Exploring the Productivity Issue of the Construction Industry: *A Case Study of a Lean Construction Project*

TDT4501 - Project Thesis

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Abstract

A primary concern of the construction industry in Norway is the significant decline in labor productivity compared to other on-land industries. Statistics show a relative difference in labor productivity, compared to the ICT industry from the year 2000 up to 2016, of 106.4%. The research in this project shows a strong correlation in how the construction industry is today and how the software industry was thirty years ago. Both industries are now utilizing agile management, and software supporting these methods. This case study looks at the new life science building project, of the University of Oslo, for the purpose of exploring the fundamental reasons for the gap in labor productivity between the ICT industry and the construction industry. The study is not to do a comparative analysis of labor productivity between the two, but to explore the phenomenon explaining the gap.

Using semi-structured interviews and observations method, with participants from the project management organization, analysis of the interviews identified three key findings: (1) problems in interaction between personnel, (2) problems in the decision making, and (3) problems in ignorance. Furthermore, the result shows two fundamental reasons causing these problems, that is, the actors' limited understanding of the new methods and actors' traditional view of contracts, interaction, and transparency. Based on these observations, the project proposes a more extensive use of a new digital tool, Cogito, to further explore the phenomenon causing the gap in labor productivity, in a lean construction project using digital tools.

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Chapter 1

Introduction

1.1 Background and Motivation

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 [2]. 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 [3]. 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. Therefore, this study is interesting for managers from other industries than only construction and ICT.

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 [4], 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.

One has often turnd to software when wanting to improve productivity, and hereunder knowledge sharing and interaction in a organization. The implementation of software in a large, complex organization is discussed by many and is shown hard to do well. In particular, the description of the top-down contra bottom-up strategy in implementation [5], promotes the importance of making slow change supported by the users. Furthermore, the intention of increasing productivity, by deploying new software is argued by Hammer, to be less sufficient [6]. Hammer promotes changing the process of work, rather than improving bits by pieces using specific software. Morover, introduction of software supproting collaboration is shown to be difficult, important in this context is that software break with the social taboos, and adoptation is, as mention, difficult [7].

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 [8], 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. A book [9] describing the making of the Bergen Academy of Art and Design-building, where Lean was one of the essential strategies. The case object of the case study in this research are using experience from this book when managing the constructions.

The motivation for this research is, therefore, to examine a construction project utilizing Lean in project management. 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 case object chosen for this project is the construction of the new life science building. The reason for choosing this project is, first, the construction is highly complex, thus becoming the most extensive educational building in Norway, with both advanced technical and environmental requirements. Second, the announced strategies for the project includes both a lean strategy and a digitalization strategy.

This thesis is *not* to do a comparative analysis on LP between the ICT-industry and the CI, rather explore the reasons causing the phenomenon. Hence the selected singe case object.

1.2 Research and Question

Based on the background and motivation the research of this project tries to identify the phenomenon causing the poor PL in CI. The main research question is, therefore:

> *What is the fundamental reason for the striking difference in labor productivity between the ICT-industry and construction industry?*

This is then broken down to two sub-questions, which this project thesis tries to answer, using a case study of the Life Science Building project.

RQ1: Why does the difference in LP between the ICT-industry and CI appear?

RQ2: How does the difference appear in the LSB-project, which utilize both agile and digital tools?

1.3 Thesis structure

Chapter 2: Literature Review provides an overview of key findings, concepts and development relevant for the research question. Furtheremore, 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 3: Method description describe the mothodology used in the project. The methodology descriptin describe and discuss the approach, data collection as well as method of anaylysis of the genereated data. Also, an evealuation of the method i provided.

Chapter 4: Case review gives an introduction of the case as context for the project. Furhteremore, descibe and discuss the result of the anaylysis of the case data.

Chapter 4: Discussion takes the data form the case study, and discuss the results with prior research identified in the literature review. The chapter is outlined by three themes discovered in the analysis of the case data. Furthermore, the evaluation of the project limitation can be found in this chapter.

Chapter 5: Conclusion and Further work answer the research questions raised in the Research and Question section. Furtheremore, proposing furhter work for the master thesis.

Chapter 2

Literature Review

This project's objective is to identify the underlying reason for the striking gap in LP between the CI and ICT-industry. For the project to identifying this gap, this thesis looks at how the construction industry, or precisely how the LSB-project, makes 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 [10], up to the 1968 NATO Garmisch conference [11], 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.

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 [12] 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 his paper from 1970 [4]. 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.

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

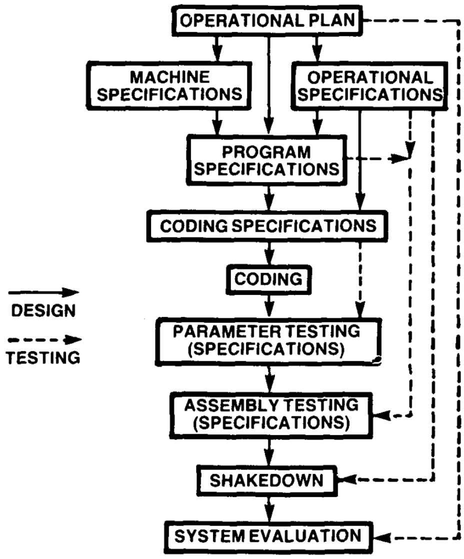

Figure 2.1: Production of a large-program system as presented of Bennington in 1956.

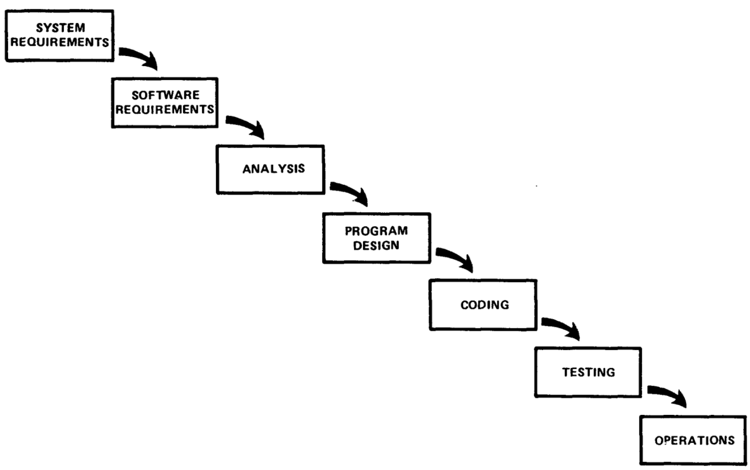

Figure 2.2: Waterfall method as proposed by Royce in 1970. Visualizing implementation steps to develop a large computer program for delivery to a customer.

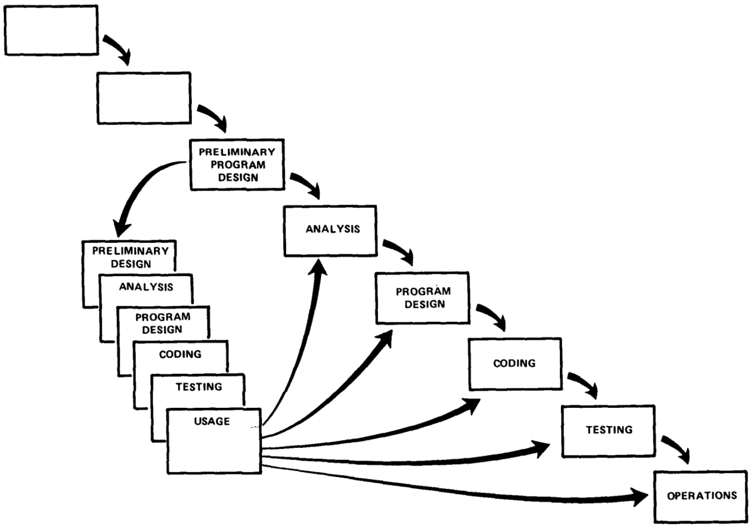

Figure 2.3: Waterfall method as proposed by Royce in 1970, including an iterative process using prototype. Attempting to do the job twice - the first result provides an early simulation of the final product.

