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

TDT4501 - Project Thesis

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Abstract

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

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Chapter 1

Introduction

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

1.1 Background and Motivation

The Construction Industry (CI) has been a significant part of engineering throughout history. Over the past century, the requirements of constructions have become more and more complex. The buildings are getting higher, the tunnels are getting longer, and the roads are getting wider. Sure, the size of things is not equal to the complexity of the construction; however, when considering automated systems, multipurpose functionality, and multiple communication platforms – the complexity is increasing. The increased complexity leads to a significant decline in labor productivity (LP), seen over the past two centuries, mentioned in the article written by SSB [1]. As well, managing these projects is much more intricate then it used to, because of the increased numbers of actors participating in the project.

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

The challenges the CI is experiencing, as well as the process used, are highly similar to what the ICT-industry was facing in the late ’80s. The ICT-industry, using the waterfall process [2], often faced the challenge of meeting the budgets and timelines. This breach had the origin in change of requirements during production, challenges in testing, and resultingly failing to deliver a finished product without bugs. These problems have been frequently present when creating large and highly user-interactive software — making for the introduction of agile software development to manage theses problems. Over the years, most of the process- and method-management in ICT is digitilized. Giving tools in which both the software developers and project managers use to aid project progression.

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

Furthermore, one has introduced Lean in the CI. The book [4] describes the making of the Bergen Academy of Art and Design-building, where Lean was one of the essential strategies. The object of the Case Study in this research are using experience from this book when managing the constructions.

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

1.2 Research and Question

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

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

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

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

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

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

1.3 Deliverables

There will be two main deliverables in this thesis.

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

Empirical review: Forklar

1.4 Thesis structure

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

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

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

Chapter 2

Literature Review

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

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

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

2.1 A Brief History of Software Engineering

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

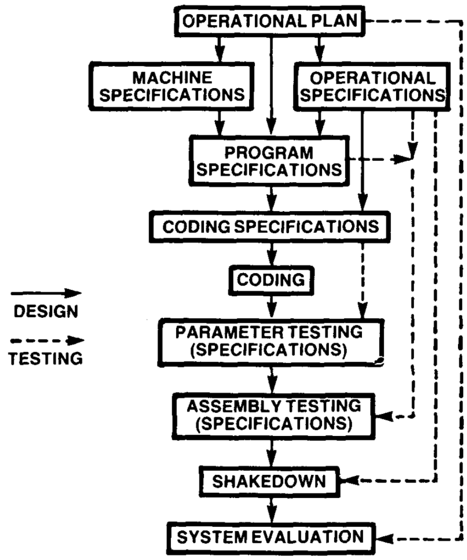

Figure 2.1: Production of a large-program system as presented of Bennington in 1956.

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

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

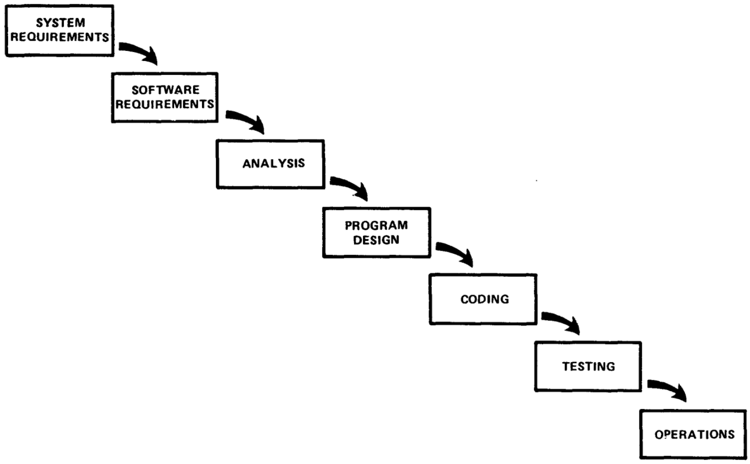

Figure 2.2: Waterfall method as proposed by Royce in 1970. Visualizing implementation steps to develop a large computer program for delivery to a customer.

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

In 1987 Barry W. Bohem wrote a paper comparing three papers from the past, with how the software industry treats process management of the time. The papers compared includes both Royce's and Bennington's paper. Bohem starts the paper with a quote from Gorge Santayana, "Those who cannot remember the past are condemned to repeat it." Even after Royce, the industry still struggled with requirements, documentation, staffing, and testing. Following the process, but forgetting the details resulting in some of the same problems previously recorded, thus the Santayana quote. An interesting detail is Bohem's discovery of the lack of prototyping and iteration, in the interpretation and use of the waterfall model: "Thou shalt not write one line of code until every detailed design specification is completed;" though both Royce and Bennington promote prototyping in the design phase.

