it needs to meet the needs and requirements of the group. When the software is thoroughly developed and tested to meet the requirements, one can argue that the software should work. Still, after a proper software development process, the critical implementation phase begins. Implementing new software has to fit the users. The article *Transforming Work Through Information Technology* by [39], describes how the deployment of new groupware in two different counties, ends in two different experiences. Central in the succeeding county, is knowledge sharing and grooming of users beforehand. They were conducting the implementation of the software in a bottom-up manner. In this case, the users were the ones who initiated the deployment. In the other county, who did not succeed, initiating the implementation was a centralized data processing department. As well, the knowledge had to be thought through manuals and learning by doing.

CSCW could also aid knowledge sharing [7], by, for example, make use of decision-making software. This way, teams having trouble making decisions can have a trusted source guiding the conclusions. Moreover, the use of ai and big data in the context to support the teams, in ways never seen before, shows promising results, when the ethical issues [40] are kept within boundaries.

In the end, to be highly successful, when fulfilled all other terms, the application has to be usable. The software could still work, but often a lot of knowledge is needed to understand the technology, if not emphasizing on high usability.

2.4.3 Contracts in the Construction Industry

This section will give an introduction to issues concerning contracts in the CI. First, a short introduction to contracts in the CI, as a context for the project.

Contracts in Construction Industry as a Context for the project

When considering how contractors work together, one has to review the contracts and the politics related. In CI and other fields where contractors are needed, the process outline, defined by SSA, often outlines how to work. During this process, in CI, the party announcing procurements creates tailor-made contracts based on the Norwegian Standard (NS), e.g., NS 8405, NS 8406, NS 8407, and others, which do not support an agile process. This yields a waterfall process.

Tailor-made deals makes for a challenging space of agreements for the entrepreneurs. This space promotes larger companies or the ones who specialize in contracts from only a few vendors. A contractor who wants to earn a new principal has to learn the contract, giving the advantage to the more experienced contractors. Often the more advanced companies are not pleased when parties introduce new contract outlines - simply because they lose their edge.

In step 4, the procuring of entrepreneurs phase of the procurement process. In this step, one has to choose an essential element of the contracts, namely, who is responsible. There are two fundamental forms of contracts: (1) Implementation Contract (*Utførelsesentreprise*): where the contractor is answerable for the implementation; and (2) Total Contract (*Totalentreprise*): where the contractor is answerable for both the design and the implementation of the construction, which imply the contractor owns the risk. In both of them, there are different ways of implementing contracts with subcontractors.

Essential in choosing the fit contract is how one expects the contractors to support one another. A deal that supports interaction is necessary when cooperation is crucial. When is not cooperation essential, one may ask? Often when constructing a modular house, where the builder (hereafter named manager) plans everything, repeatedly building the same house. When designing complex constructions, on the other hand, cooperation is highly desirable.

When constructing a highly complex construction *Utførelsesentreprise* is often chosen. This way, the risk is at the manager. Choosing the right design of the contract is crucial when aiming for a high degree of cooperation. There is three main contract design. Different is how much coordination and progress management the manager is responsible for managing. The contract models are:

- Shared Contract or Contract Management (CM) (*Byggherrestyrt entrepriser*): The manager makes all deals with subcontractors. In some cases, a subcontractor takes the lead on coordination and progress;

- Lead Contract (*Hovedentreprise*): The manager signs a lead contractor, which is responsible for a significant amount of disciplines. Furthermore, the manager establishes subcontracts with the remaining disciplines;

- General Contract (*Generalentreprise*): The manager signs a lead contractor, the general contractor, responsible for signing subcontractors, coordination and progress in the implementation;

Issues Related to Contracts

Picking the correct contract is vital in securing desired coordination and interaction, but at the same time, it needs to fit the manager's skills and resources. In the end, choosing the right sort of contract can be vital for meeting the budget. The problem with the complex domain of contracts is that managers tend to pick the same contracts [41]. Even though construction projects often vary from project to project, the procedure of picking the correct contract for the specific project is often not done.

The politics and contracts in a fragmented CI project, with a handful of contractors and sub-contractors, makes for difficulty in cooperation. Issues related to knowledge sharing is, among others, contracts and politics [42] — the issue origins in the fact that every contractor has the goal of maximizing its marginal cost [4]. This problem is especially problematic in projects consisting of several different companies, such as in complex constructions. Miller, Packham, and Thomas, in the article, also points out the fact that cooperation and knowledge sharing in mixed teams is the cornerstone in APM. This makes Lean in the CI even more complicated when complex contracts and harmonization among team members are taken into a count.

Furthermore, the considerable cost of mistrust in CI-projects is shown to be a factor in the overall cost of a project [5]. When actors are more busy protecting their contract, rather than adding to the team, the advantages of cross-functional teams can be lost. Also, prior ties could have a significant impact on how team members interact, as described in the paper of Bruvik and Rolfsen [6].

> *Positive prior ties can have a substantial effect on the development of trust at the beginning of the project.*

Furthermore, the paper is concluded by identifying four aspects that can aid interaction and cooperation: (1) a common philosophy, (2) open communication, (3) clear role expectations, and (4) a shared climate of trust. Hence, prior ties will help in establishing these aspects. One can think that negative prior ties will especially defect the second and the fourth aspect.