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

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 [13]. 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

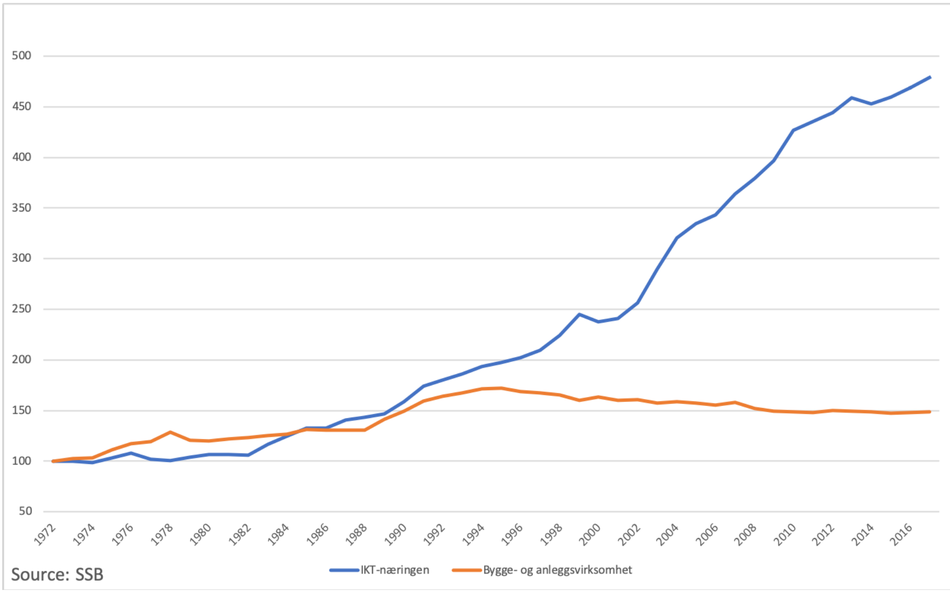

Figure 2.4: Labor productivity; ICT and CI compared from 1972 up to 2017.

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 LP measuring how a industry is discussed later in this chapter.

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.

2.2.1 A Brief History of the Construction Industry

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.

2.2.2 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.

2.2.3 Building Informantion Modeling

Building Information Modeling (BIM) is an essential tool in construction engineering. Since the introduction of 2D data generated drawings (CAD), the evaluation has been rapid. Frank Gehry's introduction of 3D in the Peter B. Lewis building is, by many, the birth of 3-D modeling in the construction business. This introduction led to a burst of innovations due to the complex construction, and the tool 3D modeling gave the engineers [8]. The evolution of BIM has been tried syntheziced by many [14]. Figure 2.5 is commonly used representation by Bew and Richards [1]. Level 3 is where one wants to be now a days, but most are still at level 2. The difference is in the level of interaction between actors and how they can use a shared model.

BIM is, in the technical sense, a file format. The BIM-file storing all information about the construction that is structure, pipes, VVS, systems, and more. Modelers and architects can change and update the file. Others, such as construction workers, can read the information when constructing the building, and assembling the systems. Furthermore, the model is an as-is-model of the final construction, making the file valuable for janitors when running the building — making for utilization of the BIM-model throughout the whole lifecycle of the building [15].

BIM has become a methodology, helping management and actors coordinate in the design phase; BIM is heavily influencing the design process. Others also suggest using BIM in safety problems during the construction, taking care of HSE while constructing, using the fourth dimension in the model, namely time [16]. Other dimensions, added to 3D and the progress/time (4D), including in the model is cost (5D), and linking between as-built and lifecycle management (6D).

In a complex construction, highly reliant on BIM, the organization's software is critical. A paper [17] looking at problems, obstacles, and benefits utilizing BIM identified essential findings. Having different software, and sub-software, exchange the model, is vital. Also, different contractors are used to different tools modeling, which makes changing to other software difficult. Furthermore, having a shared model secure the modelers and architects doing the same action twice. Thus, the importance of a shared model database is present [9].

Having a shared BIM-model implies having sufficient software architecture. Traditionally BIM has been stand-alone applications or utilizing a client-server architecture. The problem is that stakeholders and project managers have hard to get access to the shared model. Chang, in his paper [18], proposes a software-as-a-service (SaaS) architecture to support the need of the different stakeholders with a shared database. Moreover, cloud-based BIM technology is the next step in the BIM evolvement to improve the efficiency of BIM [19].

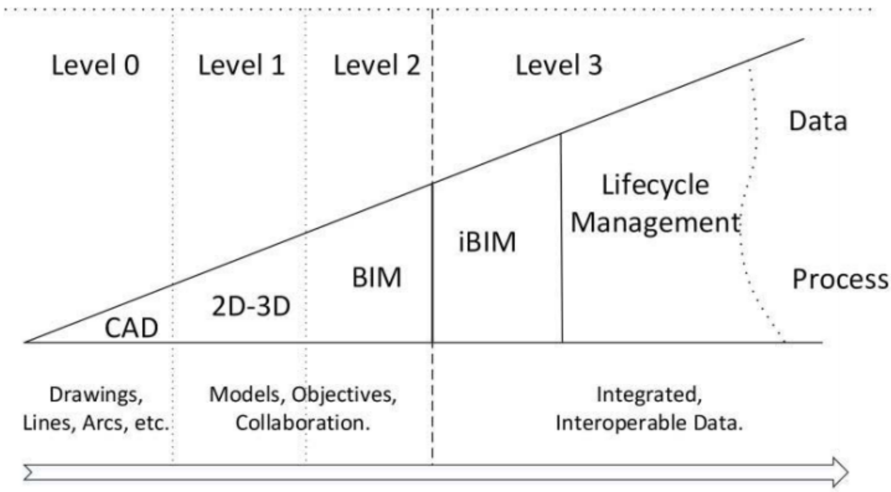

Figure 2.5: BIM Maturity Diagram [1]

2.2.4 The problem of Labor Productivity in the Construction Industry

The Norwegian CI is, as mentioned, accused of having a decline in LP. An Industry that is one of the most significant industries in On-Land Norway, with 466 billion Norwegian Kroner accumulated in 2017 [20]. A common fact shared among the industry stating that CI is facing an LP decline of 10%, since the year of 2000 [21]. Often 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 *not* declining. A reminder; the goal of this thesis is *not* to compare LP in CI and ICT, instead explore the issues causing this phenomenon to happen.

Definition of 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.