The industry, entering the 90s and the 21 century, had a set of structures, processes, and models. Furthermore, it had become a known and highly valued field of engineering. Still, the discussion of productivity- and efficiency was present. Large software developments failed to deliver at the time and cost initially planned, sometimes failing to deliver at all. Some of the repeating problems were: (1) the initial requirements often changed during

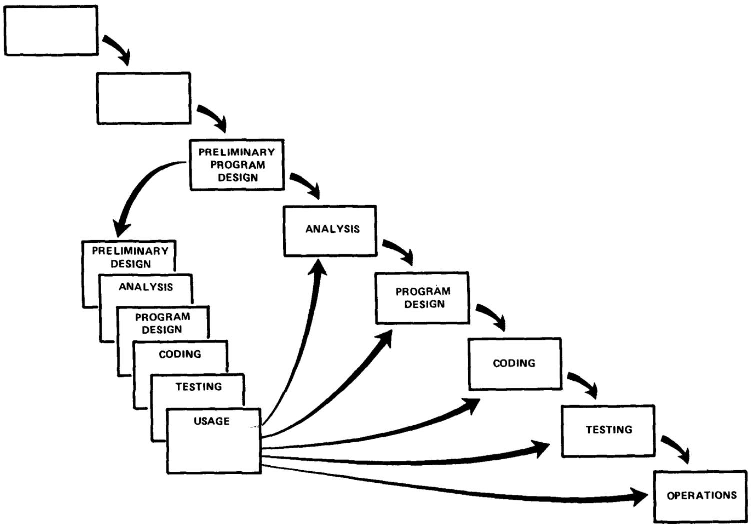

Figure 2.3: Waterfall method as proposed by Royce in 1970, including an iterative process using prototype. Attempting to do the job twice - the first result provides an early simulation of the final product.

the development process: forcing the development going back to the origin, costing both time and money; (2) the need of project management during a stage of the process: making sure developers working in parallel being exploited at an accepted level, and knowing what to implement at all times. The process models, such as Waterfall, structure the order of stages, and when to proceed to the next stage, while process methods are more concerned about guidance through each phase. Thus the need for software management methods was present and the introduction of Agile Development as a means to overcome, among others, the two problems mentioned.

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

2.2 Construction Engineering

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

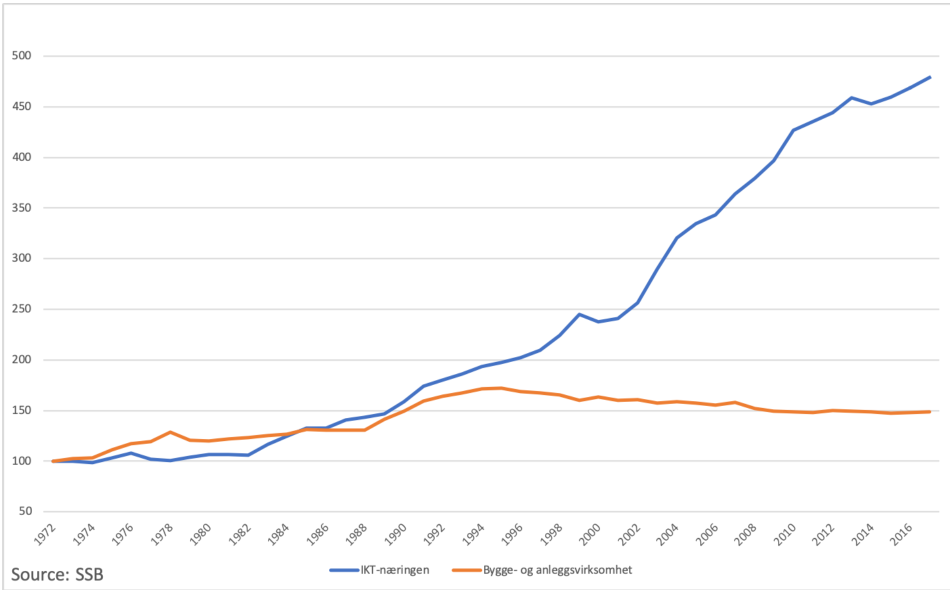

Figure 2.4: Labor productivity; ICT and CI compared from 1972 up to 2017.

construct both faster and better than ever before.