Chapter 3

Method

This chapter will give an insight into why the research is needed and what method used conducting the research. Also, the chapter gives insight into the collection of data and the following analysis, as well as and who are the participants.

3.1 Methodological Approach

This study aims to understand the whys and hows of the striking difference in LP in the ICT-industry and CI. The research is, therefore, adopting a case study-strategy of a single-case object, in the CI in Norway. Utilizing a single-case study approach, preferably than multiple, will give a more in-depth look at the problem, rather than a thin description provided by the multiple-case study [43]. This project, therefore, aims to examine a case using lean methodology, where digital tools are utilized to support both the method as well as cooperation and interaction between different actors. The project selected is the construction of the new Life Science Building, managed by Statsbygg [44]. The problem of using case study is that it is hard to produce an generealized answer to a question. The aim of the research is not to obtain generalizable findings, but to explore the phenomenon. Moreover, the result of this research will give a knowledgeable background for the following master thesis. The intention is not to measure productivity, but rather understand why the difference occurs.

This study is related to the positivism paradigm — the use of empirical observation of the participants and a desire to identify how they act on the new software and methods used in the project. Using interviews can lead to being subjective as all collection of data is done in interaction with the participants. This yields a qualitative collection of data. The purpose of this project thesis is to identify the problems worth exploring in the master

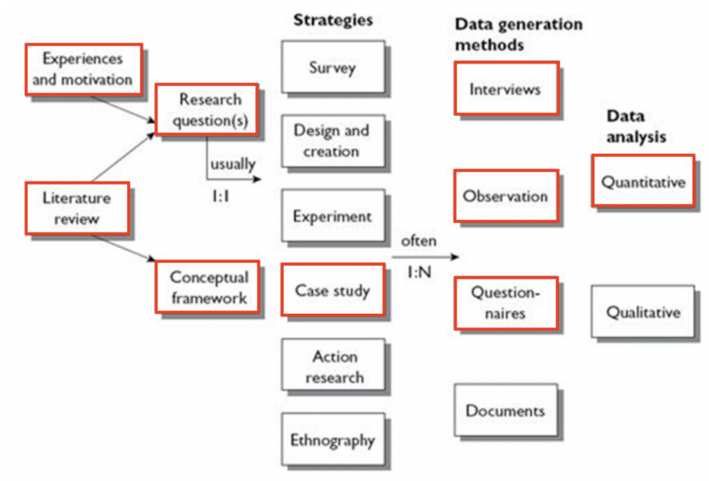

Figure 3.1: The research process used, marked with methods applied in the research.

thesis.

$RQ1$: **What is the fundamental reason for the striking difference in LP in the ICT-industry and CI-industry?**
$RQ2$: **What are the symptoms for the difference to appear in the LSB-project?**

3.2 Data Collection

The project started with a literature review, providing a knowledgeable background as basis for the project. More importantly, the project consist of a minor empirical study, utilizing observation and interviews as data generators. The interviews was conducted with a semi-structured approach, with some standardized questions, listed in Appendix 5.3, for every interview. The research process utilized in the projects can be seen in figure 3.1.

The observations were done over two days, on the project office, where different meetings were observed. The interviews were done using Skype. With the consent of the participants, the sound was recorded. After the interview, the transcript was sent to the participants for them to approve. Both interviews took about 30-40 minutes. The list of interviews can be seen in table 3.1. In addition to the observations, talking to the managers and PLs, when on-site, gave valuable insight into how the project is run.

3.3 Participants

The project researcher, Morten Bujordet, is involved in the project, creating the plans, and conducting the research.

Obervation	Meeting
1	Blackboard-meeting
2	Table-test meeting
3	Digitalization-meeting
4	BIM and dRofus introduction
Total observations	4

Table 3.1: List of observations conducted in the project thesis.

Interviewee	Function	Gender
1	Assistant Project Director & Project Manager	Male
2	Assistant Project Manager	Male
Total interviews		2

Table 3.2: Overview over interviews in the project thesis.

Supervising the project is Eric Monteiro. Monteiro is contributing with experience in research in the implementation and use of new digital tools in large scale, as welle as complex organizations.

Furthermore, Statsbygg, as the manager, has an interest in the project: giving access to the participants in the study. With Patrick Stormo Hjerpseth as the point of contact.

In the research, the actors using the digital software in the project design will be an aim for the data collection. All personal information gathered will, safely, be stored in a GDPR-compliant Cloud Service, served by NTNU. In the final report, no personal information will be published, and all actors in the data collection will be anonymized. The participants chosen for the interviews are key personnel leading the project of the managing organization. The list of interviewees can be seen in table 3.2.

3.4 Method of analysis

The analysis started by transcribing the interviews and observations. Furthermore, utilizing a thematic analysis approach, the data was coded into three themes; (1) interaction, (2) responsibility, and (3) lack of understanding. Each theme was examined, gaining an understanding of participants' perceptions. Moreover, the results were analyzed using the literature review, comparing the subjects with previous experience found in literature.

The thematic analysis was done by first transcribing the interviews. When the interviewees accepted the transcribed interviews, the process of coding was conducted. The coding of the text resulted in the three themes mentioned. It was after the definition of the themes the analysis took place, and then the conclusion of the findings. Moreover, the same themes were used analyzing the observations and when comparing with the literature review.