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

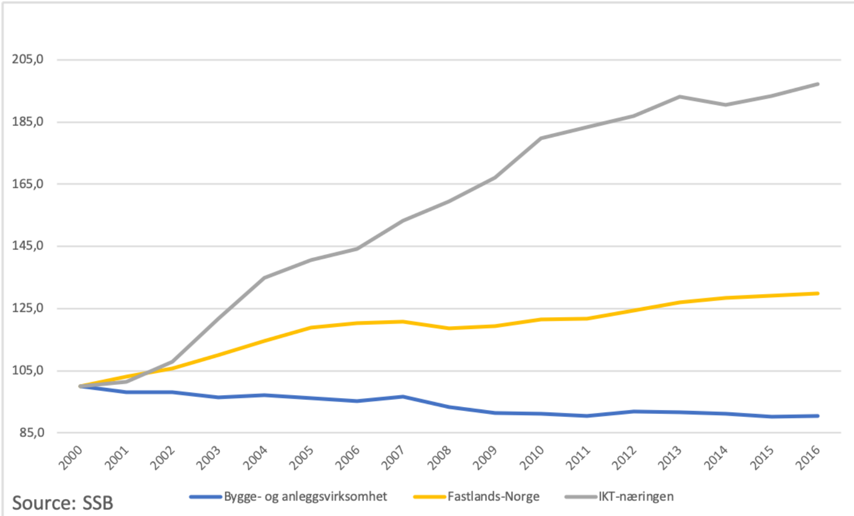

Figure 2.6: Labor productivity in the constructing industry, compared to average on-land industries in Norway, from 2000 to 2016.

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 increasing LP-rate, and some have a decreasing LP-rate, but how can this decline be, when the Industry see turnover growth?

Aspects of Labor Productivity in the Construction Industry

An article [21] posted by Statistics Norway (SSB) proclaiming that the constructing Industry (CI) suffer a substantial decline of 10%, since the year of 2000. The article shows that this trend is also present in both Sweden and Finland. Comparing these numbers, seen in figure 2.6 with the same statistics in LP in all on-land private sector businesses, where there has been an overall increase, by 30%, one can 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 2.7.

An issue paper [22] 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

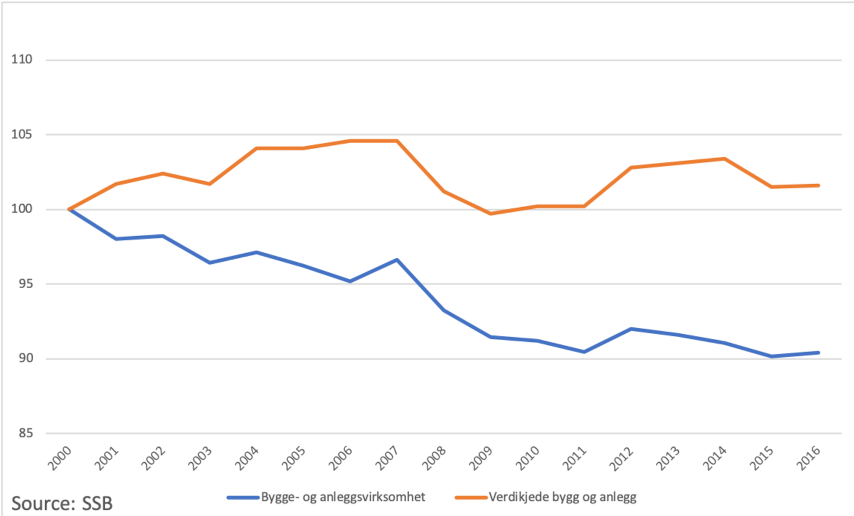

Figure 2.7: Labor productivity in the constructing industry supply chain, from 2000 to 2016.

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 LP 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 LP 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.

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 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 [23], 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 [24], Extreme Development (XP) [25], and Feature-Driven Development[26] 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 [27]. 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 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 [28]. This problem is very present for the managers [29]. Traditional project managers utilize a Gantt chart, scheduling project

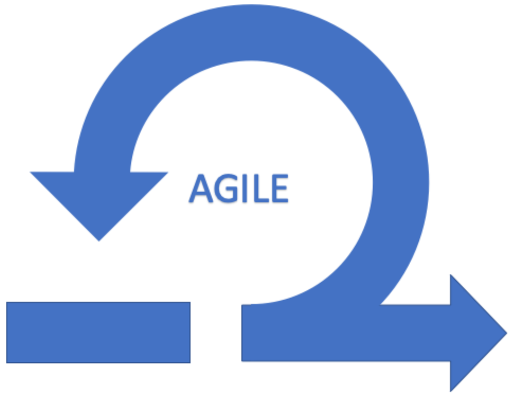

Figure 2.8: Illustration of the generic agile loop.

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 [27], 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 [30].

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 [31]. 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 [32]. These issues are well-known when considering large organizations, but are very present when the agile mindset emphasizes harmonization between different actors [33]. 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 [34].

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 [35]. 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 [36]. 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 [37]. 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* [38]. 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 [39], 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 [40]. 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 [41]. 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 [9]. 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.

Measuring productivity on project-, process- and process level

Lean is an excellent method but offers no mechanism measuring the achieved improvements, such as the burndownchart in SCRUM [24]. Skappel, in her master thesis [42], suggests using KPIs measuring the improved perfomence. Ten KPIs, is proposed, 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 a issue paper [22], a project started in 2015, establishing a state-of-the-art performance measurement tool. In 2017 the resulting Nordic 10-10 [43] program was finished. Nordic 10-10 is a version of the CII 10-10 program[44], 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.

2.3.6 Agile, a populare fade in management?

Over the past decades, many new trends in project management have emerged and later faded away. A paper [45] exploring six decades of project management trends illustrates the different perspectives of project management. Every trend argues its sovereignty. This illustrates the argument of Rolfsen, in her chapter in the book *Key Issues in Organizational Communication* [46], stating that managers are slavish following new fashions of project management. Rolfsen argues that the project management literature is a significant industry of its own. Often the literature is the one answer to every problem and criticizes the older theories, often written using pathos influencing the reader. Even though the literature promotes new methods into the organization, Rolfsen emphasizes that every fade has some good points.

Even though the focus on different fades promotes different ways of management, the goal is always the same; boost the marginal cost. The results of applying agile in the ICT-industry are promising, hence the increased LP over the past decades. The effect utilizing lean construction, on the other hand, is not to be seen in the statistics, though some papers can report on increased LP [47, 48].

Applying agile and lean has, for the most part, had a positive impact on projects. Also, every project management trend bring good points into the organization. The deployment of agile 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 [49]. 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 [50]. 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 [51], 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 [52].

Boundary Objects, introduced in the original paper [53], 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 [54], 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* [7] 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 [55] 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 [56]. 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 [5], 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 [57], 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 [58] 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 [59]. 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 [60] — the issue origins in the fact that every contractor has the goal of maximizing its marginal cost [33]. 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 [61]. 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 [62].

> *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 fundamental reason for the striking difference in labor productivity between 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 [63]. 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 [64]. 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 interpretivism paradigm — the use of empirical observation of the participants and a desire to identify how they act on the new software and methods used. 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 thesis.