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

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

2.2.1 Construction Industry Project as Context for the Project

The process of constructing, in Norway, follows a pattern described by The Norwegian standard agreements (SSA). The construction process divides into five steps: (1) the early phase: where deciding both the vision of the project and process of project conduction;

(2) the procuring of architect or adviser: starting by publishing the project and at the end awarding the best actor with a contract; (3) the design phase: where one produces different levels of design; (4) the procuring of entrepreneur(s): includes deciding on contracts, and choosing the correct contractors for the job; and (5) realization: where conducting the substantive implementation.

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

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

2.2.2 Productivity

The Norwegian CI is, as mentioned, accused of having a decline in Labor Productivity (LP). An Industry that is one of the most significant industries in On-Land Norway, with 466 billion Norwegian Kroner accumulated in 2017. A common fact shared among the industry stating that CI is facing an LP decline of 10%, since the year of 2000. Often these numbers are justified by a complex and ever-changing industry and considered not representative of the industry of today. Sure the numbers are correct, but do these numbers show us the big picture?

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

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

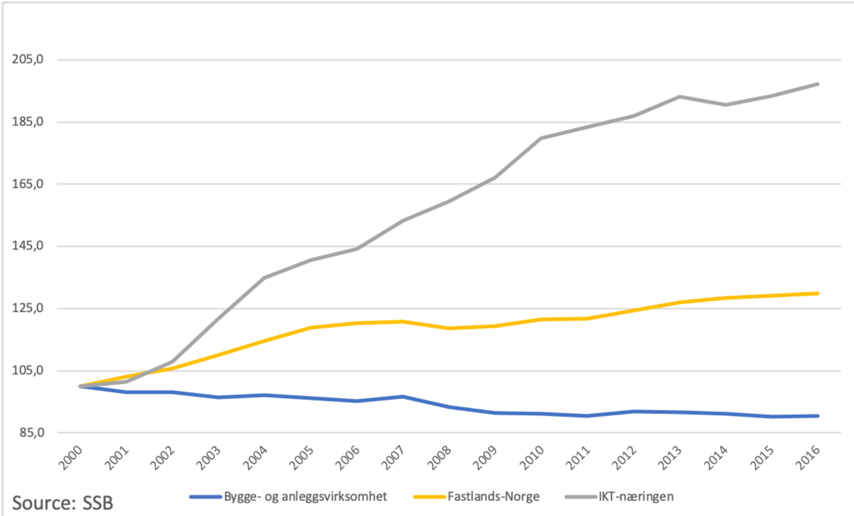

Figure 2.5: Labor productivity in the constructing industry, compared to average on-land industries in Norway, from 2000 to 2016.

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

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

By Statistics Norway (SSB) the constructing Industry (CI) suffer a substantial decline of 10%, since the year of 2000. This trend is also present in both Sweden and Finland. Comparing these numbers, seen in figure 2.5 with the same statistics in LP in all on-land private sector businesses, where there has been an overall increase, by 30%, one can arguably state that the decline is a fact. What do these statistics represent? SSB' definition of CI used in this calculation is labor that is directly involved in the on-site constructing, which is not representative of what is considered CI of 2019. Much of the work done on today's building site is prefabricated, and to get construction completed, one has to cooperate with a lot of businesses and industries. SSB explains that the reason for the small definition of CI is because of an EU-standard; hence, the comparison of the northern countries. If we consider the entire supply chain, there is a minor, in fact, increase in productivity of about 2% from 2000 to 2016, as seen in figure 2.6.

An issue paper posted by Sintef in 2013 raises the discussion about this topic. The issue paper states three central observations: (1) The numbers does not tell the whole story