3.5 Evaluation of the Method

The single-case study, as well as the use of unstructured interviews, produce results that cannot be generalized beyond the sample group. Still, they provide a more in-depth understanding of participants' perceptions, motivations, and emotions.

One can always argue that utilizing observations and interviews for data collection can tend to be subjective. However, the use of a qualitative approach is best when wanting to describe, contextualize, and gain an in-depth insight into specific concepts or phenomena, which was the case in this empirical study. Furthermore, the number of interviewees and observations was quite poor. The result produced can, thus, be questioned. Though the result of the study does not stand for itself, it is identifying the problems worth further exploration in the master thesis, which is achieved, and therefore, more acceptable.

Chapter 4

Case Study: The Life Science Building Project

This chapter will, first, introduce the case object, namely the Life Science Building-project. The presentation is an introduction to the project in itself, and the vision and strategies essential for project management. Furthermore, the case study will examine and discuss the findings of the interviews and observations conducted.

4.1 Introduction of the Life Science Building Project

The project case will examine the construction of the new life science building of the University of Oslo. When finished, the building will reach a cost of approximately 6,8 million Norwegian Kroner (NOK), and cover 66,700 square meters, with this, becoming the most extensive, detached university building in Norway. Construction builder is the Norwegian Directorate of Public Construction and Property Management (Statsbygg). The construction started on the 8 of February 2019 and is expected to finish in 2024, while the project management of this report started in 2017.

The manager, Stasbygg, is a significant organization in the Norwegian construction industry. They are on a state mission, which means that they are to realize the politics decided by the government, achieved in architecture, cultural legacy, spatial planning, and environment.

Each year, Statsbygg constructs about 100 construction projects. Some are more complex than others. The life science Building is one of the more complex. In addition to the construction of new buildings and projects, Statsbygg managing about 600 properties of these 90 outside of Norway. Examples of properties managed by Statsbygg are embassies, royal properties, colleges, and cultural buildings.

In regards to complexity, the new life science building has to meet several complex requirements: (1) the environmental: The property is to achieve Excellent in the BREEAM NOR classification of sustainable properties; (2) usability: a group of the final users has given their feedback on what they expect from the final building; and (3) technical requirements: The building is to house several faculties, some requires highly technical labs.

4.1.1 Project Vision and Strategies

The construcionn of the new Life Science Building is, in many ways, a prestige project. Defined in the vision:

> *"An even better project"*

The project is following in the line of previous two large projects running Lean Construction, with Statsbygg as manager. Starting with the Domus Medica construction concluded in 2013. This project was the first Norwegian group applying Lean. This construction was followed by the raising of the new Bergen Academy of Art and Design (BAAD). During these projects, Lean Construction was a significant part of the project management. The first project suffered substantial scope creep, which made the managers take action, applying Lean Design and Systematic Completion *Systematisk Ferdigstillelse* on the BAAD-project. The moves made gave results, and when finished in 2017, the project was by many considered one the most successful (complex) building-constructions completed in Norway.

Based on the the BAAD-project a the *Lean methodology in design and construction*-book [3] descibing the experience from the project, was made. With the previous history and recomendations from the book, Stasbygg, as a manager, defined five superior strategies in the upcoming LSB-project:

1. The Contract strategy
2. The Lean strategy
3. Stretegy of Systematic completion
4. Digitalization strategy
5. Logistics strategy

These strategies affect how the project should run and emphasize the focus of the project managers, hopefully leading to a sustainable and productive project. Following are a brief introduction to the different strategies as a context for the case. An holistic view of the

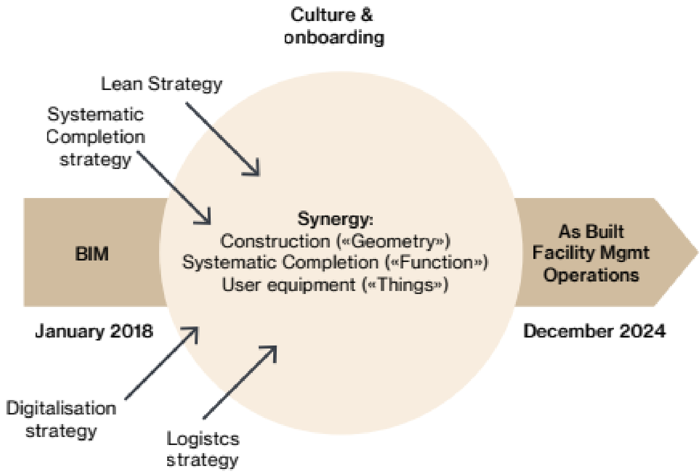

Figure 4.1: A hollistic view of Strategies in the Life Science Building-project.

strategies in the project are illustrated in figure 4.1.

The Contract Strategy

The project has made use of a customized version of the Total Contract, named by Statsbygg as Total Contract with Prior Interaction *(Totalentreprise med forutgående Samspill)*. Instead of signing single contracts with each subcontractor, the managers have assembled eight arrangements, each covering different divisions of the project. Hereunder a more Lead Contract type is applied. Figure 4.2displays the eight contract divisions. Responsible for each of the contracts, from management, is either the project manager from construction or technical. Prior Interaction applies to the design phase, where entrepreneurs are involved prior to the job they are to perform.