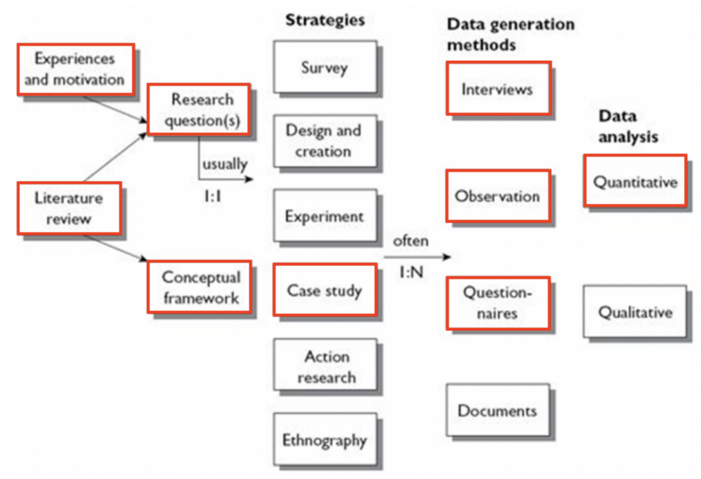

Figure 3.1: The research process used, marked with methods applied in the research.

RQ1: Why does the difference in LP between the ICT-industry and CI appear?
RQ2: How does the difference appear in the LSB-project, which utilize both agile and digital tools?

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 6.4, for every interview. The research process utilized in the projects can be seen in figure 3.1.

The observations took place over two days, in the project office, where different meetings were observed. The observations were recorded with notes and transcribed after the observations. Except for the Digitalization meeting, the Researcher was not able to ask questions during the meeting. Questions who came up was later answered by managers, or directly with participants, after the meetings. In addition to the observations and answering questions, talking to the managers and PLs, when on-site, gave valuable insight into how the project is run.

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.

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.

3.3 Participants

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

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 Data 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.

Codes	Themes
• Lack of understanding • Wrong use • New methods	Ignorance
• Responsibility? • Agrements • Protecting • Contracts	Decision Making
• Communication • Transparency • Delegation • Silo • Contracts	Interaction

Table 3.3: The process of turning of transcribed codes into different the three emerging themes.

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. Table 3.3 shows how the project combined codes into themes. As one can see, the code *Contracts* is to be found both in the *Interaction* and the *Decision Making* theme. The connection was very present and found as an underlaying reason for them both. 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 [9] 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

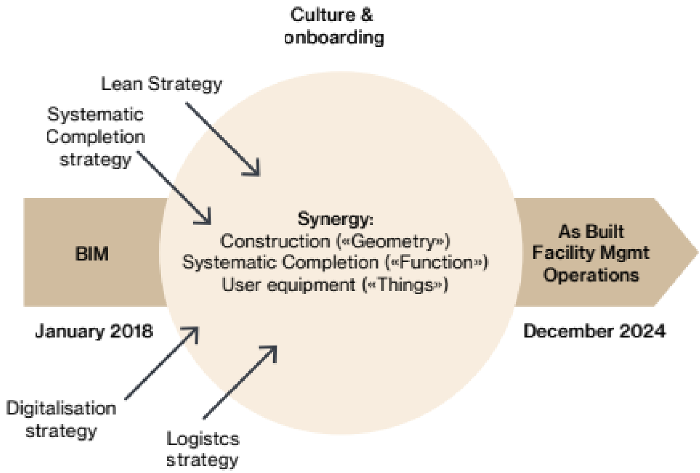

Figure 4.1: A hollistic view of Strategies in the Life Science Building-project.

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.

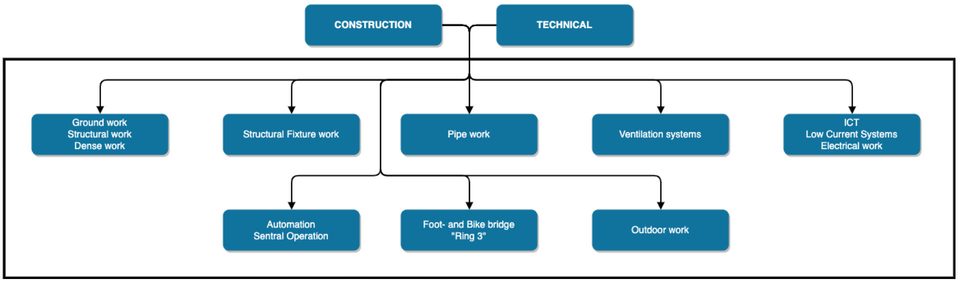

Figure 4.2: Contruction Contracts in the Life Science Building Projects, each managed by either the construction- or technical project manager.

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 Building Information Modeling (BIM) model. A BIM model is a representation of the construction stored in a particular format, namely the BIM format. The BIM-file can be used by several programs, in visualization, modeling, and operate the construction. 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

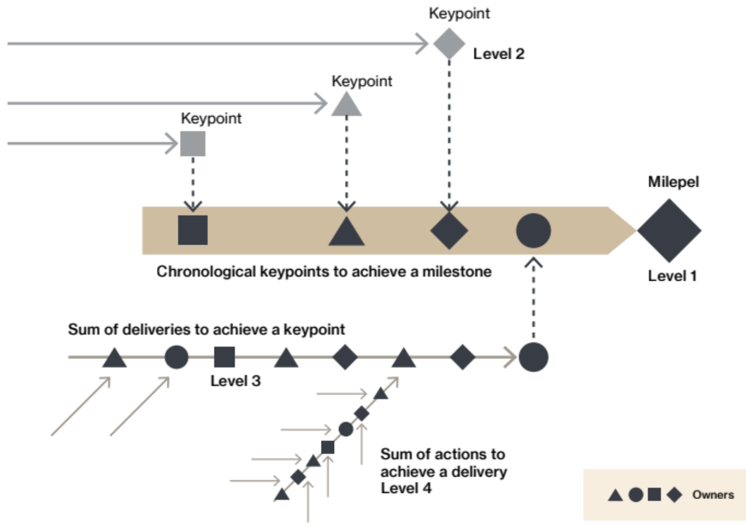

Figure 4.3: Contruction Contracts in the Life Science Building Projects, each managed by either the construction- or technical project manager.

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 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 [24], 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 2.2.2, 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. Revit, the BIM modeling tool, is, in many ways, the core of the project, supported by 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.

- **Revit:** BIM modeling tool, used in the design and construction of the project. Revit is a local software for every modeler, architect, and worker modelling. Moreover, other stakesholders and managers can see the model because there is a shared central model of BIM. The model is uploaded to the shared source once a week.

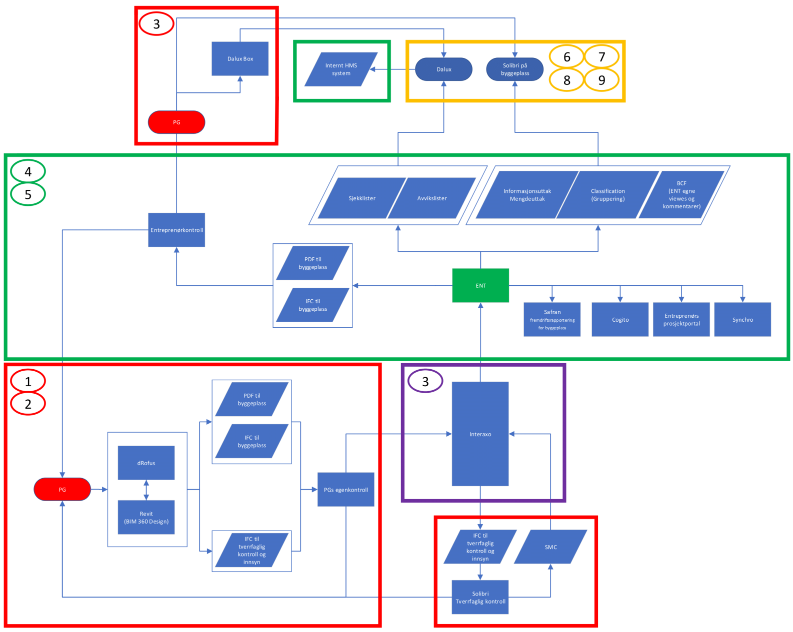

Figure 4.4: Overview over the system architecture used in the Life Science building project. Outlines representes the actors using the systems, by color: (red) Project group, (green) Entrepreneurs, (yellow) HSE, and (blue) cloud service sharing documents

- **dRofus:** Software supporting BIM. Whats defined in dRofus is known as the truth if there is a mismatch between BIM and dRofus. The software is used as the database for the BIM model and used in the planning of every room. Furthermore, the data stored in dRofus is being used in the procurement of systems and objects to the project.

