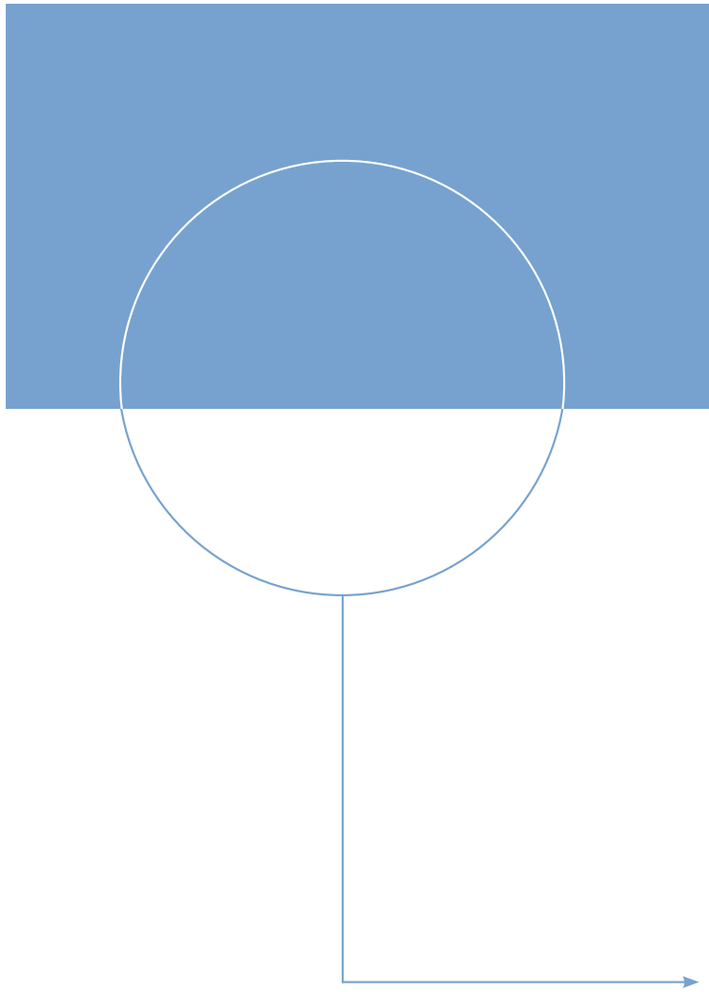

Master's thesis

2021

Eirik Færevåg Tømmervik, Mathias Berntzen Engevik, Fabian Kristoffer Elvegård Utigard

Master's thesis

NTNU
Norwegian University of
Science and Technology
Faculty of Economics and Management
Department of Industrial Economics and Technology
Management

Eirik Færevåg Tømmervik
Mathias Berntzen Engevik
Fabian Kristoffer Elvegård Utigard

Successful Innovation Adoption on Complex Construction Projects

Which drivers and barriers exist for innovation adoption and how can companies assimilate new technology, within the Norwegian construction industry

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Eirik Færevåg Tømmervik
Mathias Berntzen Engevik
Fabian Kristoffer Elvegård Utigard

NTNU School of Entrepreneurship
Submission date: June 2021
Supervisor: Roger Sørheim

Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

Preface

This thesis was written during the spring of 2021 by Eirik F. Tømmervik, Mathias B. Engevik and Fabian K. E. Utigard, students at NTNU School of Entrepreneurship (NSE), under the Department of Industrial Economics and Technology Management, at the Norwegian University of Science and Technology.

The thesis will present an empirical study on innovation adoption within the construction industry, based on unique data collected from four complex projects.

We have had the privilege of receiving academic support and guidance from our supervisor, Professor Roger Sørheim, which has been available to us at all hours of the day. The delivery of this thesis would not have been the same without his help. We are very grateful.

Our motivation to study technology innovation adoption, within the Norwegian construction industry, is due to our involvement in starting a technology-based venture, developing digital tools for industry actors. We have noticed that construction is lagging behind in terms of digitalisation, where implementing new technology has proved difficult. The combination of learning about innovation adoption from the literature, while simultaneously practicing it through our ventures, has given valuable insights into the matter.

We look forward to proceed with our venture after graduation and we will bring all acquired knowledge from NSE into our work.

Trondheim 11th of June 2021

Eirik F. Tømmervik, Mathias B. Engevik & Fabian K. E. Utigard

Abstract

The Norwegian construction industry suffers from high competitiveness, low margins and declining productivity. Innovation is pointed to as a crucial factor for the industry to renew and meet the strict requirements of tomorrow's sustainability demands [1]. However, the intensity of competition is at a level which attenuates innovation activity, and the degree of technological readiness is unevenly distributed across the industry [2]. Although the construction sector is characterised by a broad collaborative culture, the industry consistently fails to bring forward new innovations [3]. In order to reverse this trend, more research is needed on the domain.

Several cross-sectional studies have been carried out to examine the various prerequisites for innovation adoption, i.e. drivers and barriers, within the industry. The connections between empirical data and innovation literature are, however, incomplete, as the studies do not relate sufficiently to established theory on innovation adoption, or provide tangible insights into possible improvements. This master's thesis has been composed to contribute to this knowledge gap.

The purpose of the thesis is to examine existing drivers and barriers for successful innovation adoption, within the construction industry. In order to investigate which factors either promote or obstruct innovation, four complex construction projects have been examined, all with different owners and ambitions in terms of digitalisation, sustainability, and innovation. On each individual project, a triangulation has been carried out with a 360-degree perspective from the involved actors. Strategic and operational aspects have been analysed, both on the industrial and organisational level.

During the study it became clear that there are distinct differences between delivery and process oriented innovation. While the industry produces strong deliveries with innovative content, innovation related to processes are lagging behind. Ambitions and regulatory conditions are highlighted as central drivers for innovation, in addition to culture for testing and routinisation. The intense competitive situation in combination with low technological readiness, sceptical attitudes, and slow internal structures in the larger firms, have created an environment where even incremental innovations face challenges in terms of adoption. Consequently, these issues result in immense requirements for usability and compatibility with established systems and processes, for new innovations to be successfully adopted.

The thesis is concluded by summarising the prerequisites for successful innovation adoption, how these affect the industry, and by what means organisations can ensure successful routinisation. Subsequently, the implications are presented, containing suggestions for policy makers and regulators, industry actors, innovators, and for further research.

Sammendrag

Norsk byggebransje er preget av svært høy konkurranse, lave marginer og synkende produktivitet. Innovasjon trekkes frem som en avgjørende faktor i bransjens kamp for å møte morgendagens strenge krav til bærekraft [1]. Konkurranseintensiteten har imidlertidig nådd et nivå som hemmer næringens innovasjonspotensiale, i tillegg til at teknisk kompetanse er ujevnt fordelt mellom bransjeaktører [2]. Selv om byggesektoren er prosjektbasert og dermed gjennomsyret av samarbeidskultur, klarer ikke bransjen å bringe frem nye innovasjoner og omstille seg [3]. For å snu denne negative trenden er det et stort behov for mer forskning på området.

Flere empiriske studier er utført med den hensikt å undersøke de ulike forutsetningene for innovasjonsadopsjon, dvs. drivere og barrierer, innen byggebransjen. Linjene mellom empiriske data og innovasjonslitteratur er imidlertid begrensede, ettersom studiene forholder seg i liten grad til etablert teori om innovasjonsadopsjon. Denne masteroppgaven er utarbeidet for å bidra til å tette dette kunnskapshullet.

Hensikten med oppgaven er å undersøke eksisterende drivere og barrierer for vellykket innovasjonsadopsjon i byggebransjen. For å kartlegge hvilke faktorer som fremmer og hindrer innovasjon, har fire komplekse byggeprosjekter blitt undersøkt, alle med forskjellige byggherrer og ambisjonsnivå hva gjelder digitalisering, bærekraft og innovasjon. På hvert individuelle prosjekt er det gjennomført en triangulering med 360-graders perspektiv fra de respektive aktørene som er involvert. Både strategiske og operasjonelle aspekter er analysert, på bransje- og organisasjonsnivå.

I løpet av studien kom det frem et tydelig skille mellom leveranse- og prosessorientert innovasjon. Mens bransjen presterer sterkt på prosjektleveranser med høy innovasjonsgrad, er prosessorientert innovasjon nedprioritert. Byggherrens prosjektambisjoner samt regulatoriske forhold trekkes frem som sentrale drivere for innovasjon. Videre bør en kultur for testing og rutinisering være på plass. Den intense konkurransesituasjonen i kombinasjon med lav teknisk beredskap, skeptiske holdninger og trege interne strukturer i de store selskapene, har skapt et miljø der selv adopsjon av inkrementelle innovasjoner møter store utfordringer. Problemene resulterer i enorme krav til brukervennlighet og kompatibilitet med etablerte systemer og prosesser, for at nye innovasjoner skal lykkes.

Oppgaven rundes av med å oppsummere forutsetninger for vellykket innovasjonsadopsjon, hvordan dette kan påvirke bransjen, og hvordan organisasjoner kan sikre vellykket rutinisering av ny teknologi. Avslutningsvis presenteres konkrete forslag til tiltak som kan bidra til økt omstillingsevne i norsk byggebransje. Vi håper at oppgaven kan være en tankevekker for myndigheter, bransjeaktører, innovatører og være inspirasjon for videre forskning.

Contents

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List of Abbreviations

A	*Architect*
AR	*Augmented Reality*
BIM	*Building Information Modeling*
BREEAM	*BRE Environment Assessment Method*
C	*Contractor*
CEO	*Chief Executive Officer*
CI	*Closed Innovation*
C"n"	*Case "n"*
CV	*Corporate Venture*
DB	*Design Build Contract*
DBB	*Design-Bid-Build Contract*
ERP	*Enterprise Resource Planning*
GDP	*Gross Domestic Product*
Industry Level	*Industry & Project Level*
KPI	*Key Performance Indicators*
La	*Linked actor*
MOM	*Management, Operation and Maintenance*
OI	*Open Innovation*
Organisational Level	*Company & Individual Level*
P/D	*Process or delivery*
PO	*Project Owner*
R&D	*Research and Development*
SaaS	*Software as a Service*
SWP	*Software Provider*
S/P	*Strategic or Operational*
TPM	*Technical Project Manager*
VDC	*Virtual Design and Construction*
VR	*Virtual Reality*

1 Introduction

1.1 Importance of the topic

Productivity is a crucial driver for economic growth and prosperity in any society. Some industries have proved to be more prone to innovation resistance, leading to low productivity growth. This largely applies to the construction industry, where productivity has stagnated over the past 20 years. The large scale and low productivity, of construction, also means that the industry accounts for a considerable share of the world's CO2 emissions [3]. The construction and operation of buildings currently accounts for approximately 40% of total energy consumption globally, and approximately 39% of energy-related emissions of eq. CO2 [4]. Simultaneously, the industry accounts for only 13% of the world GDP. This means that greenhouse gas emissions do not correspond to the value created in the industry. The construction industry's low value-creation is due to low productivity and slim margins in the entire value chain [1, 3]. Measures has to be made within the industry to keep up with the rest of the economy. The use of innovative digital technology is considered one of the most significant initiatives to do so. [2]

The construction industry, which historically has been seen as conservative, has adopted several new solutions to improve productivity in recent years. Automation of labor-intensive processes using robot technology, digital project tools to save time and better collaboration on projects, and building information modeling (BIM) to improve the quality of deliveries, are some examples of new implementations [5, 6]. There are clear tendencies that this is a step in the right direction and that the aforementioned technologies will improve productivity and profitability in the industry. Nevertheless, these implementation processes are slow, and players are hesitant to adopt new technology [5]. Why does that seem to be the case?

1.2 Knowledge gap

It's a well-established fact that the construction industry has low margins and that increased productivity and innovation are absolutely crucial, for the industry to progress in the right direction [1]. However, the intensity of competition is at a level that constricts innovation activity, and where the degree of technological readiness is unequally distributed both between industry actors and individuals [2]. Several general empirical studies and reports have been carried out in recent years, e.g. Bygballe's Logic of innovation in construction [7–9]. The studies are cross-sectional and provide insight into the overarching barriers. However, they do not relate sufficiently to established innovation theory, such as *Innovation Adoption* and *Open Innovation*, to be able to provide enough insight into possible and tangible improvements. This research showed that the industry can be characterized as *open*, but the actors still fail to promote innovations across organisational boarders. The value creation in the industry occurs on a

project basis, which entails that all collaborations and contracts are temporary. Pilot projects are carried out to test new innovations, but the knowledge and results from these are marginally researched and measured. Thus, successful innovations from pilots do not necessarily reach the rest of the industry [7–9]. This is where a knowledge gap has been uncovered.

To close this knowledge gap, it was essential to take the findings from these complex construction projects, and link them to established innovation theory, to examine how the industry could move forward to achieve its goals. To investigate this, it was essential to study which drivers and barriers existed at the various levels in the industry. There can be a considerable difference between the strategic and operational drivers and barriers from an *Organisational level*-perspective (Company & Individual) and an *Industry level*-perspective (Industry & Project). The discovered prerequisites for innovation were an essential foundation for suggesting tangible improvements for the industry. Therefore, it was desirable to examine the theoretical and empirical findings, in relation to each other, to see how they could be transferred to the practical, or operational, aspects of the industry. This was done, such that the various actors can more effectively adopt innovations successfully, to further improve the industry.