The motivation for this model is, first, shielding the contractors from some of the risk running this project. The project is, as mentioned, very intricate in construction, as well as in management. Moreover, getting contractors willing to apply on this project, the managers will take much of the risk. Regarding cooperation the projects adds Lead Contracts. The intention of this is cooperation; besides, sharing a contract has the plan of shared responsibility and incentives for collaboration between subcontractors. Even though there is a lead contractor per division, the hope is that the group of subcontractors should feel shared responsibility. Why not have a shared responsibility,and no leading contractor, one may ask? The answer is partly laws and politics, but moreover for simplicity in regards to management; a single point of contact. As well, motivation for adding the prior interaction creates a foundation for the Lean strategy.

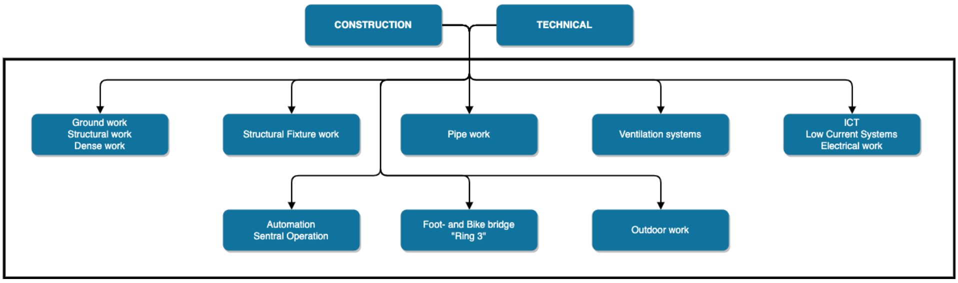

Figure 4.2: Contruction Contracts in the Life Science Building Projects, each managed by either the construction- or technical project manager.

The Lean Strategy

The Lean Strategy applied in this project is tailor-made from experience from both the Domus Medica- and BAAD-project. Two Lean strategies are applied in the LSB-project:

1. **Lean Design:** A method conserning design management and design coordination to ensure that the progress and knowledge sharing, in the Design Phase, is as good as possiblble.

2. **Lean Construction:** A method conserning the scheduling of tasks and the availability of skills and materials to ensure that the work progresses as smoothly as possiblble during the construction.

Different from the traditional design phase described in section Construction Industry Project as a Context for the Project, the LSB-project made use of an iterative method. The *Lean Design*-method has been developed by Statsbygg, after designing the Domus Medica and BAAD projects. In all projects utilizing Lean as their project methodology, this project also iterates over a product. The product, in this context, is the BiM model. The BiM model is the 3-D model of the building. The project makes use of Level of Development (LOD), mentioned in the 2.3.5 section, where each iteration, named sequence, has the intention of getting the BiM model more mature. Also, based on the Contract strategy, the result of this process is not procurement, but the final product ready for implementation - hopefully without bugs.

A problem with the traditional design phase was evaluating the overwhelming amount of documentation at the end of the phase. Bohem is also mentioning this difficulty when evaluating the waterfall process and problems of use, in his paper mentioned in section 2.1. Furthermore, it is an argument in the Agile manifesto. Having sequences, the Lean Design method, therefore, made it easier having control over all interdisciplinary correlations. In LSB-project, these sequences last up to two weeks. In every sequence, the project leaders are assigned a set of packages. Ending the sequence, the project leaders need to deliver on the packages assigned. This way, the project can identify tasks that are, or can be, risks for the project. Every week in the designing the project starts with a cermony named

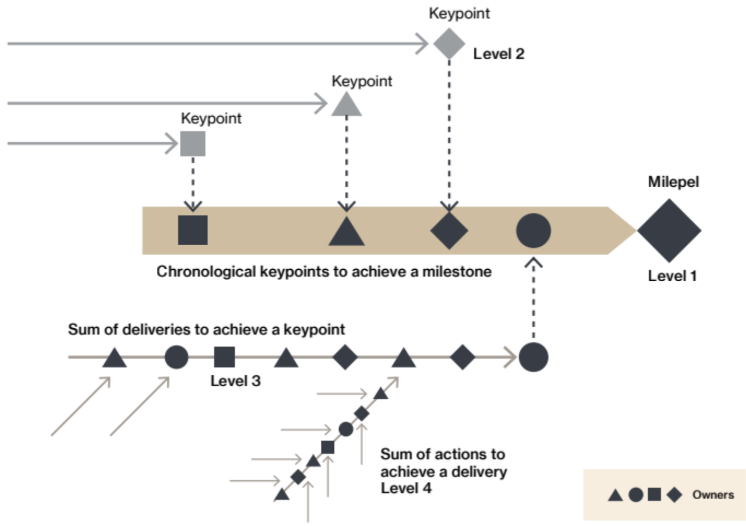

Figure 4.3: Contruction Contracts in the Life Science Building Projects, each managed by either the construction- or technical project manager.

blackboard-meeting. In this meeting all project leaders, project managers, and responsible goes through the packages and deliveries due to that meeting, or the status if not the end of a sequence. The project chair the meeting, while the rest need to the status of the their area of responsibility.

The Detail project started with a two-week planning session, which made all trailing package-planning possible. The session resulted in the process map. The process map includes four levels of tasks, illustrated in figure 4.3: (1) the Milestones: A significant planned completion of a part of the project, e.g., steering document approved; (2) Key Points: Key Points is less significant, and with a shorter time frame than milestones, but in the same way an indication of completion; (3) Deliveries: A Key Points consists of several deliveries, e.g., finishing a room or design of a floor; and (4) Actions: Actions is everything needed to be done to complete a Delivery.