- **Interaxo:** Cloud service for documents. Servicing onboarding, breach handling, and offboarding. Ineraxo is a platform gathering almost all the documents needed in a construction project. The high demand for documentation is simpler using this tool.

- **Blink:** Communication tool. This way, interactions can happen rapid and informally without booking meetings and writing extensive emails. Blink was chosen due to its confidentiality and securities policies. Other services like this are Slack and HipChat.

- **Cogito:** Visualization of ongoing and planned packages, in both the design phase and construction phase of the project. The idea of the tool came from the needs encountered in previous projects [9]. The project director and other managers of the LSB-project have formed the Cogito project, thus are invested in 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.

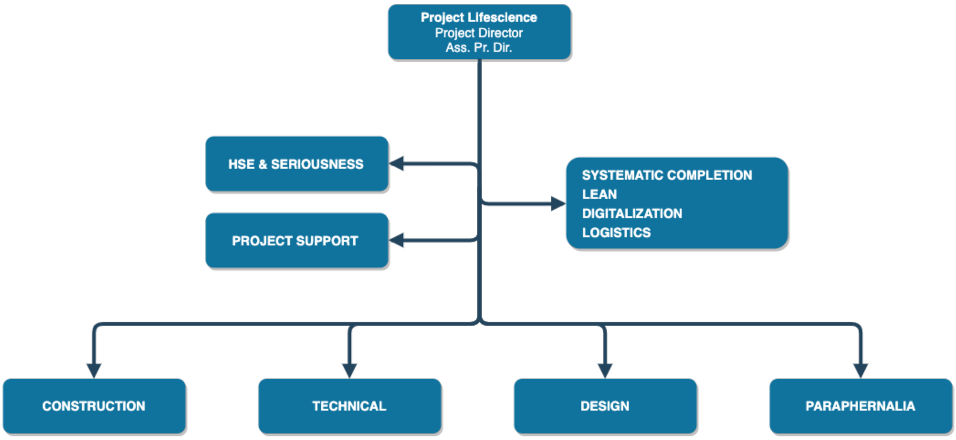

Figure 4.5: Organizational structure in the Life Science Building Project.

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.

4.2 Results of the case object

This section will examine and discuss the case results 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 [9], 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 Gantt 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. The lack of progress was reported using reports from Cogito, and compared with the initial plan given by the Gantt chart. The use of Gantt is required by the managing organization, Statsbygg, but is not used tracking progress by the project management. The use of Gantt charts is, for the most ended in the ICT-industry, but is broadly used in the CI. One can ask, as Sutherland asked [24], why using Gantt charts when they always turn out to be wrong?

The lean design method is deeply reliant on the BIM model, which is the product of the lean methodology. Therefore, the once-a-week update of the common model can tend to be thin. This can lead to modelers doing the same act twice, and cooperation between different diciplines are hard because the model is not up-to-date; moreover, the managers can not track the progress more than once a week.

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 [9], 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.

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. Though most of the project workers (modelers and architects) utilize Revit every day, most of them do not know what BIM is. The fact that it is a file format used by different software is misinterpreted. This is sadly the fact for most of the project managers and PLs as well.

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. Adding to this problem is that the tools used tend to focus on function, rather that usability. This makes for even wors understanding of the applied software.

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

Discussion

This chapter discuss the questions on the research question, and discuss the results. Using knowledge from both the litterature review and the case study. This discussion will give the foundation for the conclusion and further work discussed in chapter 6.

This project thesis tries to identify the fundamental reason for the striking difference in LP between the ICT-industry and CI, in a project utilizing lean methodology and software supporting it. The results indicate that the use of tools as lean and groupware is not as helpful as hoped, due to reduced utilization. The indication for poor LP identified in the LSB-project has a basis in the interaction between the workers, where a lack of understanding and unsure responsibility are a significant impact on the projects productivity.

This result suggests the reason for the striking difference in LP. This chapter will discuss this result around the three key themes identified in the analysis of the interview data. Furthermore, look at different approaches defeating these issues, as well as look at the limitations of this thesis.

5.1 Interaction

The interaction in a complex organization, with lots of contractors, causes a challenge for the interaction. A monumental issue is the contracts themself. The entrepreneurs are often less eager to cooperate if this could weaken their contract. Furthermore, the fear of transparency is a true barrier for good cooperation and interaction to happen. This cost of this issues is in line with Zaghoul [61], indicating the increased total cost for the project. Moreover, the contracts are in practice a concern about risk allocation. With the unsure responsibility, investigated further in section 5.3, proclaiming an even more significant increase in total cost.

The vision and strategies are an essential aspect of the management of the organization. The results contradict the claims of Buvik and Rolfsen [62] that the development of a common philosophy: namely the vision, will aid the trust among team members. The problem in the LSB-project is that the top-down approach heavily influences the management. This gives workers who have little perception of the common philosophy. Furthermore, early and clear role expectations and early development of trust are problematic in a project where there is a high degree of turnover.

The top-down approach makes for a problematic implementation of a common philosophy, but also the implementation of lean. One of the principles of the agile manifesto [23] states:

> *Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.*

This principle is contrary to the top-down approach influencing the project's structure. Also, how the lean is design is supporting the old methods used, and often contrary to the agile manifesto. The use of Gantt-chart is a prime example of this issue.

When they are applying lean in a top-down manner, it leads to the workers working in the same way as done before. This observation contradicts the claims from Ingvaldsen and Rolsen that the introduction of lean can hamper the Norwegian working model. This contradiction supports the difference between ICT-industry and CI. In the ICT-industry, the workers claim that they are working lean, while in the CI, lean is more a tool for project management.

5.2 Lack of understanding

Construction engineering is complicated and even more complicating when needing to synchronize with all other disciplines needed to get the building finished. The amount of knowledge needed in this business is immense. It is also wrong to state that the business lacks the understanding of computers and lean methodology, on a general basis. Though, in the LSB-project, there have been identified issues concerning lack of understanding, when introducing the tools used.

When considering the lean methodology, one might argue that it is not that they do not understand it, but that they will not use it. The reason might be that they have not seen the effect, and while knowing the old methods by heart, it is more natural to use those. On the other hand, when using it, they argue they are lean, just because they use the tools applied. Working on the underlying aspects of lean is, therefore, forgotten. Also, the motivation for utilizing lean is vague. When they do not grasp the motivation for utilizing lean, other than that, others have used it, and it was a success on previous projects. It seems like they have not understood the fundamental principles.