1.3 Purpose and research questions

Based on the presented knowledge gap, this thesis' intention is to examine existing drivers and barriers, for successful innovation adoption, within the construction industry. This was done from the perspective of large and complex projects, to capitalise on the knowledge of the most progressive coalitions in the industry. Strategic and operational factors were analysed, both on the industrial and organizational level. Subsequently, it has been investigated how the drivers and barriers are linked to the different levels. To be able to investigate which aspects are advantageous or obstructing for innovation adoption, various complex construction projects have been examined, all with different owners and ambitions in terms of digitalisation, sustainability, and innovation. This was done to explore how the different project actors experienced innovation on that particular project. Consequently, the purpose of the study is to investigate the following research questions:

- *What drivers and barriers for innovation adoption exist in complex construction projects?*
- *How can complex construction projects successfully adopt new technological innovations?*

1.4 Contribution

With data on strategic and operational preconditions for innovation, from project owners, contractors, consultants and software providers, on four unique and ambitious construction projects, this thesis aims to contribute to a better under-

standing of which measures actually work to successfully adopt new technology within construction. In a time where the industry is persistently blamed for low productivity, there is a desperate need for research on how to improve innovation performance. The authors' own venture is involved in one of the aforementioned projects, which in combination with three other complex projects, provides great insights on innovation drivers and barriers. This thesis in combination with the antecedent project thesis have provided research on a particular area which is relatively unexplored. The thesis has taken an important second step into the domain and will hopefully contribute to increased attention on the matter. By exploring insights from different actors tied to high ambition projects, unique data from industry leaders have been the empirical foundation for the thesis. For the purpose of uncovering the drivers and barriers, from the perspectives of all project actors, the authors have interviewed in total 17 informants, with management roles, from four different cases (construction projects). The authors hope that industry leaders can use the thesis' results to further explore the huge potential which lies within innovation, through addressing the necessary preconditions.

1.5 Preconception

The authors have a solid understanding, based on prior experience, of the topics contained in this thesis. All three authors are current students at the NTNU School of Entrepreneurship, at the Norwegian University of Science and Technology, where they have had both theoretical and practical courses in entrepreneurship and innovation. This has contributed to a better understanding of the articles and the topics related to the literature, on which this thesis is based. The authors have an academic background from computer science and structural engineering, and one of the authors have experience from working for one of Norway's leading construction companies.

In the last year, the authors have also founded a technology company, Kvist Solutions, delivering software solutions to the construction industry. Their experiences entails a familiarity with the various aspects and challenges addressed in this thesis. Additionally, these experiences indicates that the authors have the prerequisites for creating an accurate depiction of the ecosystem, within the construction industry, and how digital solutions are implemented. This, combined with their academic background creates the foundation for a holistic picture of both innovation theory and industry characteristics. These experiences are included in this thesis, both in the context chapter, the theoretical foundation, the analysis, and in the discussion.

1.6 Structure

This master thesis is structured as follows: First, a context chapter on the construction industry serves as an introduction. This should be the starting point for the thesis and provide insight into trends and how things are connected in

the industry. Subsequently, the research methods and theoretical foundation are presented. Afterwards, the results from the interviews are presented, together with an individual case analysis, which creates the basis for the cross-case analysis. Finally, the results are interpreted in a discussion, before the thesis is concluded and the authors propose further implications.

2 The Construction Industry

2.1 Background

Construction has historically been conservative when compared to other industries. Banking, furniture, public transport, agriculture, among others, has automated large parts of their value chain. The Western European construction industry, on the other hand, went the opposite direction and focused on readily available labor from Eastern Europe. This was a contributing factor for approximately 80% of construction work being carried out on the construction site. This also contributed to the fact that work efficiency has been stagnant since the 1990s [2]. Figure 1 illustrates the increase in productivity in the construction industry compared to other industries. It shows that the construction industry has increased productivity by 1% since 1995, which is approximately 60% lower compared to the worlds total economy [3].

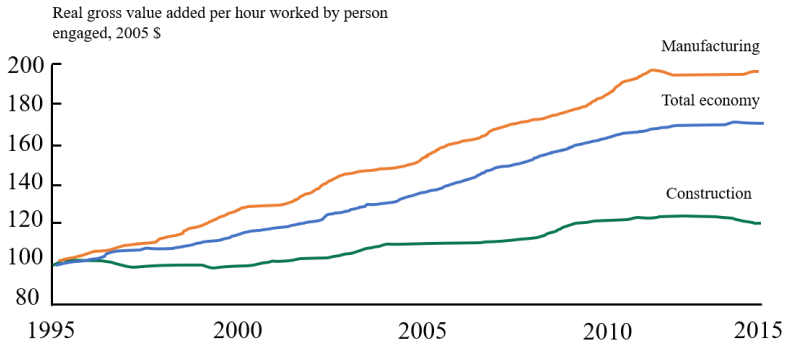

Figure 1: Global productivity growth trends

The focus of the industry has been short-term challenges with demanding customers and complex project deliveries. There has not been an industry culture to invest in long-term innovation to achieve efficiency, cost reduction, or revenue gains. Innovation in the industry takes place, to a large extent, within the individual projects and isn't scaled further to the rest of the industry. The companies consider their internal routines, information, and knowledge as a competitive advantage and are reluctant to share this information, which creates few synergies across the industry. Most of the companies' primary focus is also directly related to deliveries and execution, which makes it difficult to create new innovations. [10]

Every year, there is about $10 trillion in construction-related spending globally, equivalent to 13 percent of GDP. Thus, construction is one of the largest sectors of the world economy, employing 7 percent of the world's work force [3]. The industry has grown steadily in recent years, but the productivity has stagnated, and profitability has declined. In 2019 the revenue growth stopped in Norway,

and growth fell from 10.7% in 2018 to 6% in 2019. Several analyzes show that there has been a decline in new projects. The customers are getting bigger, the projects are getting bigger, and several large contractors are competing for the same projects. This sharpened competitive situation puts further pressure on margins, and the operating margin for the entire value chain went down from 5% in 2014 to 4.4% in 2019 [1]. The high revenue and the low margins lead to an increased risk on the various projects. This project risk creates a more significant skepticism about implementing new digital tools, as these potentially creating higher risk on the projects [11].

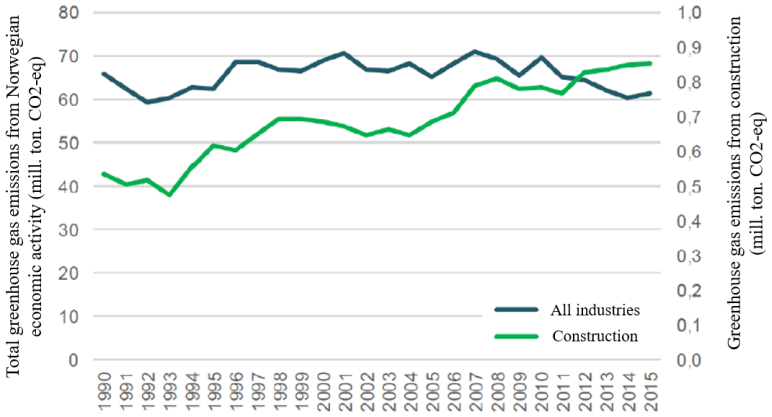

Figure 2: Emissions construction industry

As mentioned in the introduction, the low productivity of the construction industry also means that the industry accounts for a considerable share of the world's CO2 emissions [4]. Figure 2 illustrates the construction industry's emissions in connection with other industries [12]. As the figure shows, the emissions in the construction industry are growing, while the rest of the industries has a slight decline. To reverse this trend and allow construction to catch up to the others, the industry must rethink and introduce new and more efficient solutions.

2.2 Industry Players

The Norwegian construction industry is regulated by the Norwegian Government through the Law of Plans and Buildings and Technical Construction Regulations. Furthermore, The Norwegian Directorate of Public Construction and Property (Statsbygg) provides construction and property management services on behalf of the Norwegian Government. Statsbygg operates as a construction client on behalf of the government, and has consistently over 100 ongoing projects [13]. As one of the marked leaders in Norway, the company has a great influence on industry standards [14].

Value creation in the construction industry is mainly realized through individual projects. A project is a temporary organisation with a particular set of goals and boundaries, in terms of available resources and time frame. A project can be conducted internally in an organisation or it can be executed through collaboration between two or more parties across organisational boarders [15].

"The project" as a form of work has had an increasing importance over the last decades and is organised as an independent and temporary endeavor, undertaken to create a unique product or service. A project usually operates across different organisations, but can be organised internally as well. The majority of companies within the industry has several ongoing projects and their profitability depend on successful ones. Such companies may be denoted as projects based firms. A project is an organisational form designed to cope with situations characterized by great uncertainty. [16]

The construction sector contains many small companies, accompanied by a few large actors. The larger ones in Norway account for a smaller share of the national construction output, when compared to other countries [17]. This research's main focus is the larger companies and projects, as studies show that productivity decreases with growing size. This is known as the Ringelmann effect and is illustrated in Figure 3 [18].

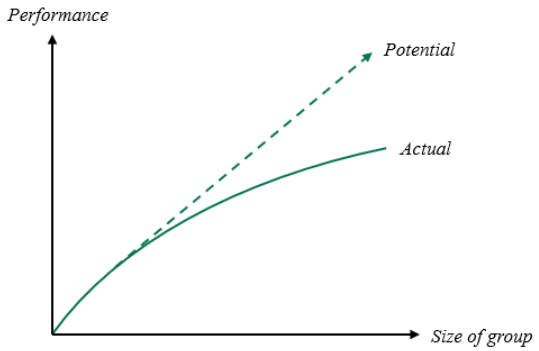

Figure 3: Correlation between team size and performance per employee

2.2.1 Project Owner / Construction client

A project owner (or construction client) is the party who commissions a building. The project owner typically has a long term perspective on a project in terms of results. There exist numerous types of clients, but for simplicity this research will separate them into two main categories, namely; the public and private sector. Generally, investors from the private sector emphasize value creation and profitability, whereas public investments also aim for societal benefits. [16]

2.2.2 Contractor

A contractor is hired by a construction client to plan and construct a given project. The contractor's attention is directed towards fulfilling the client's demands in terms of costs, time and quality. This entails the practical implementation of the project, within the strategic boundaries set by the client. The contractor is driven by result-oriented goals, combined with profitability. Norwegian contractors have been characterized by a high level competitiveness and low operating margins. [1, 16]

2.2.3 Product Supplier

Implementing a construction project is a complex task which involves assembling large quantities of components from different suppliers. The projects are supplied with a wide range of materials, products and services, ranging from support beams to BIM-software. The number of suppliers varies between projects and is dependent on project size, the degree of specialization of the suppliers, the contractor's experience, and in house competence. [16]

2.2.4 Service Provider

Assembling all the necessary components of a building requires a large work force. Great amounts of specialized personnel are necessary to complete a project. Service providers accounts for the majority of companies involved in a construction project and include consultants, architects, engineers, electricians, plumbers, concrete workers, etc. Service providers usually invoice per time unit of labour. Services are provided from different domains, the most central ones being: management, planning, and manual labour. [16]

The majority of the costs of a building project is related to this category, and the incentives for service providers to increase their efficiency are minuscule. However, if their competitors improves, competitive advantage will be lost [19]. In 2016, the businesses within manufacturing and trading of products for construction accounted for 29% of the sector's total turnover. The rest consists of service providers. Table 2 presents the turnover in the Norwegian construction industry categorized by industry player [20].

Table 2: Turnover in Norwegian construction industry in 2016

Industry player	Employed	Turnover [BNOK]	Percent [%]
Contractors	140 000	266	46
Product suppliers	62 000	165	29
Service providers	151 000	142	25
Total	*353 000*	*573*	*100*

2.2.5 Contract structures and project delivery methods

Once a construction client has announced a tender, different contractors will compete to obtain the project contract. There are multiple ways to organise a construction project, depending on the extent to which the project owner is involved and the competence of the contractor. There are two main types of project delivery methods, that is, *Design Build (DB) Contracts*, and *Design-Bid-Build (DBB) Contracts* [15]. Figure 4 illustrates the relations between the different actors usually involved in a construction project.

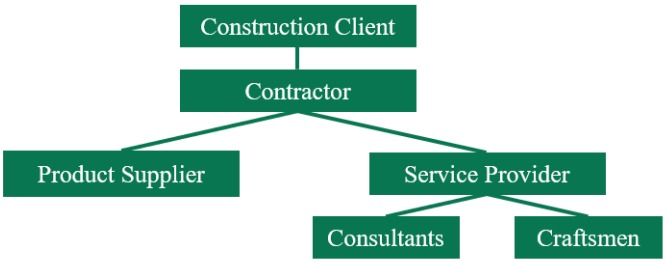

Figure 4: Roles in a building project

Design Build Contract is common in Norway and entails that the contractor is responsible for both the design and implementation stage. The contractor will then engage different service and product providers with independent contracts. Figure 5 illustrates the involvement of different actors in the phases of a DB project.

Design-Bid-Build Contracts are utilized in projects in which the project owner contracts different entities for the design and construction phase. There are different sub-types of DBB Contracts, but these will not be discussed further in this thesis.

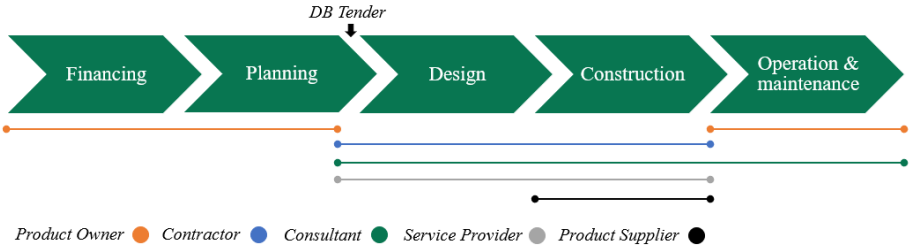

Figure 5: The involvement of different actors in the Phases of a DB project

2.2.6 Conflicts

Although the contract forms are designed to give the best result with as little conflicts as possible. Construction is an industry characterized by conflicts. In fact, conflicts and disputes accumulate a total socio-economic cost of 2,2 BMNOK from the Norwegian construction industry alone. There are no signs of any decrease of the level of conflict in the industry. [21, 22]

2.3 Digitalisation

Recent years has seen an increased focus on digitalisation and innovation in the construction industry. Terms such as Industry 4.0, to describe the digitalisation and automation trend, have been introduced [5], and according to the innovation barometer for construction in 2020, it appears that 89% of the companies in the industry work with innovations in technology [23]. Additionally, the construction industry has also prepared a digital road-map, i.e. a framework for how the construction industry can achieve competitiveness, full digitalisation, and sustainable development by 2025 [24]. This road-map is based on four assumptions:

- Establishment of a common digital platform with standard components for building and construction projects.
- Ensure that Norwegian standards, laws, and regulations are adapted for digital interaction.
- Ensure competence development in companies and education systems.
- Achieve synergies by sharing best practices on digital work processes and business models and then measuring the impact of this.