Both the Lean Construction, described in section 2.3.5, and Lean Design, make use of large planing tables. These can look like the old roadmaps used when planning the coding in Waterfall. Depending on how one makes use of the plans, the result of such planes is that they often than not end up wrong. Therefore, as Sutherland points out in his book [13], the plan is not the final solution, the plan is what is needed, and adapt thereafter. Though, in this case it seems like the time was well spent giving the project leaders valuable insight into the project. Not spendig too much time planning ahed.

The Strategy of Systematic Completion

As described in section 2.2.1, the construction process ends with the Realization phase. It is after this phase, the project, or building in our case, is tested. If tests run smoothly and the owner approves the construction, the building handover occurs. The mission of testing is to verify that the final product meets the initial requirements and specifications defined. A typical case, when conducting these sorts of tests, is discovering errors. Problems getting wors when there is no control of these errors. If the final construction has too many errors, the owner can decide not to take over the building. Consequently, the project fails to deliver on schedule. Sadly, this happens quite often.

Managing this issue, the LSB-managers has developed a method, checking the systems, functions, and geometry of the construction. The method is named *Systematic Completion* (SC). Throughout the project, SC is conducted, reducing the risk of not deliver the final project. SC follows the LOD-version, which makes for successful completion, with the correct level of quality, at the right time.

The Digitalization Strategy

The Digitalization strategy is, both important in itself, but also supportive in regards to the other strategies. The project using a digital 3-D visualization of the building as the product, driving the Lean Design method. BiM is, in many ways, the core of the project, supported by a dRofus, which is the room database. Prominent in the strategy is connecting all software used in the project and making all entrepreneurs use the same. Hopefully, one can trace the socket implemented in a room, by an electrician, through the drawings given, back to the BiM-model, and the dRofus database, where it was first planned. The resulting system can later be used by janitors, running the building, to identify errors in the system. Figure 4.4 visualize the connected systems in the project.

A significant part of the digitalization, and unique for the LSB-project, is the deployment of the Cogito Project-system. Cogito is a tool used to visualize the planning done in the design phase, supporting the Lean Design method. The tool are beeing used tracking actions, deliveries, and Key points and milestones, who is responsible. Furthermore, calculate Planned Percent Completed (PPC), which is an excellent way of identifying delays. The project is planning to use Cogito tracking both the design- and the implementation phase of the project.

The project utilizes, added to Cogito, several other software supporting Agile project management and cooperation. Under following a list of the most crucial software, concerning Agile and collaboration.

- **BiM:** 3-D modeling tool, used in design, constructing, as well as bases for operation when the building is finished.

- **Revit and dRofus:** Databases supporting BiM. Whats defined in dRofus is known as the truth, if there is missmatch between BiM and dRofus.

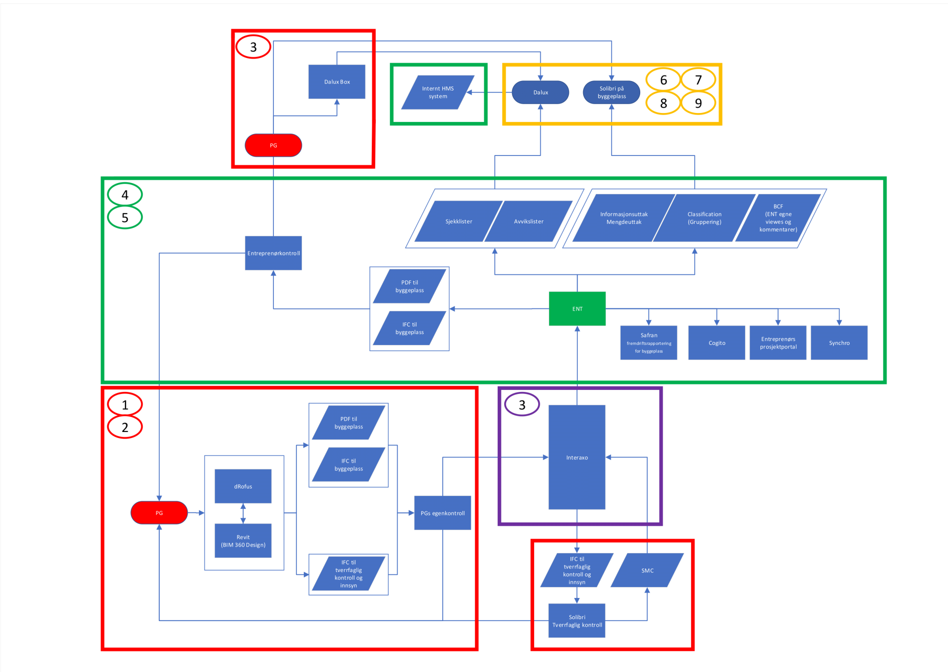

Figure 4.4: Overview over the system architecture used in the Life Science building project. Outlines representes the actors using the systems, by color: (red) Project group, (green) Entrepreneurs, (yellow) HSE, and (blue) cloud service sharing documents

- **Interacso:** Cloud service for documents. Servecing omboarding, breach handelig, and offboarding.