I addition to misinterpretation of lean, the understanding of digital tools is weak. In some cases, the digital tools applied are more a burden for the users than actual help. There are two main explanations for this problem to occure. One is that the tools investigated are for the most used by the managers, directors, and PLs, which tend to be of the older generation. The technical skillset is thus lower than the ones younger. Also, changing from one project to another with all different programs makes it even more difficult. Second, the usability of software applied is often not too good. The focus is more on the functionality of the program, rather than usability.

Both of these cases fit with the theory of a bottom up approch will be more sufficient securing the use of a certain tool [5]. While the top-down approach promotes are more broad use of the methodology, and can be sufficient for other projects later on, because the management can take the knowledge, and lessons learnd, and use it later [9]. Though, it seems like a bottom-up approach will be most effective, the initiative is hard to find in most projects and thus the top-down approch is needed implementing a new way of thinking.

Contradict to other research where one examine how users react to software improving (for the users) allready known practices [65, 66, 67]. The use of Cogito is not. Since Cogito is a tool to support the lean construction and lean design methodology, users not familiar with does do not have the prior context and understanding, which makes it even more difficult to use. Thus, using a top-down approch seems legit. The software supports only the project management, and thus not help in transparency and coordination between modelers, architects and workers.

5.3 Unsure resposibility

The LSB-project makes use of a customized contract, named *Totalentreprise med forutgående samspill*. The implications of a new contract have shown to be a more complicated issue than the intention. The intention of the contract was for the contract to support the interaction and prevent errors in the design. Also, considering the project consist of about 30 different contracting firms. The result is a problem in harmonization between the actors, thus leads to difficulty utilization of lean. This argument correlates with the previous research [33].

The project seems to have clear role expectations, as Rolfsen promotes[62]. The results show that even though the project has clear role expectations, it seems like the managers and PLs have problems in decision making. This might suggest that the contractors are up to secure their contracts and increase their revenue. However, based on prior research, one might argue that a more plausible explanation has to do with risk allocation [61].

The implications of the insecurity lead to delays and reduced utilization of human resources, which again leads to low LP.

5.4 Recommendations

The goal of this thesis was to identify the fundamental reasons for the striking gap in LP between the CI and the ICT-industry. The case seen in the previous chapter is a pioneer project due to its outspoken strategies and the use of new contracts and tools. In the research, this thesis has both found answers to the project question, as well as identified some recommendations. These recommendations face itself as further studies, but also actions for the LSB-project to make. This section is to discuss these findings.

The CI heavily invests in BIM, so do the LSB-project. The BIM maturity level 3 indicates, as mentioned in section 2.2.3, a shared BIM-resource. That is, there is a common model, used by everyone and updated so that everyone has the same knowledge about the model at every time. In the LSB-project, they do have a shared model, but this is only updated once a week. Having a shared model using a cloud-based system does not imply efficiency. Utilizing the system is demanding, and the correct tools are needed. Though the low utilization could be the symptoms of keeping up with trends [46], and not fully understand the potential of the provided tools. Having a shared model, does not help if they do not utilize the potential.

With today's technology, BIM updates could happen on the spot. As mentioned in the literature review, using a SaaS architecture could fulfill a real-time cloud-based system, providing every stakeholder the required information whenever needed. Also, having all BIM-software, including dRofus, use the shared resource will enhance productivity. Revit does not support this; thus, other measures are needed to be taken. Increasing the frequency of uploads could aid the interaction, though further investigations are needed to identify the implications of increasing such frequency. Furthermore, new updated tools are needed to make full use of what state-of-the-art cloud-architecture has to offer. Further research about BIM in an lean project could give answers to the

In the LSB-project, there is some software offered by the project managers, which are used commonly by all actors. Furthermore, every division has its specialist software needed for their specific job. All these programs often imply some authentication, which causes a challenge for some actors. Also, when introducing new software, for some, that is just another password and username. Thus, the need for a single-sign-on (SSO) is present. An SSO is giving the user access to all protected resources, after authenticated once using one single authentication mechanism, without reauthenticating. The Open Group [68] defines SSO as:

> *The mechanism whereby a single action of user authentication and authorization can permit a user to access all computers and systems where that user has access permission, without the need to enter multiple passwords.*

The need for SSO is especially present for the specialist, who is working on several projects simultaneously. Having a single-sign-on integrated with every tool needing authentication will improve efficiency dramatically. The effect of using SSO is general, thus not answer the question of this research, but this thesis recommends making use of an SSO, especially with the use of a SaaS-BIM-service.

Cogito is a significant support in interaction in the LSB-project. The tool offers transparency for project managers, and as a boundary object supporting knowledge sharing. Even though some of the PLs and managers do not like the transparency all that much, the tool is shown effective. Though the tool is effective, the potential is greater. Making workers, modelers, and architects, responsible for the task using Cogito, will make them transparent to work needed to be done. Moreover, leave some of the responsibility of the PLs. Thus, the research proposes infusing Cogito at a higher degree in the LSB-project. Research promotes a slow deployment of a new tool, also starting with one team at the time [5]. This will give a more robust deployment, and the first users can work as key personnel later in the deployment, aiding others with their knowledge. Further research is needed to explore the effect of the infusion, also to further explore the research question. Hence, the use of task boards is more common in ASD, such as scrum-board [24]. Thus, the use of Lean can feel more like an activity for the workers, modelers, and architects, more than a project management methodology.

5.5 Limitations

This project thesis has the goal of giving a direction for the upcoming master thesis. Even though the research is not to be published, the conduction of the results should be equally good.

The research question tries to identify answers to a generalized problem. Using a single case-study has the limitation of not providing the generalized answer, the method, though, will give a more in-depth observation of the phenomenon. This approach may answer some of the problems, but not all. Thus, the object observed could have displayed some of the issues, but certaynely not all.

Furthermore, the data used in the analysis is, arguably, too small. This is caused by poor planning, both from the researcher's side, but also, the contact at Statsbygg. When the planned observation was done, the project was at the end of a significant milestone, making for the small number of meetings observed. Also, the contact has been sick leave, which made for problematic planning of interviews. The collection of interviewees does not contain any workers (modelers, engineers, architects, etc.), which makes for a difficult discussion of the top-down approach due to misbalance in data.

Despite these limitations, the findings are still quite substantial. The issues reported are present, and some modifications are needed in the CI. Also, the research question has been answered. The finding can arguably describe some of the reasons for the difference in LP in the ICT-industry and CI. Still, further research is needed to establish a definite truth about the situation.

Chapter 6

Conclusion

The previous chapter analyzed and discussed the results of the research conducted in this project, as well as discuss prior research and experience identified in the literature study. This chapter aims to conceptualize the knowledge and results in a conclusion, answering the questions asked in section 6.1 and 6.2. Furthermore, giving a direction for further explorations in section 6.3.

The main research question of this projects was:

> *What is the fundamental reason for the striking difference in labor productivity between the ICT-industry and construction industry?*

Which was broken into two sub-questions:

RQ1: Why does the difference in LP between the ICT-industry and CI appear?
RQ2: How does the difference appear in the LSB-project, which utilize both agile and digital tools?

Section 6.1 and 6.2 outline the answer of RQ1 and RQ2 accordingly.

6.1 A Industry Arranged for the Past

The literature study identified an industry utilizing processes far behind its counterparts with an ever-increasing complexity hard to grasp with traditional processes and without aiding software. Most of the problems promote an agile methodology to be used in parts of the process.