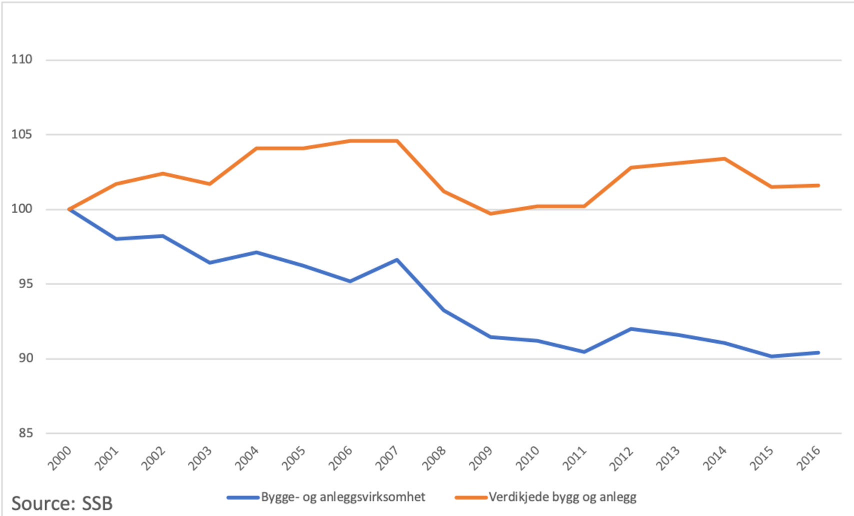

Figure 2.6: Labor productivity in the constructing industry supply chain, from 2000 to 2016.

about productivity, (2) the numbers can't be used in scientific research and (3) the numbers can not be used in comparing businesses, projects or corporations, because each project is so vastly different from one another.

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

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

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

Measuring productivity on project-, process- and process level

Practicing the bottom-up approach and implementing Lean Constructing in the design- and implementation phase, increasing productivity, and overcome difficulties (such as requirements change during design, increased complexity, and breach of planned timeline and budget) within the particular project phases. Lean is an excellent method but offers no mechanism measuring the achieved improvements. Using KPI's measuring could be a solution. Skappel [5] suggests in her master thesis, ten KPIs ensuring continuous flow improvement in Lean design process:

1. Number of work packages (deliveries) completed and delivered within a takt time
2. Number of decisions made on the wrong basis
3. Number of revisions after products in a common BIM are frozen
4. Number of unresolved questions in the dialog matrix
5. Intensity Curve - Number of questions asked in the dialog matrix and how fast these are resolved
6. Number of approved functional descriptions prepared at the right time
7. Number of correct functional descriptions revealed during table testing
8. Number of systems with developed test procedures before sending contract to contractors
9. Number of change requests due to errors and misunderstandings
10. Percentage of project material delivered to the contractors at the right time

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

In addition, by recommendation of the issue paper a project, started in 2015, establishing a state-of-the-art performance measurement tool. In 2017 the resulting Nordic 10-10 [**?**] program was finished. Nordic 10-10 is a version of the CII 10-10 program[**?**], 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,

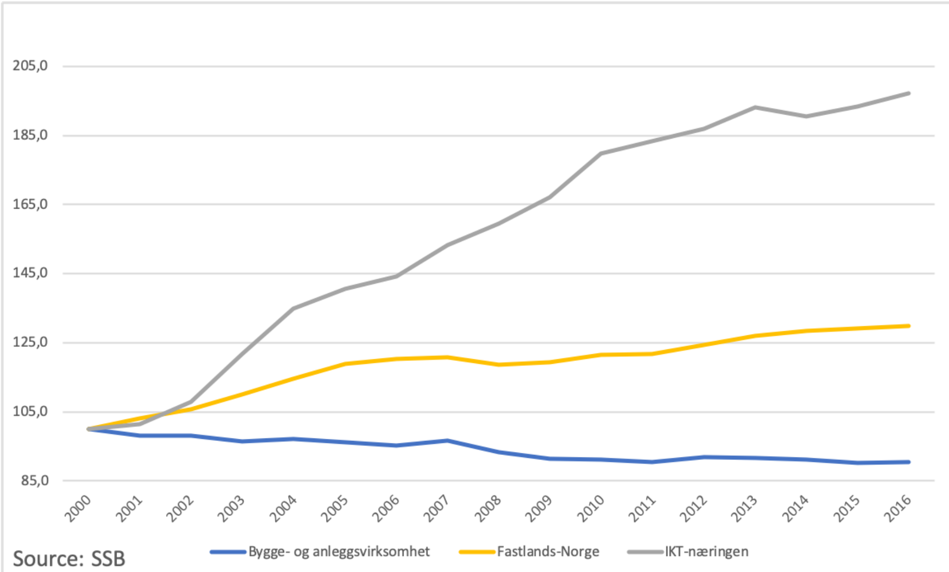

Figure 2.7: Labor productivity in ICT, compared to constructing industry and average on-land businesses in Norway, from 2000 to 2016.

regarding their project's performance, team dynamic, and organizational relationship. The surveying is done at the end of each of the five faces of the constructing project. Opposite to a standard approach, where such analysis is done only one time; at the end of the project. Using Nordic 10-10 results in more agile project management, where changes are implemented throughout the project. In some projects, they even do the analysis even more often, allowing the project manager to make changes also within each phase of the project.