- **Blink:** Communication tool. This way intricate can happen rapid and informally, without booking meetings and writing emails.

- **Cogito:** Visualization of on going and planned packages, in both the design phase and construction phase of the project.

The Logistics Strategy

Last, the Logistics Strategy. When coordinating a large number of people and paraphernalia, having control is a major challenge. In the LSB-project, there will be up to 800 people and equipment worth over 1 million NOK. These numbers argue for the logistics strategy. The strategy involves planning for goods arriving the lot, as well as where one should tossing the garbage. Considered in this strategy is also removing packaging before arriving the lot, where the goods should arrive, securing the most effective utilization of construction workers. Should the project construct a cantina, so the workers do not have to walk to the nearest McDonald's or grocery store when having lunch? Furthermore, alining workers, equipment, and goods needed to support the train in the Lean Construction strategy. This strategy could be a significant impact when considering the overall labor productivity of the project.

4.1.2 Project management in the Life Science Building-project

To manage a project, this significant, the constructing organization makes use of several different management approaches. One can divide the project management into two levels: (1) process management: The support of the process and how the teams are working together, and in what order; and (2) implementation management or method management: The management of design and implementation of the final product. The organization structure used in the project supports the two levels of project management. The first of the two, process management, is using customized phase-based process management, inspired by agile thinking. Second, implementation management utilizing the above strategies.

The construction project organization structure is, as seen in figure 4.5. Starting at the top, in charge of the project, is the project director (PD), supported by the assisting project director (APD). The board, seen on the right, consists of four managers, each responsible for different strategies of the project. On the left HSE and project support, which is responsible for i.a. Communication, economics, progress. Beneath the four divisions in the project, where design is responsible for process and management. Paraphernalia is responsible for equipment in the final building. Construction and Technical are two divisions responsible for the eight contracts. In each of the division a Project Leader (PL) is responsible. The PL in Construction and Technical the PLs are responsible for the projects concerning their contracts.

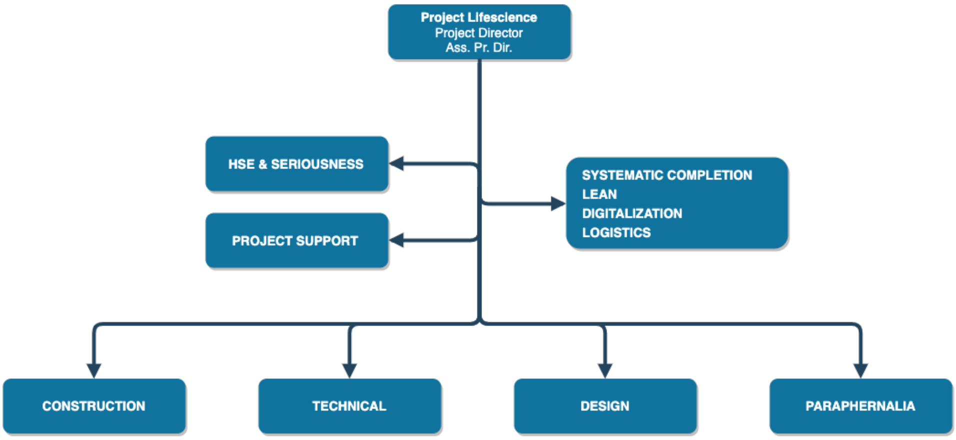

Figure 4.5: Organizational structure in the Life Science Building Project.

4.2 Examination and Discussion of the case object

This section will examine and discuss the case and try to identify the phenomenon which is causing the difference in LP in ICT compared to the CI. The case object assumes the use of agile (in the form of Lean) and digital tools. Therefore, the research will review what causes the phenomenon in a project like the LSB-project. The study discovered three themes, as mentioned in the research chapter; hence, the subsections of this section will be interaction, responsibility, and lack of understanding.

4.2.1 Interaction in the Life Science Building-Project

An essential aspect of the agile methodology is interaction and cooperation. This is one of the essential aspects of project management the managers have to do correctly. It is something the managers are aware of and need to tackle. This next sub-section will discuss the challanges interaction has to offer, in the case of the LSB-project.

Essential for the managers in the Lean strategy is the communication between every participant in the project. Also, the managers have set high expectations for the project to be Lean Extreme. This is not achievable when cooperation between different parties do not work. Pointed out by one of the interviewees:

> *If we had been lean extreme, everyone had been working like as if we were one company.*

Often this problem can be traced back to the fact that most of the contractors value the contract over cooperation and knowledge sharing.

Blink, the communication platform, was first introduced in the fall of 2019. Almost two years after the detailed design started. As much as they emphasize cooperation and communication, contra silos, a simple communication tool should have been deployed from the beginning.

On the other hand, an essential principle of the Agile Manifesto is the face-to-face conversation. In the LSB-project, many conversations happen face-to-face. The architects make use of stand-up meetings. Furthermore, the Lean Design method makes use of the Blackboard-meeting, where PLs, Principals, and managers meet discussing the past sequence. Added is the "Big room," in which importance is emphasized in the BAAD-book [3], where every discipline is gathered in one room, promoting interaction and cooperation.

A problem noticed in both the interviews and the observations is the issue of transparency. This issue was, for example, present in the blackboard-meeting. When the PLs was asked why some of the packages have not been finished, one could feel the discomfort. Some also tried to change the deadline for the deliveries for them to not seem late.