Based on a case study researching a project utilizing lean and digital tools. The project has utilized a qualitative analysis of the case study, the research has identified three themes discussed in section 5.1, 5.3, and 5.2 of the Discussion chapter. These are the problems causing the difference in LP, discovered in this project.

Problems in the interaction between the personnel: To make the project run as smooth as possible, the people working have to cooperate. This is difficult without proper communication and interaction between different parties. If not cooperating properly, productivity decreases drastically.

Problems in decision making: Deciding on more or less critical questions is the root of much time spent. Often the problem is rooted in role complications. All the time spent on not deciding is fundamental in the LP gap.

Problems in ignorance: The industry has become more complex, making the industry taking action. This causes a rapid change in methods and tools. Following these changes are, therefore, difficult, causing misinterpretation and misuse of what could be useful measures.

6.2 Problems hampering the new methods

The discovery of the three themes in the previous section is the formation of two key underlying reasons for the LP issue to be present, in a project like the LSB-project, which utilizing both agile and digital tools.

1. **The actors' traditional perception** of interaction, transparency, and contracts hamper with the project's ability to utilize the strength of lean. The way LPs shelter the modellers from the blackboard-meetings are examples of how interaction and trancparency occur, because one are more concerned protecting their contracts.

2. **The actors' limited understanding** of the lean methods because of the lack of previous experience. The older PLs utilizing old tools such as Gantt charts are examples of this.

These two reseans are important for one another. If the understanding of lean had been good enough one could have understand the limitaions the traditional perception causes.

6.3 Further Work

Based on the results of the case study, creating a software collecting all the different software used, with a single sign-on, is a wanted addition to the project. Helping in knowledge sharing and is a way of taking explicit knowledge to a more manageable explicit knowledge [53]. Furthermore, more frequent updates of the shared BIM-model, or deployment of a SaaS solution could help the issue of interaction. Hence, BIM is a major part of the

LSB-project.

Further research is prohibited to understand the implications of these results, moreover, to understand the main question. The use of agile and digital tools can help cut the gap in LP. Cogito is mainly used by the mangers, PLs, and directors supporting the Lean methodology, while both management and workers use BiM.

Based on these conclusions, the LSB-project should consider more extensive use of Cogito, but the speed of the deployment is vital. A planned implementation for one team at the time, with the help of users, is, therefore, desired [5]. Looking at how the users make use of Cogito can give valuable insight into the interaction, decision making, and lack of knowledge identified by this project. Furthermore, explain the phenomenon of the striking LP-gap between the ICT-industry and CI in a project utilizing lean and digital tools.

Bibliography

[1] M. Bew og M. Richards: *BIM Maturity Diagram*, 2008.

[2] Hannah Wood og Philip Ashton: *Factors of complexity in construction projects*. 2009.

[3] Steinar Todsen: *Produktivitetsfall i bygg og anlegg*. https://www.ssb.no/bygg-bolig-og-eiendom/artikler-og-publikasjoner/produktivitsfall-i-bygg-og-anlegg, January 2018.

[4] W. W. Royce: *Managing the Development of Large Software Systems: Concepts and Techniques*. I *Proceedings of the 9th International Conference on Software Engineering*, ICSE '87, sider 328–338, Los Alamitos, CA, USA, 1987. IEEE Computer Society Press, ISBN 0-89791-216-0. `http://dl.acm.org/citation.cfm?id=41765.41801`.

[5] Daniel Robey og Sundeep Sahay: *Transforming Work Through Information Technology: A Comparative Case Study of Geographic Information Systems in County Government*. Information Systems Research, 7(1):93–110, 1996.

[6] Michael Hammer: *Reengineering work: don't automate, obliterate*. Harvard business review, 68(4):104–112, 1990.

[7] Jonathan Grudin: *Computer-supported cooperative work: history and focus*. Computer, 27:19–26, 1994.

[8] Richard Boland, Kalle Lyytinen og Youngjin Yoo: *Wakes of Innovation in Project Networks: The Case of Digital 3-D Representations in Architecture, Engineering, and Construction*. Organization Science, 18:631–647, August 0002.

[9] Hans Thomas Holm, Astrid Renata Van Veen, Sven Wertebach og Per Roger Johansen: *Lean metodikk i praksis*. Ad Notam Forlag, 2018.

[10] Luigi Federico Menabrea og Ada Lovelace: *Sketch of the analytical engine invented by Charles Babbage*, 1842.

[11] Peter Naur og Brian Randell: *Software Engineering: Report of a conference sponsored by the NATO Science Committee, Garmisch, Germany, 7th-11th October 1968*. 1969.

[12] Herbert D Benington: *Production of large computer programs*. Annals of the History of Computing, 5(4):350–361, 1983.

[13] Barry W Boehm: *Improving software productivity*. Computer, (9):43–57, 1987.

[14] Cong Liang, Weisheng Lu, Steve Rowlinson og Xiaoling Zhang: *Development of a multifunctional BIM maturity model*. Journal of construction engineering and management, 142(11):06016003, 2016.

[15] Yusuf Arayici, Ghassan Aouad *et al.*: *Building information modelling (BIM) for construction lifecycle management*. Construction and Building: Design, Materials, and Techniques, 2010:99–118, 2010.

[16] JP Zhang og ZZ Hu: *BIM-and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies*. Automation in construction, 20(2):155–166, 2011.

[17] Darius Migilinskas, Vladimir Popov, Virgaudas Juocevicius og Leonas Ustinovichius: *The benefits, obstacles and problems of practical BIM implementation*. Procedia Engineering, 57:767–774, 2013.

[18] Tien Hsiang Chuang, Bo Cing Lee og I Chen Wu: *Applying cloud computing technology to BIM visualization and manipulation*. I *28th International Symposium on Automation and Robotics in Construction*, bind 201, sider 144–149, 2011.

[19] Johnny Wong, Xiangyu Wang, Heng Li og Greg Chan: *A review of cloud-based BIM technology in the construction sector*. Journal of information technology in construction, 19:281–291, 2014.

[20] *Veksten i bygg og anlegg fortsatt i fjor*, 2019. `https://www.ssb.no/bygg-bolig-og-eiendom/artikler-og-publikasjoner/veksten-i-bygg-og-anlegg-fortsatte-i-fjor`.

[21] Statistics of Norway: *Produktivitetsfall i bygg og an-*

legg, January 2018. https://www.ssb.no/bygg-bolig-og-eiendom/artikler-og-publikasjoner/produktivitsfall-i-bygg-og-anlegg.

[22] Jan Alexander Langlo, S Bakken, OJ Karud, E Malm og B Andersen: *Måling av produktivitet og prestasjoner i byggenæringen*. Trondheim: SINTEF Byggforsk, side 7, 2013.

[23] Kent Beck, Mike Beedle, Arie van Bennekum, Alistair Cockburn, Ward Cunningham, Martin Fowler, James Grenning, Jim Highsmith, Andrew Hunt, Ron Jeffries, Jon Kern, Brian Marick, Robert C. Martin, Steve Mellor, Ken Schwaber, Jeff Sutherland og Dave Thomas: *Manifesto for Agile Software Development*, 2001. http://www.agilemanifesto.org/.

[24] J.J. Sutherland: *Scrum: The Art of Doing Twice the Work in Half the Time*. Crown Publishing Group, 2014.

[25] Kent Beck: *Extreme Programming Explained: Embrace Change*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2000, ISBN 0-201-61641-6.

[26] Steve R Palmer og Mac Felsing: *A practical guide to feature-driven development*. Pearson Education, 2001.