Based on these assumptions, the construction industry has set itself ambitious goals connected with the digitalisation work. By 2025, there should be:

- 50% reduction of CO2 emissions
- 25% cost reduction
- 50% faster project execution
- 50% increase in exports of products and services

These goals have pushed industry actors to be more innovative and implement new solutions. Some opportunities have been created, and there has been an increase in the adoption of new technology [5]. This has led to, among other things, better collaboration, delivery on time and budget, and cost reduction. One of the largest and most important digital entrances in recent years has been BIM, and other simulation programs. BIM has increased the quality of construction, as errors made in earlier stages can be avoided when one can simulate the entire construction process. Big Data analytics can also help project

managers in making more efficient and well-informed decisions based on historical data [5]. The use of BIM has also made it easier to keep projects on schedule and on budget [25].

Due to the large number of personnel and various actors involved in a construction project, cloud-based project management tools have become essential in all projects. This has proved an effective way to improve cooperation and communication between the various actors [6]. In recent years, simulation technologies such as Augmented Reality (AR) and Virtual Reality (VR) have also been introduced to the industry. This has allowed project owners to gain a greater insight into the building's details and execution before the building is constructed [25]. On this basis, customers can be involved in the planning process for a better adaptation of the building.

The construction industry has a high proportion of occupational injuries and accidents due to the dangerous working conditions that may occur [26]. Therefore, many researchers and practitioners present different approaches to improve construction sites' safety, e.g. by using virtual safety training where both VR and AR can be used. Automation of labor-intensive processes using robot-, and innovative production-, technologies, such as prefabricated building elements, has also resulted in time savings and material reduction. Additionally, automated tracking of equipment and materials using built-in sensors has been seen to reduce material costs [5].

The new adoptions seem to have improved productivity within the industry. Nevertheless, the broader implications of digitalisation and automation are still relatively unknown in construction, which may be causing the enduring slow progress. Broad innovation adoption may also be implicated by the intricate value chain, affected by the many stakeholders and complexity of projects. Furthermore, the construction industry consists of large numbers of small and medium-sized companies with limited investment opportunities in new technology innovations [27]. For the construction industry to be digitalised efficiently and achieve its goals, the entire sector depends on cooperation.

The industry has acknowledged the necessity of innovation and change in building practises. Construction City is a measure implemented by different industry players, in collaboration with the government, to stimulate the sector to innovate through shared knowledge etc. [28]. Such measures will hopefully increase cooperation between the different players and create synergies across the industry.

3 Research Methodology

The following section outlines the specific research methodology applied in the master thesis. As mention in the introduction, the thesis aims to map drivers and barriers for successful innovation adoption, within the construction industry. The section is structured in the following four segments; (1) *Research design* - including learning's from a previous pilot study, (2) *Data acquisition* - procedure of acquisition, (3) *Analysing the data* - containing a description of the within-case and cross-case analysis, and (4) *Reflections on strengths and weaknesses.*

3.1 Research Design

This thesis' purpose was prepared based on the results of the authors' project thesis. Thus, these results also influenced the research method of choice. The established research questions could be answered both quantitatively and qualitatively [29]. Since this thesis aim was to map the various drivers and barriers in complex construction projects, it was essential to acquire deeper insight and detailed nuances of previous experiences. Therefore, it was decided to study the cases empirically through in-depth interviews, before examining the results [30]. A multi-case study was conducted, where the various cases were built around complex construction projects, with perspectives from different industry actors on the respective projects. Figure 6 presents the chosen research method, step-by-step.

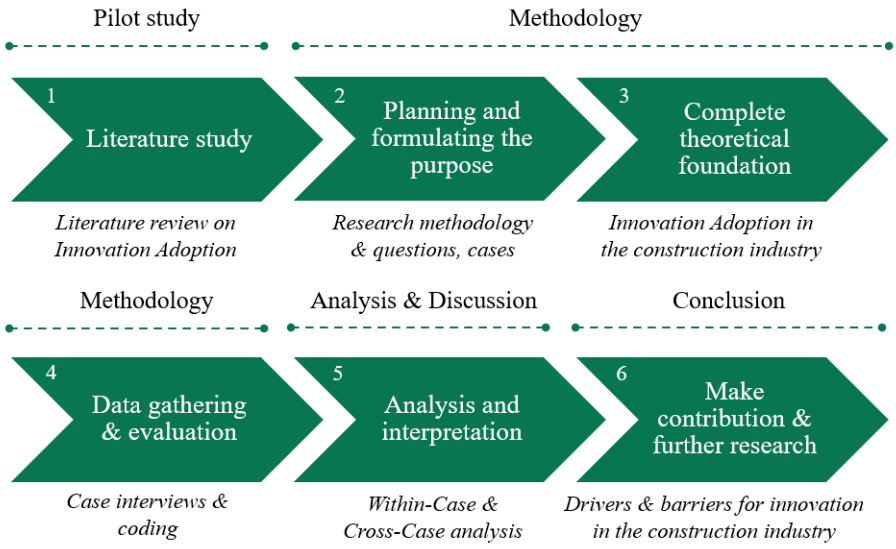

Figure 6: Research Methodology, step-by-step

The multi-case study outlines the primary basis of data in this thesis. The theme is highly relevant and is also unique in relation to the industry being analysed.

Four construction projects have been investigated, divided into 17 in-depth interviews. A triangulation has been carried out with a 360-degree perspective from different actors, on each individual case. In addition, the authors' previous experiences from the industry have been essential for the analysis at depth and level of detail. This has also been central to getting in touch with the right people on the respective construction projects.

3.1.1 Pilot study

As mentioned, a pilot study was conducted during the autumn of 2020, looking into barriers and opportunities within the Norwegian construction industry, as a basis for this master thesis. The pilot study was mainly an industry inquiry linked to the relevant theory about innovation adoption and illustrative interviews that connected the broad general lines. This is the theoretical foundation of this thesis. In addition, some new theory which was seen as relevant during the preparation of this thesis has been added. Based on the pilot study and the authors' experience from their own company, some interesting findings were identified, as listed in Table 3.

Table 3: Findings and learnings from the pilot study

Findings
1. *Construction clients aren't under the same financial stress and high risk, as the contractors. This entails that they could be a central actor in introducing new innovation to the industry.*
2.*The industry requires tools that provide a high level of technology integration.*
3. *The industry has recently formed several external initiatives, such as innovation clusters and investment programs for startups.*
4. *The larger firms depend on more detailed plans and strategies for innovation.*
5. *Construction firms often lack technology readiness, limiting the complexity of, and the probability of their routinisation, of new technology innovation.*
Learnings
1. *It may be appropriate to interview all the different perspectives on a construction project to acquire a holistic picture.*
2. *The interviewees should be better prepared to answer specific questions in the best possible way.*
3. *The interview template should be linked to a specific construction project. If not, the answers will be very general.*
4. *Link the interview template more to a specific theory to discuss the results against the relevant theory more easily.*
5. *Ask more critical questions and dig deeper for a better justification on various topics.*

Based on these findings and learnings, a shift in focus on the master thesis and some adjustments in the research method about case selection and data acquisition were made, such as the triangulation. This is described in more detail later in this section.

3.1.2 Multiple-Case study & triangulation

Research done through a multiple-case study allows analysis of events within their relevant context, in addition to exploring their development over time. Through case studies, one can achieve a holistic, in-depth understanding of complex situations. In the context of this thesis, a case can be defined as one construction project. Within each case, a triangulation of involved actors has been carried out, so that all perspectives were considered and analysed. Therefore, at least one consultant, software provider, project owner, and contractor have been interviewed in each case. Additionally, there have been some follow-up interviews with other actors to further investigate interesting findings. A triangulation, which combines different perspectives, can reveal weaknesses or strengths in the individual perspectives. Suppose the different perspectives point in different directions, indicating a bias of some variation, or inversely, if the perspectives all point in the same direction, it could indicate results of high validity. This could provide valuable insights, as the construction industry consists of many unique industry players, with differing perspectives on a construction project. Combining a multiple-case study with theory on innovation adoption enables insight into which drivers and barriers exist and, subsequently, how successful innovation adoption can be facilitated. [29]

3.1.3 Selection of Cases

As the construction sector houses an enormous amount of companies, the degree of resistance towards innovation within specific firms is equally varied. The same applies to the various construction projects around the country. In order to ensure the information provided is relevant to the thesis, a systematic approach for case selection has been established, based on the research questions and findings in the pilot study [30]. Additionally, the focus needs to be on innovation to ensure the cases are comparable. The following criteria determine the selection of cases and interviewees:

- The construction project and the relevant industry player must be present in Norway.
- The construction project must have a contract size of more than 300 MNOK.
- A form of innovation must have been used in the construction project.
- The respective industry player must have an incentive for increased productivity within the construction industry.

- The respective industry player must have some degree of technology readiness.
- The interviewee must be a decision-maker, e.g. project leader, sales director, product owner or innovation responsible, etc.

As mentioned, the authors' experiences and networks have been used to reach the right cases and interviewees. However, with one exception, none of the cases or interviewees were in direct affiliation with the authors' professional industry network. This was desirable as it assured as objective and honest answers as possible. The exception was the last case, which was carried out as action research. This is a construction project in which the authors' company, Kvist, delivers software. This case was included for comparative reasons, as well as including the authors' experience. It was desirable to interview different types of construction projects, with varying forms of innovation. Characteristics for the different cases have been described in table 4 below.

Table 4: Characteristics of the cases

Comparison	Case One	Case Two	Case Three	Case Four
Contract size [mNOK]	300-500	400-600	400-600	1000-1300
Contract form	DB	DB + Innovation Contract	DB	DB
Innovation	Corona reporting tool, BIM-software	Smart light management system	Innovation process/ tender	Digital twin in tender, Process tool sustainability certification

As table 4 presents, the cases were large and complex construction projects, all with similar forms of contracts. The most significant difference between the cases were the type of innovation being tested and/or implemented.

3.2 Data acquisition

The data acquisition has been carried out through three steps: *Step One*: The interviewees sent relevant documents and filled out a simple form. This was done to obtain objective data, in preparation for the interviews. *Step Two*: Conducting semi-structured, in-depth interviews. This is the primary source of data in this thesis. *Step Three*: Documentation of research data through recording of interviews and transcription. This segment describes these three steps, with accompanying reflections on the decisions, impacting the thesis.

3.2.1 In-Depth Interviews

As mentioned, the primary data acquisition has been carried out through in-depth interviews. These have been conducted based on a semi-structured interview guide (see *Appendix A & B*), designed with open-ended questions. This allowed the interviewees to give meaningful and holistic answers, describing their experiences, while also allowing the interviewer to control the topics [31]. Choosing suitable subjects for the interviews was crucial in answering the purpose of the study [32]. To ensure this, the central points from the various theoretical frameworks, paired with key findings from the pilot study, served as a starting point. Subsequently, this was linked to the interviewees' innovation perspective on the respective building projects.

In addition to choosing the suitable topics, it was essential to choose the right interviewees associated with the various cases [32]. As mentioned, a triangulation was carried out to get all the perspectives on a construction project. Since the authors already have experience from the industry, there was a good basis for selecting the right interview subjects. Table 5 below presents the various interviewees with their associated characteristics.

Table 5: List of cases and interviewees

Case	Industry player	Type/Size	Role
Case 1	Project Owner	Public/National	Project leader
	Consultant (Technical)	Private/National	Project leader
	Consultant (Architect)	Private/National	Project leader
	Contractor	Private/International	Project leader
	Software Provider	Private/International	Sales manager
Case 2	Project Owner	Private/National	Project leader
	Consultant (Architect)	Private/International	Project leader
	Contractor	Private/International	Project leader
	Software Provider 1	Private/International	Project leader
	Software Provider 2	Private/International	Sales director
Case 3	Project Owner	Non-profit/National	Project leader
	Consultant (Architect)	Private/National	Project leader
	Contractor	Private/International	Project leader
	Software Provider	Private/International	Sales director
Case 4	Project Owner	Public/National	Project leader
	Contractor	Private/International	Project leader
	Software Provider	Private/National	Product owner

Throughout all the interviews, two of the authors were present. One led the interview, while the other noted incidents, statements, or other things that seemed to be of significance [33]. The interviews were structured in three phases, namely; warm-up, reflection, and wrap-up. Therefore, the interviews started by giving the interviewee a general introduction to the interview topic. Then, they

were asked some elementary questions about themselves and and the company. Even though this information was largely available beforehand, it made the interviewee more comfortable, while starting to reflect on past events. Thus, it was a useful approach to opening an interview [34]. To conclude the interview, the subject was asked if they could be contacted, in order to conduct follow-up questions, if more data was needed. During the whole interview, the interviewer frequently asked follow-up questions to clarify and make the conversation more organic and fluent [33].