The will of sharing knowledge is essential in the goal of being lean extreme. The contractors seem to be afraid of sharing their knowledge. Again, using the example of the blackboard-meeting when contractors have to address their progress the past week. They are afraid of being exposed as not as good. Furthermore, the contractors tend to be less willing to cooperate in these situations. A reflection from an interview speaking of the issue:

> *Constructive criticism is absent in the industry. The attitude is more towards pointing fingers, because one is not used to collaborate. I have done my job, you have done yours. I will rather stand here a point at you, because I have not got what I was supposed to.*

Arguments are that they frown upon the new way of doing things. Therefore, they tend to do it the old way. These actions are the case because the PL is old and experienced, and they are the ones in charge. This issue boils down to the project organization and strategies, which support a top-down approach.

The Top-Down Approach

The LSB-project has, as mentioned two layers of management, and supporting, is the five strategies. Responsible for each part of the project is a PL. Based on the strategies, which the PL are to follow, the project has to be managed using Lean. The BAAD-book promotes this top-down approach. Arguing that using a bottom-up approach will not give a lasting effect, because the project will, when finished, dissolve. The consequence of using this approach is that the workers often do not feel the same affiliation to the method used. One can argue that a worker should not decide upon which project management method the PLs are using. Looking at it from a software developer's point-of-view, this makes no sense. Sure, making sure that Lean diffusion is essential, but having it work, one needs to involve the workers. If workers are failing to deliver an action or delivery, it is the PL who will take the blame. Another factor is the fear of knowledge sharing in the CI is very present. This fear comes from the standard way of always protecting the firms' contract. A norm for the contractors, in complex constructions, has been hiring separate personnel responsible for the deviation.

Keeping Track of Project Status

When running a considerable project like the LSB-project, keeping track is critical. The Cogito tool supports an overview of which packages currently in production, as well as calculates the PPC. Not available are typical KPIs: how well are the production, what is the status in the current sequence, and what is the LP of the project? One could probably utilize tools such as BiM and Cogito, to produce stats, using these as bases for the proposed KPIs by Skappel. Also, the NORDIC 10-10 tool could be beneficial, analyzing the project performance.

On the other hand, the project utilizes something they describe as a Gannt chart, keeping track of the planned progress. The use of this chart ables the managers reporting some progress, and create calculations on the progress. The chart was planned out at the beginning of the design phase. At the time of the interviews, the forecast indicated a lack of progress. This phenomenon is something that has been happening a lot in the CI.

Moreover, it occurred in the ICT-industry when Gannt-charts was more frequently used. One can, as Sutherland asked, why using Gannt charts when they always turn out to be wrong. For the managers and project managers, though, this overview helps in communication.

Two Important Issues

These incidents are prime examples of issues in the CI: (1) transparency: people are afraid of showing their weaknesses. Their skills have never been questioned, and they are not used to ask for help; and (2) the industry tend to keep some of the old ways of doing things: even though they use agile and newer ways of project managmenet, the PLs are often veterans, and the methods used are stiped down such that they can keep some of the old methods.

4.2.2 Responsibility Between Actors

Essential for a project is the ability to take action and make decisions. The problem, in this case, is that the responsibility is quite unsure. Who is going to take action when the problem is concerning the entrepreneur? The contractors themself, the PLs, or even the managers?

The problem often originates in the contracts. The contract applied in the LSB-project has never been utilized before, and therefore causing some problems understanding the responsibility. Also, the goal of the contract has been interaction and cooperation, whose goal is not to have a single person directing every action.

The responsibility, at this stage, is at Statsbygg. The intention of the contract is for the contractors to identify problems before the implementation phase. Therefore, the contractors are to have their say in the decisions. This is not working properly. An example is when the project was to decide on which LOD type to utilize.

> *I think we used three meetings deciding if we should utilize MMI as LOD for all objects. Because one of the entrepreneurs was more known to another method. They used a 1,2,3,4 grading, instead of 100, 200, 300, 350, 400, and 500, as we have been using.*

The top-down approach also influences decision making. Concerned by the lean approach in the LSB-project is mostly the PL, managers, and directors. An argument used is that they shelter the workers who are conduction the modeling, drawing, and designing of the building. Participating in the blackboard-meetings, and using the Cogito tool is the PLs.

If a worker identifies an error, the worker has to tell this to the PL. The PL has to decide if it is for the PL to decide. If not, the decision is taken further up the hierarchy. The worker has to wait until the decision is made before action can be made. This way of doing things is not very autonomous.

4.2.3 Lack of understanding

The lack of understanding and ignorance is very much present in the LSB-project. The phenomenon can be seen in how people lack the knowledge and use the applied tools wrong. This sub-section will discuss the issue two subdomains; in the use of lean methods and the use of digital tools.

Understanding of Lean

A part of the motivation applying Lean in the LSB-project has been the LP problem. The managers believe that getting everyone on board and understand the Lean concept and the project's strategies are essential to make the cooperation work. The managers believe that making the workers understand all this will give them a significant gain:

> *The gain is safer calculations, better productivity, and perhaps more correct constructed building.*

An issue for the managers has been educating entrepreneurs and workers on the reasons behind the lean strategy.