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

Since the introduction of SCRUM [6], in 1995, the use of it, and other SDM, has been wastly spread throughout the majority of software development projects in the world, and Norway as well. It is, therefore, fascinating looking at the figure 2.4. Comparing LP in ICT and CI from 1972, up to the beginning of the '90s. Sky-rocketing after dot com, at the beginning of this century, while CI has a slight declining graph after breaking the millennia. Knowing the Agile manifesto was published in 2001 makes for a promising correlation. Though, one can not use LP as a single source of indication, nor stating that SDM is the single reason for the progress; this result yields for implementing agile project management in other industries. The next section will, accordingly, introduce different agile project methods.

2.3 Agile Project Management

This section will give an overview of Agile in the context of project management, as well as provide an introduction of different Agile management methods relevant to this project.

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

Agile Project Management (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 [7], 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.

Varius Agile Software development methods

This section will give a short introduction of some known ASDs such as; Extreme Programming (XP), SCRUM, or Kamban. These methods promote smaller teams of 5-12 people; therefore, also included is a short elaboration of ASD in large scale corporations, which encourages comparison between SD and Construction.

Extreme Programming

Kanban

Scrum

Agile software development in large scale corporations

2.3.3 Lean

Lean Construction

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?

2.4.1 Comunication and Knowledge sharing

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 lust 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.

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. 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.

Boundary Objects, introduced in the original paper [8], 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 [9], 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* [10] describe the motivation for groupware:

> *"The complexity of managing large government software contracts provided further incentive to apply technology to group work."*

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 [11] described as the only successful, CSCW application is e-mail. Groupware has been an essential part of collaborative work, but what makes good groupware?

To make groupware work, first, it needs to meet the needs and requirements of the group. When the software is thoroughly developed and tested to meet the requirements, one can argue that the software should work. Still, after a proper software development process, the critical implementation phase begins. Implementing new software has to fit the users. The article *Transforming Work Through Information Technology* by [12], 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.

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

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;

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.

Chapter 3

Case Study: The Life Science Building Project

3.1 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.

3.1.1 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 BAAB-project a the *Lean methodology in design and construction*-book [4] 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 strategies in the project are illustrated in figure 3.1.

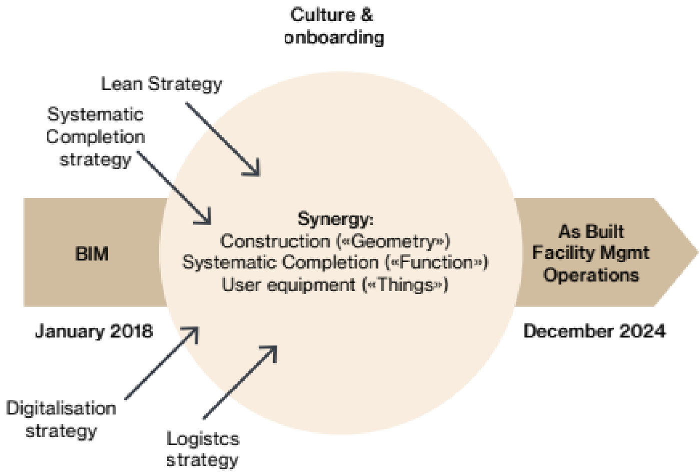

Figure 3.1: A hollistic view of Strategies in the Life Science Building-project.

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 3.2displays 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.

The Lean Strategy

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

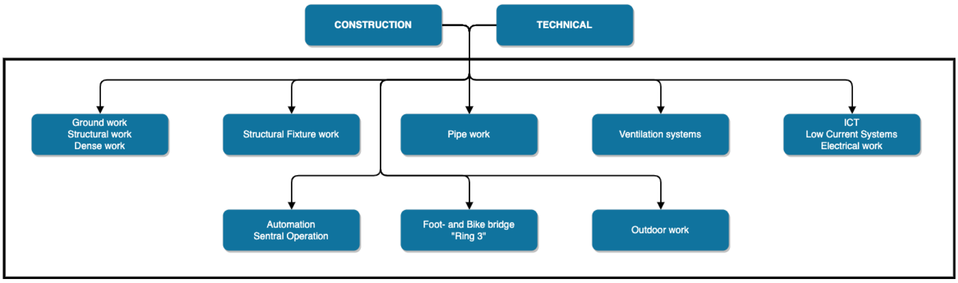

Figure 3.2: Contruction Contracts in the Life Science Building Projects, each managed by either the construction- or technical project manager.