3.2.2 Secondary data

The interviewees sent relevant documents related to the respective project and filled out some simple questions. This was done because written documents are not based on spontaneous information, as opposed to an in-depth interview. Such written information is also more reflective and well thought through. For the research, it can be both positive and negative. The written form can be answered as the desired truth, but it can also lead to more processed and precise information [33]. Another desired effect of sending out such a request before conducting the interviews was that the interviewees became more updated on the construction project and prepared for the interview. The interviewees answered the following questions:

- *Brief description of the collaboration on the project.*
- *Simple drawing of the contract structure.*
- *The most important innovations that were implemented.*
- *The biggest challenges on the project.*

3.2.3 Documentation

Due to covid-19 pandemic (corona), all interviews were conducted digitally. In order to document all raw material, the audio from each interview was transcribed into separate documents. For all the authors to have a sufficient understanding of each individual case, the author who was not present transcribed the respective interview. All interviews were structured according to each case, together with the pre-filled questionnaires and other relevant information. As a result, all research data was clearly structured as a good starting point before coding and analysing the data material. This is described in more detail in the following segment.

3.3 Analysing the data

Analysis in qualitative studies has its peculiarity in that it is not locked to one phase of the study, but is a process throughout the study. This thesis is characterised by an inductive analysis where one strives to find common denominators

and patterns in a larger data material. In this thesis, a within-case and a cross-case analysis have been carried out [35]. The within-case analysis goes through each individual case separately, while the cross-case analysis looks at these in comparison to each other. In order to be able to carry out such analyses, it is essential to structure the raw data sensibly. This was accomplished by coding in three steps [35]:

- *Step One*: First, open coding was used, where all interviews were structured without predefined codes. This was done as the data material is the basis for theory and is not only analysed to verify already discovered theory.
- *Step Two*: As a result of open coding, there were many different codes, which then had to be sub-categorised. This is called axial coding.
- *Step Three*: The last step is selective coding, which defined the core categories. This created the main theme of the study, and less relevant codes and categories were removed.

To carry out this coding process, Nvivo was used as an analysis tool. This makes it easy to structure the codes and complete all three steps efficiently. This process can be seen as thematic analysis. Thematic analysis can be described as somewhat diffuse, however, it still provides sufficient data management in qualitative analysis. This provides the researchers with a foundation for an improved theoretical understanding of the data, which can contribute to the literature within its respective field [32].

3.3.1 Within-Case Analysis

The within-case analysis aims to analyze each case in its own context. Through the structuring of data, the responses from the interviewees, i.e. the project owner, consultant, and contractor, were divided into three main categories: *Innovation*, *Procurement and investment*, and *Collaboration and industry views*. For the software providers, the following division was used: *Innovation*, *Investment and goals*, *Price model and customers*. When relevant, a separate category for *Corona* was added. The findings from each industry actor are presented separately, associated with the respective case. Finally, each case have been summarized as a whole, using a table presenting key findings. The results from these tables became the foundation for the cross-case analysis. [36]

3.3.2 Cross-Case Analysis

Through the cross-case analysis, the cases were compared analytically, following the within-case analysis. The cross-case starts by listing all findings in the summary tables schematically. This was to provide an overview before a more thematic analysis occurred. The thematic analysis occurs at two different levels, i.e. the Industry and Organisational. Additionally, the analysis incorporated

the sub-themes of *strategic* and *operational* drivers and barriers. These analyses, together with the theoretical foundation, form the basis for the discussion.

3.4 Reflections on strengths and weaknesses

The method of choice is the greatest strength of this thesis. Four complex construction projects have been investigated, divided into 17 in-depth interviews. A triangulation has been carried out with a 360-degree perspective, from different actors on each individual case. In addition, the authors' previous experiences from the industry have been essential for the analysis at depth and level of detail. It is not a given to have access to such a data set in a master thesis, but it has given us extensive insights, which has been a solid foundation for the analysis.

As mentioned, Case Four is based on the authors' own company and involvement in a construction project. Such research is called action research and is an approach to research where the researcher is part of the study being conducted. By linking action with reflection, and theory with practice, the action researcher seeks solutions to various challenges of a complex nature. The main advantage of such an approach is that the researcher gets close to the problem, gets a better understanding of the process, and can uncover connections other methods does not uncover. A disadvantage associated with this approach is that the verifiability of the research can be weakened. Most of the process is challenging to recreate, and the story and its causal connections are retold as it is experienced. This creates the possibility for incorrect findings, as a result of hindsight bias [37]. To counteract this, the findings have been discussed with all the authors and objective outsiders. The authors' agenda could also affect the results, as the company could possibly benefit from the results. However, the company would not benefit from inaccurate results, as they will be used mainly for future planning and strategising. Therefore, there has been immense focus on objective and correct results throughout the preparation of the thesis.

The interviewees' wish to portray their company as innovative, and an industry leader, could also affect the responses. This is also something which was experienced during the pilot study. Therefore, the interviews were focused on the interviewees sticking to objective facts, rather than visions and "bragging".

When collecting data through interviews, face-to-face interviews are the most promising [33]. However, due to corona, all interviews were conducted digitally. It is known that by eliminating the physical presence and body language, which may participate in the interview's interpretation, the validity may be reduced. Nevertheless, digital meetings have become much more common during the pandemic, and the authors feel that the quality has been almost as good as in physical interviews. Another important factor to consider, in interviews, is to create trust, especially considering the short engagement. As a result, the interviewer emphasized the warm-up phase of the interviews to make the interviewee comfortable [34].

4 Theoretical Foundation

Over the last decades, technology innovations has been integrated in many industries, which has increased efficiency, productivity and profitability throughout supply chains. However, some industries have been more prone to integrating and developing new processes, compared to others who are lagging behind the technological progress. The introduction of new digital innovations into a company is not as straight forward as it may seem. Adoption of new innovations depends on different factors affecting the company, i.e. the Technological, Organisational and Industrial context of the firm. The technological context refers to the current technological orientation of a company. The Organisational context refers to the structures and individuals within a company, that determine how new innovations are adopted. The industry context are the factors surrounding the company, such as industry culture, regulations, project structures, etc. Conducting a multi-level analysis is crucial as factors at the various levels are partially interconnected and affects one another.[38]

In this section, relevant theories related to drivers and barriers of innovation will be discussed. This section consists of four segments, structured as follows; The first part, Innovation, contains Open Innovation Theory and theory on Technology Innovation Adoption, in order to map potential drivers and barriers for implementing new technology innovations. Secondly, an Industry level perspective is taken, where the theory presented gives an overview of how firms, in the industry as a whole, collaborate and share knowledge in order to bring forward new innovative products and services. Next, theory on the Organisational level is investigated, that is, how different firms choose to approach new innovations, as well as the underlying structures and processes dictating their orientation towards innovation. This will provide insight into the drivers and barriers that have to be considered to ensure successful innovation adoption within organisations. This multi-layered approach is taken to fully understand the complex drivers and barriers of innovation within construction, through exploring the incentives and characteristics of the involved actors, from different levels of perspective. Finally, there is a theory summary, containing an overview of the two levels.

4.1 Innovation

Innovation is a broad term, with many definitions. Schumpeter defined innovation as new combinations of resources, creating a market unbalance, by a process he called *Creative destruction* [39]. This could be done through; (1) Extension of a current solution, (2) Renewing by doing something new with an established method, or (3) Creation of something new entirely. Kirzner argued that knowledge is unevenly distributed, and that innovations can be created through acting on these discrepancies [40]. Dagestad et al. has a simplified definition which reads *"Innovation is a new and improved solution, which is so good that it's actually applied."* [41]. Additionally, in assimilating technological

innovations, a company must undergo three phases, i.e. *initiation - adoption - routinisation*. [42]

While there can be many types of innovation, there are two types that can help distinguish the impact of a new solution, i.e. *Incremental* and *Radical*. Incremental innovation can be defined as improvements to existing solutions, through continuous development. Radical innovation, on the other hand, can be defined as entirely new solutions, through new, unique or discontinuous practises. To be considered radical, an innovation should be novel and unique compared to both pre-existing and current solutions. Additionally, it has to be successfully adopted, impacting possible future innovation. [43]

The way an industry is structured influences the assimilation process of new innovations to a great extent, and what drives and hinders innovation are exceedingly related to industry-specific circumstances [7, 42]. The project owner, or client, alongside the regulatory environment, are concluded by several studies to be the most important drivers, and potential barriers, for innovation [7, 8]. New project or company objectives, that cannot be met with existing and familiar tools or processes, trigger necessary search activities to explore new solutions. Blayse & Manley further concludes that the more demanding experienced the project owner is, the likelihood of successful innovation on the commissioned projects increases [8]. However, introducing new solutions in complex systems such as construction can create unexpected consequences and is considered risky [7].

4.1.1 Innovation openness and collaboration

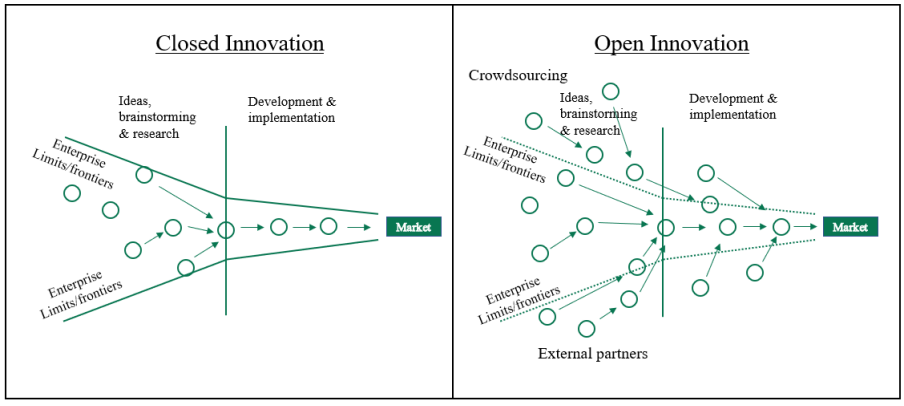

Figure 7: Closed vs Open Innovation

Chesbrough defines Open Innovation (OI) as *"deliberate use of internal and external knowledge to increase the speed of domestic innovation and expand the market for external use of innovation"* [38, p. 53]. Innovation adoption is a term often used to describe the firm and its employees' abilities and attitudes

towards using and integrating new products and services in their work. This term involves how innovations are diffused through an organisation and how firms exploit their resources and to what extent they explore which opportunities exist outside of the organisational boarders. OI suggests that firms can and should collaborate across organisational borders in order to reap benefits such as reduced costs of conducting research and developing new products and services [44, 45], early incorporation of customers in development processes, improving performance in planning and delivering projects [46], and reduction of time to market [47]. Furthermore, external collaboration and openness help to share risks associated with new product development and brand reputation [38]. Web-based technology is progressing at a swift pace, and is considered one of the key drivers for an open business landscape. Nevertheless, to exploit the benefits presented to full extent, companies need to efficiently adopt to new digital innovations. [42]

Closed Innovation (CI) is refereed to as the old paradigm of which companies innovate. The logic of CI has an internal focus, and encourages companies to be self-reliant to the greatest possible extent. CI logic is based on some implicit rules which a firm should oblige to in order to sustain and gain competitive advantage in an industry. The firm should:

- Hire the best people to work for them
- Develop new products and services for the market internally
- Invest in internal R&D in order to be market leader.
- Control Intellectual property so that competitors won't profit from their ideas.

The rules create an image that the company which introduces an innovation to the market first will win [48, p. xxii].

In Open innovation Chesbrough suggests that firms can and should use internal and external ideas and paths to the market, in order to advance their technology. These ideas are combined into systems where business models define the requirements to create value. Simultaneously, internal mechanisms are defined in order to claim some portion of that value. Furthermore, Chesbrough addresses the opportunity for an internal idea to be distributed through an external channel to generate additional value.

Open Innovation obey principles in great contrast to CI-logic and can be summarized as follows:

- Not all smart people work for one company, hence, the company should work with smart people internally as well as externally.
- A company can profit from research which originate from the outside. The importance of building a good business model outweighs being first to market.

- A company should profit when others need their IP. Additionally, when it benefits the company's business model, they should buy others' IP.

If done correctly, the company can position themselves more agile in a fast-paced ever-changing business landscape and reap the benefits introduced initially [48, p. xxv-xxvii]. An empirical study conducted by Bygballe and Ingemansson argues that construction companies that interact with other actors to develop and implement new technologies, are more successful at doing so compared to companies which focus on internal innovation [7].

There are, however, several problems and barriers with implementing OI strategies. Problems such as loss of knowledge and competitive advantage, increased coordination and administrative costs, and loss of control of the process are acknowledged as the most common risks associated with OI. Additionally, finding the right collaboration partner combined with allocation of time and resources are the most widespread internal barriers for implementing OI activities [49].

Many industries are in a transition between the two paradigms introduced. Semi-open firms are firms that cooperate with others but retain the R&D and innovation in-house. [50]

4.1.2 Innovation acceptance and attributes

Diffusion of innovation is often discussed on an individual level, but are in fact also applicable to companies. The *innovators* and *early majority* are firms taking a higher risk, to gain a competitive advantage and/or increased future return. The early majority are more cautious, than the prior, but willingly adopt new innovation once it's tested. The *late majority* are more sceptical, where the adoption at this point may be an economic necessity. Lastly, the *laggards* are extremely slow to incorporate adoption, mostly focusing on their core business, and how it's been done traditionally [51]. A determining variable of which category a firm can be placed into, is its size. Almost all small firms are in the innovator to early adopters categories. Large corporations can also innovate, but a larger amount of these will usually be found in the late majority or even as laggards [52].