Since this project is such a pioneer project, some of the PLs have never before used lean. This issue is reflected in what they are saying:

> *We were told to use it; thus, we are Lean.*

Proclaiming stupidity is wrong. It is just that they have no experience using Lean. The problem of getting the PLs to know how to utilize the strategies is therefore present.

In the research, the project asked managers why they utilize Lean in the LSB-project – unexpected answers where given. The common answer was the success of the BAAD-project. Furthermore, when asked why the thought of Lean first appeared, the answer was the ideas of Lean correlated with the experience from prior Construction projects. The will to change, though, originated in this thought:

Why does always building sites appear as a shit hole?

Moreover, the motivation for Lean Design, on the other hand, originated in the scope creep experienced in the Domus Medica-project, where the Design Phase resulted in errors, and extensive change of design had to be conducted during the realization phase. Even though not articulated, the last reason is similar to the ones discussed in the literature review concerning symptoms for applying agile. Also, in the Lean methodology in design and construction-book [3], complex construction, leading to extensive, and often bewildering, documentation, adds to the argument of using Lean in constructions.

Understanding of Software

In the interviews, the interviewees were both knowledged about lean. The participants interviewed were, infact, some of the most knowledged people on the entire project. This can not be said about computer knowledge. The knowledge in the use of technical tools was lamentable.

In the interviews, the interviewees were both knowledged about lean. The participants interviewed were, infact, some of the most knowledged people on the entire project. This can not be said about computer knowledge. The knowledge in the use of technical tools was lamentable.

As we have already seen, the LSB-project has a high degree of technology diffusion, supported by the Digitalization Strategy. When introducing new technology, it is, therefore, widespread. When considering the technology infusion, on the other hand, one can not say the result is just as good. Sure, there are some examples where infusion is at a hi degree, BiM, for example. The designers and modelers use BiM, and when the model is complete, the construction workers and installers use the model on the building lot. Cogito, on the other hand, is not that well infused. After all, the software is one of the prestige products of the LSB-project, which makes it odd not utilize it more.

When considering technology infusion and defusion in the LSB-project, it seems like the managers have decided on how well defusion and infusion shall be. The problem is for them to make the users see the potential and usefulness of the tools given. For some users, a new digital tool or software is no more than a password and username, that needs to be remembered. This problem is especially present regarding the late deployment of

Blink. This added to the fact that most users feel that new software is a burden, makes for difficult utilization of the digital tools.

Handle these challenges the digitalization managers have made use of seminars teaching the staff on how to use a particular software. This introduction was enough until new workers had to be on-boarded later in the project. Facing these issues, the managers arranged drop-in-training, where users struggling could come by and ask questions. Sadly these meetings did not go as planned, resulting in zero participants. It was not before a mail invite, showing others struggling with the same issue, that the workers felt the courage to meet up.

A whole lot of the software used in the project promotes knowledge sharing. A problem when depending on software to be used as bounding objects is the tacit knowledge needed using the software. That is why a platform, assembling all the digital tools used in the LSB-project, is sought.

Chapter 5

Analysis and Discussion

This chapter tries to analyse and discuss the questions asked in the Research and Question section of the introduction. Using knowledge from both the litterature review and the case study, presented in section 5.1. This analysis will give the foundation for the further work discussed in section 5.2.

5.1 Analysis of the Case

During this research, the project has tried to identify the symptoms leading to the use of APM. In the literature review, the project discovered a correlation of symptoms in CI and ICT, arguing for the use of APM. These are documentation, change of requirements/design during production, handling errors, and testing. In the case study, the managers had other arguments using Lean, namely the success of prior projects. —> Analysis

5.2 Further Work

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Appendix

5.3 Intervjuguide

Intervjuguide
Navn og rolle:
Dato:

Avklaringer og informasjon:

- Avklare anonymitet/åpenhet
- Informere intervjuobjektet at det vil bli tilsendt transkribert versjon i etterkant av intervjuet.
- Informere om bruk av lydopptak
- Kandidat for mulighet til å presentere seg selv og sin erfaring.

Mitt prosjekt
Prosjektets påstand er at byggebransjen i dag opplever mange av de samme symptomene som programvareutvikling opplevde for 30 år tilbake og stadig opplever. Utfordringene opplevd er: Stadig endring av requirements under produksjon, slite med å nå tidsplan og budsjett, økende kompleksitet – hvert prosjekt er noe helt nytt, og sist med ikke minst problemer med ferdigstillelse. Programvareutvikling har derfor tatt i bruk agil prosjektstyring for å løse flere av disse problemene.

Sett i lys av dette ønsker prosjektet (jeg) å se hvordan et byggeprosjekt med høy kompleksitet utnytter smidige metodikker (inkluder Lean), støttet av digitale verktøy i sin prosjekthverdag.

Temaer som ønskes belyst

1. Bruk av agile metoder og lean i prosjektet

(a) Hvordan og hvorfor benytter prosjektet agile og lean metodikk i prosjektet?

(b) Er det noen utfordringer ved denne bruken?

2. Bruk av digitale prosjekteringsverktøy i prosjektet

   (a) Hvordan og hvilke digitale digitale prosjekteringsverktøy benyttes i prosjektet?

   (b) Finnes det noen utfordringer ved denne bruken?

3. Andre faktorer

   (a) Er det andre faktorer som påvirker bruken av prosjekt metodikk eller verktøyene i prosjekthverdagen?