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 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 BAAB projects. In all projects utilizing Lean as their project methodology, this project also iterates over a product. The product, in this context, is the BiM model. The BiM model is the 3-D model of the building. The project makes use of Level of Development (LOD), mentioned in the 2.3.3 section, where each iteration 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 iteration, the Lean Design method, therefore, made it easier having control over all interdisciplinary correlations. In LSB-project, these iterations are named sequences and takes up two weeks. In every sequence, the project leaders are assigned a set of packages. Ending the sequence, the project leaders need to deliver on the packages assigned. This way, the project can identify tasks that are, or can be, risks for the project.

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 3.3: (1) the Milestones: A significant planned completion of a part of the project, e.g., steering document approved; (2) Key

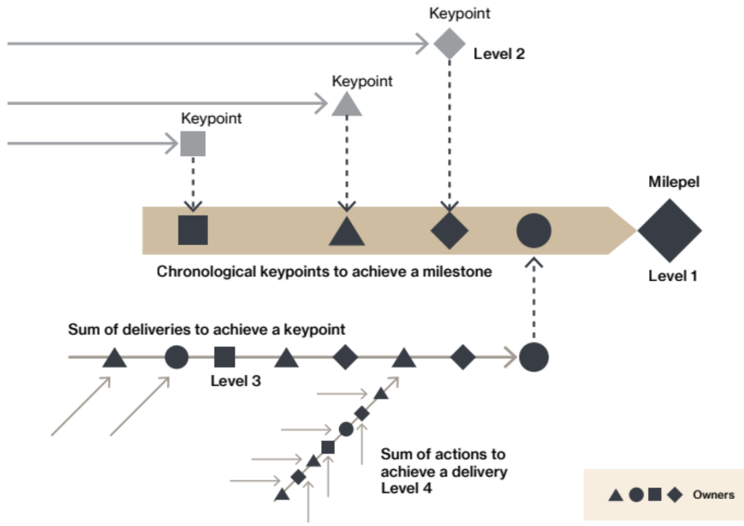

Figure 3.3: Contruction Contracts in the Life Science Building Projects, each managed by either the construction- or technical project manager.

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 2.3.3, 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 [6], the plan is not the final solution, the plan is what is needed, and adapt thereafter. Though, in this case it seems like the time was well spent giving the project leaders valuable insight into the project. Not spendig too much time planning ahed.

The Strategy of Systematic Completion

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

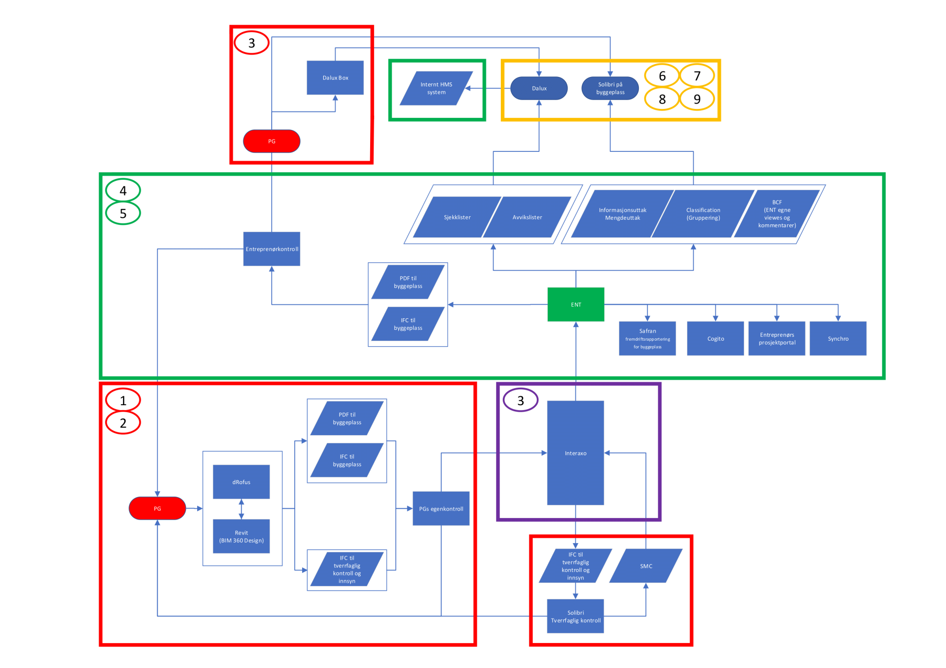

Figure 3.4: Overview over the system architecture used in the Life Science building project. Outlines representes the actors using the systems, by color: (red) Project group, (green) Entrepreneurs, (yellow) HSE, and (blue) cloud service sharing documents