The subjective assessment of an innovation is essential for the adoption process. Everett Rogers suggests that analysis of innovations should be done in the potential adopter's own perspective and situation [51, 53]. This is to emphasize the importance of the subjective nature of innovations. Robertson and Gatignon suggest that the description of innovations from manufacturers or distributors is likely to differ from the subjective approach. This is also based on the fact that the perception of subjective characteristics of innovations will significantly impact the outcome of the adoption process [54]. The adoption process is often seen as a hierarchical sequence from knowledge, awareness, and evaluation to full adoption [55]. Information about innovations is essential to create a positive perception of the benefit and favorable attitude to the innovation described [56]. This is in line with traditional diffusion models, which are based on the

assumption that raising consumer awareness of innovations will lead to positive attitudes, facilitating acceptance [51].

For potential adopters, innovation attributes are essential, and observations show that the main attributes taken into consideration are relative advantage, compatibility, complexity, trial-ability, and observability [51, 53].

- *Relative advantage* refers to the uniqueness of demand value and financial return.
- *Compatibility* refers to compliance with customers' existing values, previous experience, and potential users' needs.
- *Complexity* is the degree to which the product is perceived as challenging to understand and use.
- *Trial-ability* is the degree to which the product can be experimented with.
- *Observability* that the results of an innovation are visible to others.

Relative advantage and complexity represent the "functional dimension" of innovation. On the other hand, compatibility, trial-ability, and observability represent the "social dimension" of an innovation. Complexity negatively affects acceptance of innovation, while the other four factors have a positive effect. Although innovation characteristics are expected to influence innovation acceptance, it is crucial to assess lead-users' role in improving such attributes in the development process while modifying products to promote innovation. [57]

4.2 Industry level

The environment in which a firm operates determines the opportunities and constraints that the firm is presented with and bounded by. In the context of this thesis, the industry level refers to the industry as a whole, in addition to construction projects. The industry presents obvious external characteristics that might affect the extent to which Open Innovation is effective [58]. However, others suggest that there are small varieties in the rate of adoption of new innovations across different industries. [59]

4.2.1 Innovation processes

At an industry level, there are two opposing perspectives on technological progress, that is, major breakthroughs occurring in a discontinuous matter or a continuous stream of minor changes. The majority of industry specific studies support the latter perspective. Consequently, the literature suggests that the majority of successful innovations consist of products and services with relatively small improvements from existing options on the market. [60, p.180-190]

Another way of analyzing processes of innovation, is to look at the advancement of technology in relation to market forces. That is, the hypothesis of *"demand pull"* and *"technology push"*. A technology push perspective emphasizes that

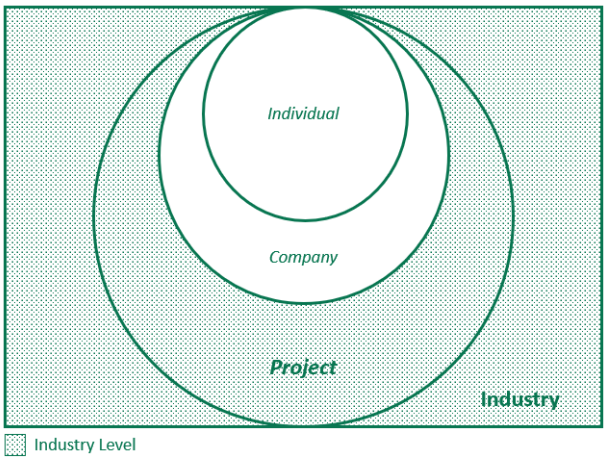

Figure 8: Industry level

the speed of technological advancement and magnitude of R&D resources available influence the level of innovation. In contrast, the demand pull perspective entails that market need is the key determinant when producing innovations [60, p.181]. However, a review of different studies on both hypothesis where executed by Mowery and Rosenberg, concluding that the widely accepted idea that market pull forces outweighs the importance of technology push in stimulating innovation lacks empirical evidence. [61]

The general macroeconomic situation will affect the capacity of firms to engage in investment and innovation. Innovation is, to some degree, demand driven and that engaging in entrepreneurial activities is less risky in a situation when aggregate demand is growing [62, p. 341]. Regulatory conditions is strongly linked to the macroeconomic situation, and can provide signals which encourage or discourage innovation activity. Regulations affect accessibility to information, property rights, taxes and technical standards required in different sectors. These factors are all important for innovation, and can vary greatly between sectors. [63]

4.2.2 Industry characteristics

Research conducted on the three strategies introduced (open, semi-open and closed) find correlations between firm size and degree of openness. Firms with Open innovation strategies are usually smaller and allocate less resources to R&D than semi-open ones. But, they are larger and more R&D intensive than closed innovators. This result seems to be reasonably stable across various industries [50]. However, in some industries R&D plays a more central role for innovation, whilst other industries are more reliant of successful adoption of technology that already exist [63].

Less R&D-intensive firms need external knowledge more, but their capacity to absorb it is relatively low. Thus, they cannot exploit it properly, and therefore, decide to adopt a more closed strategy. On the other hand, large and R&D-intensive companies are associated with greater capacity to absorb external knowledge, but the need for it is usually smaller. Hence, they choose to be semi-open, as they exploit the external knowledge, but it is not the core of their innovation activities. Lastly, between these two groups are firms that are open innovators. They have both the capacity to exploit external knowledge combined with a significant need for it. [50]

4.2.3 Market structure and competition

Van Cayselle suggests that a market structure somewhere in between monopoly and perfect competition promotes the highest rate of innovation [64]. Competition intensity can be defined as *"the degree that the company is affected by competitors in the market"*. [42]

Intensive rivalry implies that after one has innovated, competitors will imitate the innovation in short time. In other words, competitive advantage is lost quickly after innovation. In contrast, low rivalry implies that the threat of a rival firm performing innovation is low. Hence, there are few incentives for both competitors to innovate. Cayselle concludes that intermediate intensity of rivalry to obtain a new product is best for the innovative activity in an economy or industry [64]. The same goes for software adoption. [42]

In some industries, this competition is brutal. Only the best products and services can survive. In other industries, a certain type of product or service will always secure some market share, simply because the newer products cannot compete with the existing one in all application areas. In the first type of industry, competitors face vertical product differentiation, while the second type of industry is more towards horizontal product differentiation. [64]

By adopting new IT systems, companies may change the rules of competition in an industry, which may provide implications for the entire industry structure. As digital tools improve a firm's market responsiveness, information transparency and operational efficiency, adopting new digital tools is essential to maintain competitive edge. Thus, competition is likely to stimulate firms towards initiation and adoption of technology. Nevertheless, companies in competitive environments are more influenced by the competitive pressure to leap frequently from the current solutions to new technology. Hence, such firms are less likely to utilize digital tools to the extent needed to routinise it. This is refereed to as the *"Assimilation gap"*. [42]

In competitive industries, such as construction, Bygballe & Ingemansson states that regulatory measures greatly affects to what extent innovation is lucrative. If policy makers do not acknowledge that innovation is not encouraged by price competition but rather by interaction and collaboration, then it will not facilitate innovation. The procurement systems that permeate the construction

industry is pointed to as an hindrance for innovation, with contracts that trigger price competition rather than interaction between the involved actors [7].

4.2.4 Search strategies and collaboration

There is consensus that cross-functional collaboration combined with market knowledge is an essential resource for successful innovation. Furthermore, the specific characteristics of the external collaboration and market knowledge may influence innovation performance. The literature presents a spectrum between two ways a firm can approach other industry actors. One way is to have a relation with many actors in the industry, providing broad and distributed knowledge and business relationships (Breadth). Contrarily, a firm can choose to collaborate closely with less partners, providing a more specified domain of knowledge (Depth). [65]

Breadth or *"Knowledge breadth"* can be defined as a company's understanding of a broad range of various customer and competitor characteristics. Collaboration breadth is defined as the number of different types of sources with which a firm cooperates. Companies associated with wide market knowledge and a broad portfolio of collaboration partners have a greater potential for combining elements from different domains in order to recognize opportunities. Breadth is associated with creativity and exploration. Cooperation breadth brings more diverse inputs to explore opportunities and provide access to market to exploit opportunities. Combined, this will increase innovation performance [66]. More specifically, collaboration breadth tends to promote incremental innovation [67, 68]. However, when market knowledge is too broad, the knowledge may provide limited contributions to an innovation project. Bringing in marginally useful information or leaving out relevant information might be devastating for innovation performance. [65]

Furthermore, literature address a correlation between number of collaboration partners on a project and increasing administrative costs. In a project which demands collaboration with multiple firms, the project owner must allocate resources to search for suitable partners, agree on contracts and coordinate joint efforts [69, 70]. However, in the eyes of assimilation literature, software can reduce these transaction costs, and mitigate market friction by increasing information transparency [42]. On the other hand, productivity improvements in value chains are more likely to occur when firms are actually willing to make a transaction-specific investment [69].

Depth, or *"Deep market knowledge"*, implies high interdependencies among the knowledge elements. However, deep knowledge involves a greater risk of misinterpretation and misapplication in product innovation, because it mitigates the company's ability to map new connections among different pieces of knowledge. That being said, a new product based on deep market knowledge limits competitors' ability to understand all involved knowledge elements and their connection. This is because market knowledge depth reflects a complex understanding of the

causal interdependencies among customer problems and requirements and potential competitor strengths and, thus increasing the likelihood of the emergence of new ideas that are highly unique to the firm [65]. Radical innovations tend to require deep collaborations with R&D focus. [67, 68]

An empirical study conducted by Pärttöa & Saariluomaa argues that the construction industry fails to bring forward innovations despite the collaborative culture. This is a consequence of the conflict between the financial resources available on a project and the time that is required in order to successfully develop new innovations. Furthermore, they state that construction projects are associated with short-term thinking due to this conflict, which ultimately leads to planning and construction being two simultaneous processes. This leads to haste and a sense of urgency, which dramatically mitigates innovation. [9]. The subject of conflict of interest is also underlined by Bygballe & Ingemansson, who argue that for innovation to be successful, proper incentives must be in place. That is, the benefits and positive results are split between the participators who share the risk of the innovation project [7].

4.3 Organisational level

People who are collaborating to achieve a particular goal, may structure themselves as an organisation. In the context of this thesis, the organisational level refers to companies and firms as well as the individuals who work within them.

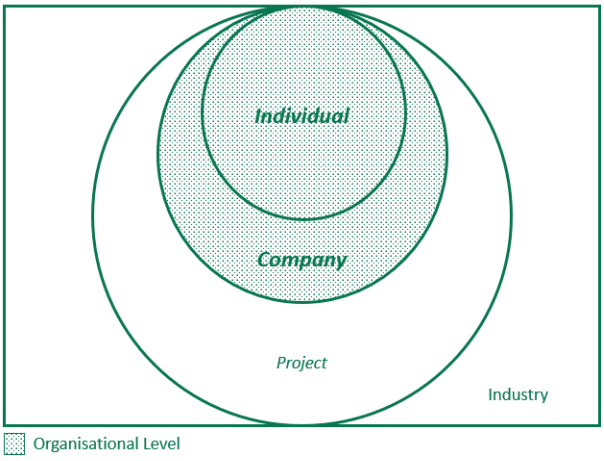

Figure 9: Organisational level

All successful companies will at some point have to pursue corporate entrepreneurship, because once they have successfully exploited their internal capabilities, they will depend on exploring new and unrelated opportunities to maintain a certain growth rate [71]. Companies are then met with the challenge of optimizing their current core business, while also pursuing new and promising business

opportunities. Those capable of doing both simultaneously achieve organisational ambidexterity [72]. Ambidexterity is most commonly described through organisational mechanisms, such as formal structures within companies [73]. Hence, an organisation's structure is central in a company's ability to adopt new innovations.

Because a company's survival in a market is dependent on an efficient and quality-centred core business, the company structure and management often favor this aspect. This is a result of the uncertainty and new knowledge requirements that comes with innovation. There are, however, several ways in which a company can pursue exploration, to increase their ambidexterity. These are (but not limited to); Investing in, or collaborating with, start-ups, Creating corporate ventures internally, Or facilitating incubator/innovation programs to support employees in intrapreneurship. This approach's aim is to create radically new innovations, rather than the incremental progress that can be made from within a company's core business. [72, 74]

Larger organisations have often struggled to implement exploratory strategies, which, as mentioned, seem to be rooted in their structure. Despite this, they usually have an initial advantage, due to their resources, over smaller firms, but in later stages they have to overcome severe structural inertia.[75] [42] Start-ups on the other hand are more suitable for radical innovation in the later stages such as routinisation, because of their structure. As a result, established companies trying to increase their corporate entrepreneurship, aim to implement structures that replicate those of a start-up [74]. In literature, this is often described in the context of corporate ventures (CVs), and is linked to positive financial and/or strategic outcomes [71]. Thus, CVs creates organisational systems, processes and practises that focus on developing business opportunities.

Bygballe & Ingemansson argue in their empirical study that the temporary nature combined with the competitiveness in the industry affects the individual project participants to a great extent. A project member is assigned to a new project, as soon as the ongoing project is completed. The person is faced with a new objective and presented with a new deadline, hence, there is practically no time to analyse and reflect on the experiences made in the former project. Nor is there time to participate in an innovation project unless the client demands it. [7]

4.3.1 Lead users and opinion leaders

The individual perspective also impacts an organisation. Some are eager to try new things; others are severely resistant to change. Companies are defined by the very employees of which it consists. Individuals, especially leaders, significantly impact a company's culture, strategic profile, and resistance to innovation. Observations of successful and effective adoption processes show that *"lead users"* and *"opinion leaders"* are critical to success. This applies both in the development phase, but also in the adoption process itself. A lead user is

defined as being ahead of the rest of the market regarding their needs, motivations, and qualifications [76]. This results in unique characteristics compared to ordinary consumers in terms of consumer knowledge, user experience, control point, motivation, and innovation [77, 78]. The approach of using lead users during a development phase helps organisations minimize the risk by developing new products that translate customer needs and thus increase the likelihood that they will be accepted in the market [79]. This involvement of customers in the innovation process can minimize the risk of failure [80]. These user-centred innovation processes provide more significant advantages over the manufacturer-centred innovation development systems that have been the mainstay of trade for hundreds of years [81].