[27] Pekka Abrahamsson, Outi Salo, Jussi Ronkainen og Juhani Warsta: *Agile software development methods: Review and analysis*. 2002.

[28] Michael Lang, Kieran Conboy og Siobhán Keaveney: *Cost estimation in agile software development projects*. I *Information Systems Development*, sider 689–706. Springer, 2013.

[29] Tore Dybå og Torgeir Dingsøyr: *Empirical studies of agile software development: A systematic review*. Information and software technology, 50(9-10):833–859, 2008.

[30] *E-procurement Process*, 2019. anskaffelser.no/public-procurement/e-procurement/e-procurement-process.

[31] Peng Xu: *Coordination in large agile projects*. Review of Business Information Systems (RBIS), 13(4), 2009.

[32] Torgeir Dingsøyr og Nils Brede Moe: *Research challenges in large-scale agile software development*. ACM SIGSOFT Software Engineering Notes, 38(5):38–39, 2013.

[33] Christopher JM Miller, Gary A Packham og Brychan C Thomas: *Harmonization between main contractors and subcontractors: a prerequisite for lean construction?*

Journal of Construction Research, 3(01):67–82, 2002.

[34] Stein Otto Svorstøl: *Tailoring Agile Methods for Large Projects-A Case Study of a Large Agile Project*. Masteroppgave, NTNU, 2017.

[35] Darja Smite, Nils Brede Moe, Georgiana Levinta og Marcin Floryan: *Spotify Guilds: How to Succeed With Knowledge Sharing in Large-Scale Agile Organizations*. IEEE Software, 36(2):51–57, 2019.

[36] Christina Benjaminsen: *Slik jobber de aller beste teamene*, 2019. `https://gemini.no/2019/11/slik-jobber-de-aller-beste-teamene/`.

[37] Ronald M Becker: *Lean manufacturing and the Toyota production system*. Encyclopedia of world biography, 1998.

[38] Eric Ries: *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*. Crown Books, 2011.

[39] Robert L Owen og Lauri Koskela: *Agile construction project management*. I *6th International Postgraduate Research Conference in the Built and Human Environment*, bind 6, 2006.

[40] Ossama Salem, J Solomon, A Genaidy og I Minkarah: *Lean construction: From theory to implementation*. Journal of management in engineering, 22(4):168–175, 2006.

[41] Gregory A Howell: *What is lean construction-1999*. Citeseer, 1999.

[42] Hedvig Skappel: *KPIs in a Lean design process*. Masteroppgave, Norwegian University of Life Sciences, ÅS, 2017.

[43] *Nordic 10-10*, November 2019. `https://nordic10-10.org/`.

[44] *CII 10-10 Program*, November 2019. `http://www.10-10program.org/`.

[45] Milind Padalkar og Saji Gopinath: *Six decades of project management research: Thematic trends and future opportunities*. International Journal of Project Management, 34(7):1305–1321, 2016.

[46] Monica Rolfsen: *The tyranny of trends? Towards an alternative perspective on fads in management*. I *Key issues in organizational communication*, sider 126–142. Routledge, 2004.

[47] Remon Fayek Aziz og Sherif Mohamed Hafez: *Applying lean thinking in construc-*

tion and performance improvement. Alexandria Engineering Journal, 52(4):679–695, 2013.

[48] Glenn Ballard og Greg Howell: *Implementing lean construction: stabilizing work flow*. Lean construction, sider 101–110, 1994.

[49] Andrew RJ Dainty, Jidong Qin og Patricia M Carrillo: *HRM strategies for promoting knowledge sharing within construction project organisations: a case study*. I *Knowledge management in the construction industry: A socio-technical perspective*, sider 18–33. IGI Global, 2005.

[50] Peihua Zhang og Fung F. Ng: *Attitude toward knowledge sharing in construction teams*. Industrial Management & Data Systems, 112(9):1326–1347, 2012. `https://search.proquest.com/docview/1080974233?accountid=12870`.

[51] J. M. Kamara, G. Augenbroe, C. J. Anumba og P. M. Carrillo: *Knowledge management in the architecture, engineering and construction industry*. Construction Innovation, 2(1):53–67, Mars 2002. `https://search.proquest.com/docview/218321531?accountid=12870`.

[52] Serkan Kivrak, Gokhan Arslan, Irem Dikmen og M Talat Birgonul: *Capturing knowledge in construction projects: Knowledge platform for contractors*. Journal of Management in Engineering, 24(2):87–95, 2008.

[53] S. Star og J. Griesemer: *Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39*. Social Studies of Science, 19(3):387–420, 1989.

[54] Andrew L. Friedman og Dominic S. Cornford: *Computer Systems Development: History Organization and Implementation*. John Wiley & Sons, Inc., New York, NY, USA, 1989, ISBN 0471923990.

[55] Bob Ensor: *How Can We Make Groupware Practical? (Panel)*. I *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '90, sider 87–89, New York, NY, USA, 1990. ACM, ISBN 0-201-50932-6. `http://doi.acm.org/10.1145/97243.97259`.

[56] Ramanath Subramanyam, Fei Lee Weisstein og Mayuram S Krishnan: *User participation in software development projects*. Communications of the ACM, 53(3):137–141, 2010.

[57] Leslie Monplaisir: *Enhancing CSCW with Advanced Decision Making Tools for an Agile Manufacturing System Design Application*. Group Decision & Negotiation, 11(1):45–63, 2002.

[58] Jason J Jung: *Computational collective intelligence with big data: Challenges and opportunities*, 2017.

[59] Ola Lædre, Kjell Austeng, Tore I Haugen og Ole Jonny Klakegg: *Procurement routes in public building and construction projects*. Journal of construction engineering and management, 132(7):689–696, 2006.

[60] Ali Mohammed Alashwal, Hamzah Abdul Rahman og Abdul Mutalib Beksin: *Knowledge sharing in a fragmented construction industry: On the hindsight*. Scientific Research and Essays, 6(7):1530–1536, 2011.

[61] Ramy Zaghloul og Francis Hartman: *Construction contracts: the cost of mistrust*. International Journal of Project Management, 21(6):419–424, 2003.

[62] Marte Pettersen Buvik og Monica Rolfsen: *Prior ties and trust development in project teams – A case study from the construction industry*. 2015.

[63] Robert K Yin: *Case study research design and methods applied*. Social Research Methods Series, 5, 1993.

[64] *UiO, Livsvitenskap. Nybygg*, November 2019. https://www.statsbygg.no/Prosjekter-og-eiendommer/Byggeprosjekter/UiO-Livsvitenskap/.

[65] Jon O'Brien, Tom Rodden, Mark Rouncefield og John Hughes: *At home with the technology: an ethnographic study of a set-top-box trial*. ACM Transactions on Computer-Human Interaction (TOCHI), 6(3):282–308, 1999.

[66] Dag Svanæs, Ole Andreas Alsos og Yngve Dahl: *Usability testing of mobile ICT for clinical settings: Methodological and practical challenges*. International journal of medical informatics, 79(4):e24–e34, 2010.

[67] Else Nygren og Peter Henriksson: *Reading the medical record. I. Analysis of physician's ways of reading the medical record*. Computer methods and programs in biomedicine, 39(1-2):1–12, 1992.

[68] Open Group: *Single Sign-On*, 2019. http://www.opengroup.org/security/l2-sso.htm.

Appendix

6.4 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?