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

The Digitalization Strategy

The Digitalization strategy is, both important in itself, but also supportive in regards to the other strategies. The project using a digital 3-D visualization of the building as the product, driving the Lean Design method. BiM is, in many ways, the core of the project, supported by a dRofus, which is the room database. Prominent in the strategy is connecting all software used in the project and making all entrepreneurs use the same. Hopefully, one can trace the socket implemented in a room, by an electrician, through the drawings given, back to the BiM-model, and the dRofus database, where it was first planned. The resulting system can later be used by janitors, running the building, to identify errors in the system. Figure 3.4 visualize the connected systems in the project.

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

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

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

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

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

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

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

The Logistics Strategy

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

3.1.2 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

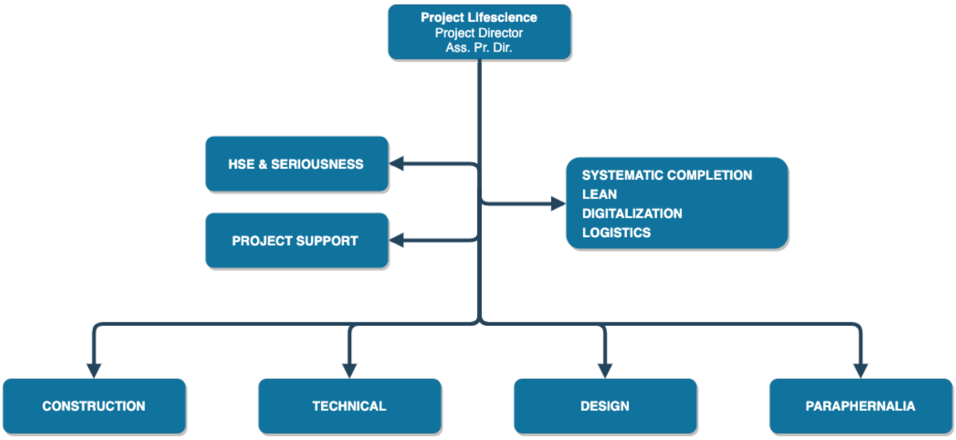

Figure 3.5: Organizational structure in the Life Science Building Project.

together, and in what order; and (2) implementation management or method management: The management of design and implementation of the final product. The organization structure used in the project supports the two levels of project management. The first of the two, process management, is using customized phase-based process management, inspired by agile thinking. Second, implementation management utilizing the above strategies.

The construction project organization structure is, as seen in figure 3.5. Starting at the top, in charge of the project, is the project director, supported by the assisting project director. 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.

3.2 Cooperation in the Life Science Building Project

The LCB-project is, as mentioned, a Norwegian pioneer construction, with a grand vision and intricate strategies, not conducted at this scale before. Running pioneering work is often a conglomeration of trial and error, and the LCB-project is not different. This section will look at the Case and discuss how the project utilizes Lean and supportive software. As well as, how does knowledge sharing work, and what are the problems regarding cooperation in the LCB-project?

Chapter 4

Analysis and Discussion

This chapter tries to analyse and discuss the questions asked in the Research and Question section of the introduction. Using knowledge from both the litterature review and the case study, presented in section 4.1. This analysis will give the foundation for the further work discussed in section 4.2.

4.1 Analysis of the Case

4.2 Further Work

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Appendix

4.3 Intervjuguide

Intervjuguide
Navn og rolle:
Dato:

Avklaringer og informasjon:

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

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

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

Temaer som ønskes belyst

1. Bruk av agile metoder og lean i prosjektet

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

(b) Er det noen utfordringer ved denne bruken?

2. Bruk av digitale prosjekteringsverktøy i prosjektet

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

   (b) Finnes det noen utfordringer ved denne bruken?

3. Andre faktorer

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