Based on the characteristics of lead users, as described above, in the innovation process, their use results in a higher accelerated diffusion rate for the new products [80, 81]. A lead user should have two roles in the innovation process. First, leading users are expected to support the innovation development process to make innovation features more appealing. It is conceptualized that the lead users' effect will be more substantial on functional attributes, such as relative advantage and complexity. Lead users should be able to find ways to increase the value of the innovation and make it more understandable to ordinary consumers [57].

In addition to being a lead user, one of the main actors in speeding up the diffusion process is the opinion leader [82]. This is supported by Everett Rogers, who proved that opinion leaders have significant roles in "activating diffusion networks" [51]. Besides, several diffusion researchers have long argued that a particular set of factors, such as evaluation of innovation attributes and opinion management variables, are the best predictors of diffusion rates [83]. Opinion leaders have been identified as having greater access to mass media and interpersonal networks than their followers. They are also perceived as having a higher socioeconomic status and a tendency to adopt new innovative ideas ahead of their followers [53]. Their most important characteristics are knowledge, social influence, innovation, and interpersonal factors [53, 83]. Opinion leaders influence the decision-making process of consumers by spreading positive word of mouth. Besides, they serve as role models to be imitated [83]. This relationship was supported by diffusion research, which emphasizes that opinion leaders influence the evaluation of new innovation, influencing the rate of diffusion [53].

Both lead users and opinion leaders can be defined as Champions and can, in many cases, be the same person. In summary, companies should consider the use of lead users and opinion leaders and assess the cultural factors that maximize the diffusion of innovation. Lead users are proposed to influence both innovation development and modification. Their role is crucial in optimizing the effect of functional attributes, such as relative advantage and complexity. Communication skills are vital to the adoption process for innovation, as it includes the word-of-mouth role through both lead users and opinion leaders, along with other interpersonal networks. Lead users' role is crucial in reducing

complexity and increasing the relative advantage of attracting users to innovate. At the same time, opinion leaders are essential to driving innovation diffusion in conservative and risk-averse industries and societies [57]. Additionally, Bygballe & Ingemansson conclude in their empirical studies that these types of employees bring an attitude which contribute to a culture of innovation, absorptive ability in the firm and ultimately more thorough innovation strategy. Hence, lead users and opinion leaders are important drivers of innovation, and these must be given slack resources for innovation, which will benefit the firm [7].

4.3.2 Corporate structure

Organisational measures to increase exploration can be found in almost all industries, and the CV of choice varies from internally focused, such as internal start-up teams/intrapreneurship programs, to an external focus, such as joint/external ventures, investments in start-ups, and acquisitions. As these types of organisational measures are wide spread in the industry, there are countless structures based on the previous mentioned CVs, with different variations. Different objectives also determine the CV structure of choice. These can be to acquire new talent, new markets, increase profits, or simply to create new business. [74]

Several studies have linked corporate entrepreneurship to positive financial and strategic outcomes. Corporate entrepreneurship can be achieved either through increased performance and growth, or through organisational learning [74]. However, there are also significant costs accompanying new innovation, both from the initial investment and the associated risk. High perceived risk and cost does, however, not seem to discourage innovation. Yet, it does determine the focus of the innovation strategy. That is, if the innovation is internally or externally focused (or a combination). Smaller companies usually restrict their strategy to being exclusively internal or external, while larger companies may prefer a combination of the two. Additionally, companies where internal information is an important source for innovation are also more likely to have a combined focus. [84]

Companies can be categorised in three main groups, namely Small, Planning and Organic firms. The different categories depend on different factors for innovation. Small companies, with a centralised management, depend on the individual level of innovation residing with their leaders. Planning companies, have an well-defined structure, with integrated organisational and control systems, spanning the different departments. These companies often pursue a systematic process of innovation, and depend on clear strategies to enable entrepreneurship. Vague visions of innovation will make Planning companies shift their focus to optimisation of their core business. A problem with Planners is that they are less agile in response to their changing surroundings. Organic companies are found in dynamic environments where the demands of customers, technologies and the competition change continuously. Hence, the Organic companies try to be responsive to their surroundings. This is done through a flat structure, where

lower level employees have increased authority. These companies also rely on their internal experts creating new innovations, in response to the opportunities and challenges perceived in the market. Lastly, Organic companies have open communication between organisational members, and the different departments have diverse abilities, based on their market focus. [85]

4.3.3 Technological context

The literature presents two major factors in software assimilation, which are, *Technology Readiness* and *Technology Integration*. Technology readiness is the established technology infrastructure and the knowledge of IT human resource professionals, within the company. Both are needed to build a firm that can utilize technology for new applications. Hence, companies with a high level of technology readiness adopt and routinise new innovation more efficiently, and with higher rate of success, than others. Technology integration is the degree of connectivity between databases and information systems, both within the firm and with external systems. The integration aims to make systems and processes more responsive and compatible with counterparts. High technology integration correlates with reduced processing time, improved customer service, and lower procurement costs. This integration is crucial as data needs to flow seamlessly through the value chain. [42]

Bygballe & Ingemansson's study suggest that while industry relations are an important source of innovation, existing relations may also act as a hinder for innovation. This is a consequence of path dependencies and the incremental nature of construction innovation. Over time, the incremental innovations have resulted in a web of interdependent solutions, which makes it difficult to replace or combine them with any new technology that does not integrate well. A new solution will affect the entire web of surrounding solutions which the old solution is connected to. Implementing new technology that differs excessively from existing solutions involves large adoption costs. [7]

4.4 Summary of Theoretical foundation

In this segment, the key points from the Theoretical foundation have been summarised, according to what is most relevant for the discussion, namely points relating directly to successful innovation adoption, or drivers and barriers.

4.4.1 Innovation in general

- Successful innovation assimilation contains three stages; Initiation, Adoption, and Routinisation
- Incremental innovation involves improving an established process. Radical innovation means creating something new entirely.

4.4.2 Industry level

- Innovation drivers and barriers are largely affected by industry-specific circumstances. Within construction, empirical studies claim that project owners and the regulatory conditions are the key drivers, as well as possible hinders, for innovation.
- The terms *"broad"* and *"deep"* collaborations are introduced in relation to open innovation. Collaborating and searching broadly increases a firms ability to explore opportunities, and conduct incremental innovation with partners. However, increased breadth implies high transaction costs.
- The depth of collaborations and searches determine to what extent opportunities can be exploited and is necessary for developing new technology. Deep collaboration increases likelihood for developing radical innovations, but can also lead to misinterpretations of user needs and market demand.
- There are several barriers to implement open innovation strategies, including the risk of losing control, knowledge, competitive advantage as well as discovering the right partners. However, studies show that construction companies which collaborate more with others, perform better in terms of innovation.
- Construction projects are characterized by collaborations in which conflicts of interest occur frequently between involved actors, which impedes innovation within the industry.
- Competition is an important driver to stimulate innovation and adoption of new technologies, but is most efficient when at an intermediate level. Too competitive environments lead to frequent replacements of technological products, meaning no technology will ever be properly adopted. Excessive competition may shift companies' focus towards core business, away from innovative activity.
- Studies show that the construction industry is permeated by tenders which trigger price competition, rather than interaction in order to bring forward

new innovations.

- Despite market demand often being a driver from an innovators perspective, technology push approaches is also a possible way to successfully adopt innovations, studies show. Tech-push innovations have different barriers to overcome, mainly on the organisational level.

4.4.3 Organisational level

- The technology readiness and technology integration of a firm determines how prepared it is for adopting and routinising new technology innovations.
- A company's structure is important for its ability to routinise innovation. Large firms usually have the resources for innovation, but often lack the proper structures to promote innovation. Small firms have the structure in place but often lack the resources.
- Planning companies have strategic and systematic plans for innovation, however, vague plans will eventually make them shift their focus towards their core business. Organic firms are more adapted to their surroundings, enabling them to incorporate innovation more effectively, through flat structures, internal experts, and open communication between departments, based on market focus.
- Individuals within organisations can be important for adopting innovations, either as opinion leaders or as lead users. Both can be described as *"champions"* or *early adopters*.
- Studies show that lead users and opinion leaders can contribute to an innovation culture, increasing a firm's technological readiness and ability to adopt innovations to a great extent.
- Some essential attributes of successful innvations are the; Relative advantage, Compatibility, Complexity, Trial-ability, and Observability.
- The incremental nature of innovation has created a web of interdependent solutions in the construction industry. This dramatically reduces the success of radical innovations, but also incremental innovations that is developed outside of the network.
- Companies can pursue exploration either through internal measures, e.g. intrapreneurship, or external measures, e.g. joint ventures. Larger companies usually prefer a combination, while smaller choose one or the other.
- Temporary construction projects with hasty deadlines create limited space for the individual to reflect on experiences made from a project. These reflections can potentially contribute to reveal existing problems and find new solutions, which lay the foundation for innovation.

5 Within-Case Analysis

In this section the different cases were analysed separately, looking at the different actors, through three main categories: *Innovation*, *Procurement and investment*, and *Collaboration and industry views*. For the software providers, the following division was used: *Innovation*, *Investment and goals*, *Price model and customers*. When relevant, a separate category for *Corona* was added.

In light of this thesis, a distinction between two types of innovation became necessary, due to different preconditions for successful adoption. First, there is innovation linked to the delivery to the client, e.g a new type of electrical monitoring in a building. Secondly, innovative solutions which improves processes or management, thus, indirectly improving the quality of delivery, e.g a new file storage system. Additionally, the focus in this analysis is on innovations of a technical nature.

5.1 Case One

In the first case the tender was sent out as a competition, where contractors had to submit their contribution for the complete design, before the project owner chose a contractor. Thus, the project had a Design Build Contract model, where the contractor collaborated with architect consultants, in order to compete on the tender. The total value of the tender was 300-500 MNOK. The Project owner hired the contractor through the Design Build Contract, and a consulting technical project manager, where the former had to hire all other project parties. The project lasted three years, where the construction phase made up about half of that.

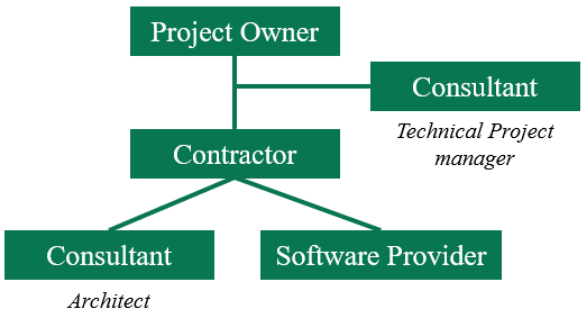

Figure 10: Design Build Contract - Case One

5.1.1 Project Owner

The Project owner is within the Norwegian public sector. They work with real estate management for a municipality.

5.1.1.1 Innovation

They claim that they try to evolve and utilize innovation, and are now working on getting a better handle on the tools the rest of the industry is using. They have a department working with digital tools, and frequently run courses on new software. Additionally, they try to use all the same tools as the contractors. One problem they have is that a lot of employees are struggling with Management, Operation and Maintenace (MOM) reporting. The biggest challenge is knowledge, as there are a lot of digital tools to keep up with. The younger generation whom have the technical knowledge, may not see it in the context of the construction, and thus, have to be paired up with employees with experience within the industry.

The reason for not using the more advanced tools, such as complete BIM models, is their internal organisation and management. They are a large actor with limited resources, such that their current capacity isn't capable of using the most advanced solutions. This is something they are working on improving, but they are currently in a transitional phase. Additionally, they had to require the contractor to archive documentation in one of their systems; Interaxo. This is pointed to as unnecessary and improvable, considering that it forces the contractor to perform some tasks twice. It is emphasised that these issues does not stem from a lack of competence, but rather a lack of resources and organisation, which in time will be improved.

5.1.1.2 Procurement and Investment

New purchases are done at the corporate level. The department responsible for digital tools decide which ones should be used by employees, however, they listen to input from projects and personnel in their decision making. As a public actor in Norway, they are bound by the regulations regarding public procurement. This entails short time horizons on deals with service providers, which has to be announced through a tenders. This sometimes leads to different systems on buildings in the same area, which makes operation and maintenance challenging. Additionally, this could mean that the most adequate provider loses the tender, as worse solutions could fit the tender description, at a better price.

5.1.1.3 Collaboration and industry views

As the Project owner is a public actor, they aren't concerned with the same competitiveness as the private sector. However, they think that the industry has a shared responsibility, in reaching their sustainability and productivity goals. In their case, the politicians and voters decide the ambition of sustainability, which increasingly comes as a requirement, and the project management has to include it into the project plans. The project owner, political environment and contractor has to collaborate, to ensure that the project costs are managed carefully, as the ambition increases. A lot of politicians want to include a lot of

ambitious goals into public projects, which can make them quite costly.

5.1.1.4 Corona

The Corona pandemic hasn't really impacted the Project owner notably, apart from home offices, and digital meetings. There has, however, been an improvement in basic technical communication within the municipality.

5.1.2 Consultant - Technical Project Manager

The Technical project manager (TPM) consultant is brought onto the project, to assist the Project owner in management. The TPM comes from a consultant firm, which mainly work with project management.

5.1.2.1 Innovation

The TPM firm are always looking for ways to improve, but are tied to their customers' choice of digital platforms, as they are working as external consultants. However, their attitude towards using new digital solutions is described as positive, but considering that they have a lot of experience from different projects, they are rarely exposed to completely new platforms. They are actively searching for software which can keep them competitive, in addition to having a team working on an internal system in smart sheets until a sufficient digital service has been found.

5.1.2.2 Procurement and investment

Digital tools for internal use is purchased at the corporate level. However, new solutions are evaluated by the employees, whom search for and recommend new solutions. The preferred agreement is when corporate purchases a number of licences, as this ensures that if they have a good tool, the project or department won't have to consider the added cost, potentially creating a barrier for use. If there is a digital solution which is required relating to a project, it can be added to the internal project cost, however, it's usually a demanded in the tender that the contractor provide such solutions. In this case, all digital solutions were either internal or provided by the contractor.

Software or systems for external use are the other actors' responsibility. For example, public project owners usually have their own systems in place, but smaller actors may not, and if so, they are expected to purchase the required services. In these cases the TPM will recommend a viable solution.

5.1.2.3 Collaboration and industry views

The TPM's motivation for evolving their internal processes is that they compete on performing good technical construction project management. They are concerned with the systematic completion of the project, and thus, try to incorporate any tools and processes that help into their firms workflow. In this

case, for example, they have a contract of 2000 hours, in which they are obliged to complete successful management of the project. If they can't finish in time, they still have to see the project through. Hence, they constantly look for ways to increase efficiency, relating to their tasks.

The TPM argues that the Project owners are responsible for the industry goals. They control the construction process and ambition, whereas the TPM has to deliver quality and innovation to the Project owners standard. The TPM claim that a step in the right direction, from public actors at least, could be; improved communication internally, as well as a focus on the end users, rather than only focusing on cost and schedule. The technological and innovative ambitions has to be better described in the tender, setting the standard.

5.1.2.4 Corona

The pandemic has pushed the TPM firm to use digital platforms more efficiently, especially relating to on site inspections and meetings/communication.

5.1.3 Consultant - Architect

The architect is from a smaller firm, with a lot of experience with this exact type of project. They have around 30 projects annually and the architect is currently involved in four projects.

5.1.3.1 Innovation

The architect claims they commonly invest in innovation, and points out that the whole office just went through a course for one of their digital services. They use software for drawing, namely Archicad, as well as a software for combining and comparing digital project files, called Solibri. They were just purchasing the most recent versions of both of the aforementioned services. Additionally, employees have a budget and three days per year, reserved for courses and learning, and they are obliged to share their leanings with the rest of the firm upon their return.

The biggest challenge with innovation is the increased complexity of their tasks. You have to be more accurate and add more information into digital drawings, and thus, their tasks have actually become more time consuming in recent years. This comes from a general industry shift of more accuracy in planning.

5.1.3.2 Procurement and investment

The criteria for purchasing a new innovation is the perceived usefulness, in terms of helping them improve their projects. This could be through results themselves, or time savings. All purchases are made by the CEO, according to their ambitions for the company. Anyone at the company can make a suggestion, but the decision remains with the manager. This also includes software used in projects such as in this case, whereas they are hired as consultants, they have

to compete on price and quality. Thus, they need to purchase the best tools for themselves to stay competitive. One key concern when purchasing digital solutions is the support agreement, where they prefer unlimited support, as this lowers the bar for asking questions.

5.1.3.3 Collaboration and industry view

The architect firm's have a history of winning competitions for projects, such as in this case, where they won together with the Contractor. This used to be their main strategy of landing projects, however, recently they have also been contacted by an increasing number of customers directly.

The architect feels that the responsibility of reaching the industry goals lies with the industry as a whole, however, they draw attention to the Project owners and especially municipalities setting strict requirements. Statsbygg, the Norwegian Directorate of Public Construction and Property, is a good example where they created a template for how to use BIM and plan the different phases of the project. When the rest of the industry saw the benefits, everyone implemented Statbygg's template. Additionally, the importance of early collaboration is highlighted, because if all the technical engineers and architects has to work together in the design phase, this creates less discrepancies upon construction.

5.1.4 Contractor

The contractor is a larger firm, and has projects of this size and type about every five years, as well as about six large projects in general every year. Also, they have a significant number of smaller projects.

5.1.4.1 Innovation

The Contractor argues that they are the actor pushing for new methods and digital solutions. They start using the newest solutions and have a large apparatus, prepared for technical innovation, e.g. skilled BIM technicians. They have their own department for sustainability and for digital solutions. When they introduce something new they usually use a project such as this as a trial or pilot. In this project they have tested several new solutions for personnel registration, relating to the ongoing pandemic.

The main driver for adopting an innovation is that the competition has adopted something new, and they need to keep up. New innovation is rarely encouraged or pushed from the Project owner, however, in some cases regulatory factors may spark the need for something new. Their key criteria for adopting a new digital solution is the usefulness, combined with ease of use, so that everyone actually wants to utilise it. Additionally, it has to be convertible, linked, or in the same format, as their existing solutions. The largest hurdles in adopting some new innovation is their conservative and sceptical attitude, as well as the high bar for usability.

5.1.4.2 Procurement and investment

The department of Virtual Design and Construction (VDC) is responsible for purchasing new digital solutions. This is done at the corporate level. This entails that innovations that are to be tested on a project, in a pilot, has to get approved centrally. The corporation is quite conservative with these permissions and projects have no budgets for innovation. If they need a sub-contractor to have access to the same digital service as them, they might purchase it on behalf of them, however, this is an uncommon occurrence. Additionally, if a service is extraordinarily expensive, the VDC sometimes purchases number of licences, which then has to be shared between employees. They are, however, sceptical of smaller actors as they want to know the solutions they choose will last and work. When asked how they invest in technology to become more efficient, Onclick LCA is referenced. This is a software service that which performs a Lifecycle Analysis automatically.

5.1.4.3 Collaboration and industry views

To stay competitive the Contractor regularly invests in new technology, based on industry movements. Additionally, they try to hire younger and more technically advanced personnel. The responsibility of the industry reaching their goals of productivity, is equally shared throughout. However, relating to sustainability, there is a communal responsibility, from the Project owners and such as in this case, the municipality. When the Project owner sets an ambition for the project in the tender, such as BREEAM, than a lot of the sustainable aspects fall into place. Us contractors can claim we try to do right by society, but we're in hard competition and cannot afford to

5.1.4.4 Corona

Corona has created a need for better digital solutions for keeping track of peoples movements on the construction site, relating to infections, in addition to who enters and leaves the area. The pandemic has also increased costs, as a result of extra cleaning and infection control, and pushed collaboration to become more digital.

5.1.5 Software Provider

The software provider is one of several used in this project. This specific provider's services were used by the Contractor and all sub-contractors. It's a tool for digital collaboration on the construction plans and BIM model. They have only been present in Norway for a few years, however, they could be categorized as a market leader. They provide a Software as a Service (SaaS) or a "off the shelf"-solution for their customers.

5.1.5.1 Innovation

The software provider in this project has little internal knowledge of the construction industry, however, they work in tight collaboration with industry actors, on how to improve their service. The customers present demands and issues, while the software provider has to present solutions. They have regular meetings to keep a good dialog. However, if an actor comes with a request, a solution is never tailor made, but rather created so that it can be used by the entire industry. Every contractor has their way of doing things, and the software requires some adaptation to the new norm.

5.1.5.2 Investments and goals

They have been able to fund their ventures without taking on any outside investors. This has been done through slowly building their service portfolio, brick by brick, from the profits of their initial offering. In effect they have directed all their income profits towards hiring more in-house developers, and developing new services. The reason for their swift success in Norway, was apparently a slower, more tedious process in their country of origin.

According to the Software provider, some see them as a market leader. All though, this hasn't been confirmed by a third party, he argues that their system is the most complete in their specific area of operations. Thus, while others have better solutions for other aspects within the industry, they have the broadest coverage of tools in their domain. As a result, they have been reaching their goals for growth reliably, both in the Norwegian market and internationally. They think word of mouth, based on the usefulness and increased efficiency of their solution, were to central to their success.

5.1.5.3 Price model and customers

The software service comes with two different pricing models. First, there is a corporate license, with a free flow of users and projects. The price of this model is set based on a calculation of the customers revenue streams and chosen service components. Secondly, there is a project licence, which has a fixed price based on how many service components are added, however, there is no limit on users. Support is always included, both email and phone, at no extra cost. This is a central part of their sales process, where they try to create a sense of security. This is reflected in how they let customers access the software for a couple of weeks, before presenting them with an offer. They want the customers to get to know the software, without the stress of decision making, and with tight followup from a sales representative. This ensures that new customers understands the software's purpose and its usability, before a purchasing.

The main customers are the contractors and sub-contractors, as is the case in this project. These are the actors whom need the software in their day-to-day operations. Additionally, there are Project owners and Advisors, who can be characterised as secondary users. Traditionally, the Project owners has pushed

the purchase over to the Contractor, however there has been a change, where the owners increasingly wants to maintain documentation upon completion, as well as take more owner the processes within the project. Sub-contractors usually purchase the same system as the contractor separately, while sometimes they have their own systems and, therefore, have to move everything into the contractor's system. They may also work directly with the contractor's system, but this entails loosing all their data when the project is finished, possibly leading to them being less competitive.

5.1.5.4 Corona

When the pandemic struck they feared a stagnation of income, or even a decline, however, this was not the case. In stead, their 2020 results showed a 30% increase in revenue in Norway and almost 60% internationally. Essentially, the only impact they felt from the pandemic was the increased use of home offices.

5.1.6 Case One Summary

The project was characterised as a success, where they delivered on time and on budget, despite some initial turbulence between the different actors, combined with the ongoing pandemic. The miscommunications early on were actually pointed to as a reason for why the team worked so well in the later stages of the projects. There were two initiatives on this project that can be characterised as innovative. First, there was the infection tracking systems that had to be put in place, as a result of government regulations. This was described as a hassle and they couldn't seem to find a system that gave them proper oversight, combined with ease of use. Secondly, there was the BIM collaboration software, which according to the contractor would have been used regardless of the tender demand. While this system isn't a new in this project, it has only been used for about three years, so it can be considered from an innovation adoption standpoint. This software came as a result of increased need for efficiency and detailed plans. This is also the software offered by the interviewed Software supplier. This software seems to have been positively received by professionals, however, as the technical project manager points out, its unrealistic to expect all sub-contractors and building operators to have the technical knowledge to use these tools.

"They push it (the software) aggressively, thinking it should be a universal tool for everyone... But it has to be a low bar, you can't just roll it out and expect everyone to use it. I think it's to technical for that."

Table 6: Summary Case One

Findings	P/D	La
Industry level		
Innovation		
Tender does not promote/requires process innovation, however it does promote delivery innovation through ambition	P, D	PO
Project ambition set in government goals and by PO.	D	PO, C
Driven by regulations	P, D	PO, C
Driven by project ambition	D	All excl. SWP
New infection tracking software as a result of Corona regulations.	P	C
Profitable project.	D	All
Procurement and investment		
Budget for innovation on project	D	PO
Think they are responsible for choosing tools for project process innovation	P	C
Can run pilot of innovation on project	P	C
Collaboration and industry views		
Think PO's are responsible for sustainability goals	D	TPM, C
Think industry goals are a communal / public / government responsibility	D	PO, C, A
The industry is unprepared for technically advanced innovation	P	TPM
Attitude and age are the biggest hurdles currently	P	TPM, C
Corona		
Had a positive impact on digital teamwork	P	All
Led too new procurements	P	C
Led to increased costs	P	C
Organisational level		
Innovation		
Driven by competetiveness / to better compete on tenders thorugh efficiency	P	C, A, TPM
Worried about complexity (Usefullness and ease of use)	P	C, TPM, PO
Has regular courses & training	P	A
Sceptical and conservative	P	PO, C
Requires linkes to exsisting systems or formats	P	C
BIM software driven by productivity and competetiveness, despite being a technology demand, in the Project owners tender	P	C
Procurement and investment		
Prefers corporate/central procurement	P	All
Prefers included support	P, D	C, A

Prefers personal licences if the software is abnormally expensive	P, D	C
Collaboration and industry views		
Sceptical towards smaller actors software	P, D	C
Knowledge and organisation is biggest challenge	P	PO
Corona		
Led to increased profits	P	SWP

P/D: *Process or delivery*, La: *Linked actor*, PO: *Project Owner*, A: *Architect*
C: *Contractor*, TPM: *Technical Project Manager*, SWP: *Software Provider*

5.2 Case Two

The second case was a project which emerged from encouragement by some participants at a sustainability conference. A construction client gathered different actors, including a contractor, energy consultant and an architect, to form an alliance whose goal was to take on the challenge of constructing the most sustainable building of its type in Norway.

The result was a new concept with exceptional ambitions in terms of sustainability. The project did not have have an initial tender process, as the participants in the design phase were determined through the alliance. However, the contract was formed as a Design Build Contract where the entire alliance was involved from designing, to construction. Six years elapsed from the concept was defined until the construction phase began. The long wait was due to rigid regulatory processes and negotiations with the municipality. The construction phase lasted for 2 years, though some processes are not yet completed due to some conflicts that emerged during the project. The total value of the project was between 400 and 600 MNOK.

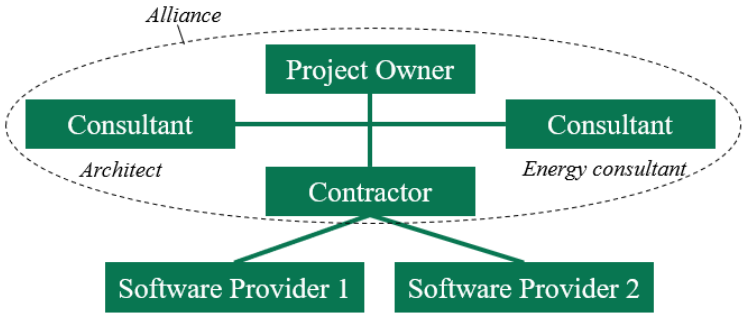

Figure 11: Design Build Contract - Case Two

The design build contract was signed early in the process. However, the innovation processes that was specifically linked to the project, not the concept, was

included after the construction phase was initiated. The project owner separated an individual innovation contract on the project, including the alliance, with relevant subcontractors and suppliers.

5.2.1 Project Owner

The project owner, or the construction client, is a large private company which is listed on Oslo Stock Exchange. The company has roughly 10-20 ongoing construction projects, and operates and manages numerous buildings in different regions of Norway.

5.2.1.1 Innovation

The company is referred to as an ambitious and innovative actor, which is one of the market leaders within their segment. The company was the initiator of an alliance which formed one of the most sustainable measures the Norwegian, which is pointed out as one of their innovative actions drag the industry in the right direction.

The company claims to be proactive in terms of innovation, but has strict protocols for innovative activity. However, in order to maintain their market leader status, they must adapt to new technology continuously. As they are listed on a stock exchange, they conduct detailed profitability analysis on each new measure on a project, to manage risk and ensure profitability. The company measures KPI's in order to maintain control of their needs in great detail. A key driver for a new innovation to be adopted, is that their needs are fulfilled. Their needs are closely linked to their strategic goals, which are customer satisfaction, profitability and sustainability.

In this case, the company had ambitions to a spearhead in terms of sustainability, which created very distinct needs for the delivery innovations that should be adopted. Energy efficiency and sustainable materials where high priority. The need for low energy consumption lead to specific innovation requirements in the tender to the suppliers and subcontractors, e.g on smart lighting systems. Furthermore, other needs for user satisfaction where mapped from other projects, through data analysis and workshops with the users, e.g charging stations for electric cars.

5.2.1.2 Procurement and investment

The procurement process usually involves testing a new product or service in one project, with all their projects in mind. That is, if a product provides sufficient value to one project, the company enrolls the product quickly to all projects. The project owner was more than happy to invest in new products on behalf of contractors, given that the particular products returns value in the form of reduced construction time, or similar, on the project. There exists a designated department within the company which analyses new technology and brings in new innovations. The project costs ends up at the project owner. The

company is somewhat bound to fulfill regulations set by the government, which set a framework for what their needs are.

The project owner has framework agreements with many suppliers and subcontractors on an organizational level, which directly affects which companies are included in a project. The tender is announced as a competition between the actors who are included in the mentioned agreements.

5.2.1.3 Collaboration and industry views

As the company is listed on Oslo Stock Exchange, they are driven by market forces. The company's economic growth and strategic profile incentives owners, trading stocks in the open market. However, the company acknowledge its responsibility as an influence in the industry. Given the competitiveness and small margins within construction, innovation must be included in the tender to be give incentives to the project participants. Moreover, the company must be ambitions in terms of digitalisation and sustainability to maintain a lucrative and attractive image to stock investors, that act in accordance to large global trends. On the other hand, their ambition is largely affected by the regulations and goals set by the government, as a building is both constrained by regulations and pushed by the goals applied to the industry. Additionally, the construction client must comply with criteria set by banks and financial institutions in order to get loans, whereas e.g "green loans" will provide better conditions if a building is sustainable and digital.

5.2.2 Architect

The architect on this project is a large Norwegian actor. The architect is usually brought into a project in a Design Build contract by a tender announced by the contractor. In this project, however, the architect was involved in the alliance from commencement and had massive influence on creation of the sustainable concept. The architects are paid on an hourly basis or by fixed price, depending on the phase of the project and the nature of the service.

5.2.2.1 Innovation

In terms of documentation, file storage and project management, the architect will adopt the contractors tools. Concerning design tools, the company has a dedicated department that is constantly looking and analysing new technology. There is a rich culture within the company for testing new products both at an individual level as well as on projects. In order to successfully adopt new technology on a project, the construction client and the contractor must participate in the assimilation process. The architect underlines the importance of starting with innovative measures in the preliminary project. In the detailed part of the design phase, it is too late, and will cause restructuring processes and ultimately delays and extra costs.

5.2.2.2 Procurement and investment

From the exploratory culture in the workplace, the company is relatively up to speed regarding available technology. A new innovation can be introduced either through employees at the firm (design tools etc), or though the project owner or contractor (process tools). A usual process of adopting a new innovation includes testing at a individual level, then test on one project, then try to influence the decision makers on other projects. Adopting a new tool is resource-intensive, but necessary when the environment in which the company operates utilize a specific product. Their customers appreciate to work in the same model in the same tool. Thus, it's important to have competent personnel available for questions and training at work, to ensure successful adoption. Procurement is done centrally in the organization, or in many cases the tools are provided by the contractor.

5.2.2.3 Collaboration and industry views

The architect compete with other actors mainly on price and design quality. Consequently, any product or service that can increase their productivity or provide tools for delivering their services at a higher quality are appreciated. This project, however, has been different than most, due to its ambition. The firm acknowledges that a lot of the responsibility to digitalise the industry and adopting innovations lies with themselves, as they have a great influence on how buildings are constructed, as seen in this case. Despite this being an unprofitable project for the architect, the company has experienced an increase in suppliers that are presenting new sustainable products to them, and the concept has been adapted to multiple other buildings with greater economic benefits.

5.2.3 Contractor

The contractor on this project is a large international actor operating in Norway and abroad. The company is usually involved in Design Build Contracts within construction and infrastructure projects.

5.2.3.1 Innovation

The company claims to be a market leader within sustainability and digital innovation. There are separate departments responsible for ensuring that the company is among leaders in their respective areas. The contractor's responsibility on this project was to ensure steady progress and to sort out the logistics between the various contributing actors. Processes are what they specialize at, as they claim, an innovation is only an innovation for that one project. The different actors will then transfer the knowledge or product onto the next project. The competitive advantage lies in the process to successfully bring forward and adopt new innovations. The contractor deals with a lot of risk on these types of projects, and has little capacity to invest in new innovations, separate from

delivery. Products and services which increases productivity, were considered the most relevant innovations.

The contractor is responsible for delivering to the project owner's specifications, and the informant states, relating to project innovation, that all the results depend on the owner's ambitions. Many issues emerged from the delivery innovation processes on this particular projects. The form of the Design Build contract in combination with the parallel innovation contract is highlighted as the root of all these conflicts. This was, partially, due to the innovation processes being initiated after the construction phase begun, but also, a result of the contract terms for incentiviseing the various actors. Some were payed per unit sold, whilst other billed at an hourly rate. As a result, parts of a the delivery was still not completed, two years after the building was handed over to the tenants. This conflict was pointed to by every informant in this case.

5.2.3.2 Procurement and innovation

The company consists of many different departments, specialising in various domains. The individual project teams have considerable authority to procure software and innovations as they please. If a project finds some technology valuable, the company will procure it centrally, through a cite license, and distribute the product wherever it's needed. However, the informant stated that there are two distinct types of innovation. First, there is innovation linked to the delivery to the client, e.g a new type of roof on a building. Secondly innovative tools that indirectly improves the quality of the delivery, e.g new file storage system.

5.2.3.3 Collaboration and industry views

The contractors compete for projects with high risks and low margins. Consequently, the contractor is immensely concerned with risk, and states that in a perfect world, financial risk would be more evenly distributed between the various actors on a project, based on the actual risk taken. On this particular project, the financial costs and risks, in the innovation contract, where shared equally between the contractor and the construction client only, which the informant points to as a major flaw in the innovation model. A success criteria for successful innovation is to include all participants with the risks and rewards of the projects, which incentivises every actor to commit to the process.

5.2.3.4 Corona

The software supplier for one of the innovations in the project was an international actor, so around the first lockdown, there was a one month delay. Nonetheless, the team developed better understanding of digital collaboration.

5.2.4 Software Provider 1

The first software provider (SW1) is a large international actor operating on all continents, delivering software mainly towards construction automation. This entails digital systems controlling light, ventilation, electricity, security etc. The firm has developers abroad, and has a toolbox of applications, that are combined in order to satisfy customer demands. Furthermore, SW1 has a large network of suppliers for different IoT-hardware and other technical installations, which can be delivered in addition to software products and services.

5.2.4.1 Innovation

SW1 states that they even though they sell applications "of the shelf", large complex buildings are becoming increasingly unique and smart, and project owners are constantly demanding new products. Therefore, the company have had to adjust their applications to suit specific needs at individual projects.

"There exists no single answer to anything anymore".

Clients demand innovation in nearly every contract the company wins, so innovation is a major part of their core competence. However, as SW1 usually works on older framework contracts, the informant draws out that Design Build contracts are limiting the potential for innovation. The reason lies in the function based structure of the contract, which is more result oriented than process oriented. And innovation requires a long process. As the DB contract has a fixed price, and does not provide sufficient detail of results, it can sometimes end with sub-optimal deliveries.

The problem on this project was that the goal was not adequately detailed, and the DB contract states that the project owner must approve all changes in the project. This leads to long processes on every adjustment which is difficult and time consuming. Additionally, the innovation contract was initiated late in this project, creating a poor foundation for innovation. There was too little time available for detailing, which lead to many changes during construction.

5.2.4.2 Investments and goals

Everything starts with the project owner's ambition. They lie the foundation in terms of goals, contract form, budget etc. SW1 is a large actor which provides general solutions. Startups are important as they can digitalise more specific processes and create products that solve small, but important problems. The large actors do not have the capability to address the small problems, which accumulate to large barriers to transform the industry.

Regarding innovation investments and related developing costs, the informant shares that they cover these costs internally. They only adapt their products to the customer, and that is what they pay for. Later, when the product is in use, the customer pays through a subscription model with floating licenses. Earlier,

they sold licenses and upgrades. Today, the customer can choose between the two models.

5.2.4.3 Price model and customers

The company had a framework agreement with the project owner, and was included in the innovation tender, competing with two other firms. The tender included ten innovation areas, where the three competitors would propose their offer. After winning the project, a DB contract and the innovation contract were formed. The latter included 10 options for innovation according to the aforementioned innovation areas, whereas 3 were triggered by the client. One of the innovation projects lead to great dissatisfaction with the contractor and project owner. As mentioned above, the problems emerged from the poor contract form, with one DB contract and a separate innovation contract.

The company sells their products and services at increasingly high levels in their customer's hierarchies. Framework agreements are ordinary to them. They are brought in through projects, but the DB contract is immensely influenced by the framework agreements.

5.2.5 Software Provider 2

The second software provider (SW2) is a large actor, despite being considerably smaller than SW1. SW2 sells software "off the shelf", for documentation, analysis and quality assurance in the construction and infrastructure industries. They have thousands of customers, and contractors make up the majority of their customer base. On this building project, the company supplied with software to monitor an electricity grid. The company has existed for nearly 40 years.

5.2.5.1 Innovation

A focus on innovation keeps the company competitive. They have close contact with customers and user to map needs for future products and areas of improvement, on existing products. A key driver for them is to detect future regulations, affecting their customers deliveries. Thus, they develop tools that solve the customers needs immediately after a new law or regulation is applied. Furthermore, the contractor may approach SW2 with the tender document where a criteria for the delivery is highlighted. Then they develop a product that satisfy that criteria, which is an obvious need for the contractor. One of the most important success criteria when they develop innovative solutions, is that the tool does not interfere or change the users habits and behaviour. The tool must be adapted to the user's workflow.

5.2.5.2 Investment and goals

The project owner is affected by by regulations and laws set by the government. The ambitions and goals are often directly linked to these regulations. However, the client decides what to purchase and adopt in terms of innovative tools. Some years ago, a typical project size was around 100-300 MNOK. Now, they have several projects in the range of 1-3 BNOK. The projects are getting bigger, leading to more room for investments in new products and services. Especially if a product will make the construction process more efficient.

The respondent states that the industry needs more startups, as the big actors cannot solve the many small problems in existence within construction. As a large actor, they depend on smaller firms that can integrate into their solution to solve small problems.

In the company's experience, it's favorable to cover development costs related to new innovations internally, as this ensures control of the development direction. A customer that pays for the development may influence the solution to a such degree that the product will not be relevant to sell "off the shelf", as a general solution. Covering these costs are possible because they are a big company. It could be more difficult for startups.

5.2.5.3 Price model and customers

The company sell floating software licences, with an additional support agreement at 25% of license costs, billed yearly. They are currently transferring over to SaaS-solutions, as implementation costs are lower, they can deliver faster and the barrier to test new products are lower for the customer. However, moving their entire product portfolio to the cloud is a massive operation, which could be very costly. Also, going from licenses to SaaS will demand a decreased revenue for some period, whilst increasing recurring revenue. Additionally, SaaS pushes them to deliver better because customer could leave at anytime.

They help contractors with adopting new software because they need good customer experiences. Early adopters and champions help them to a great extent, and they are situated within projects. They assist in getting the software purchased centrally, however, the projects has a lot of authority nowadays and can often purchase software autonomously.

"The success of a sales and adoption process, depends on whether or not we have a champion on a project"

5.2.6 Case Two Summary

The project was one of the first of its kind, requiring a great amount of innovation. Large parts of the innovation were vastly successful, leading to satisfactory solutions in addition to generating profits for every actor (architects excluded). The government was immensely involved in the preliminary project as the building did not meet the existing requirements from the municipality. Through years

of negotiations and discussions, the parts agreed to a compromise, mainly on the building's physical appearance. In terms of digital innovations related to the delivery, one innovation pointed to, by all involved parties, as a challenging experience. This was mainly due to the structure of the DB contract in combination with the innovation contract. The parties were incentivised on different foundations, leading to a conflict of interest.

Table 7: Summary Case Two

Findings	**P/D**	**La**
Industry level		
Innovation		
Separate innovation contract from DB tender, to incentivice innovation	D	All
Different incentives in innovation contract led to conflicts of intrest	D	PO, C, A
Project started as an alliance between PO, Contractor, Architect, and Energy Consultants, to develop a concept for sustainable buildings	D	PO, C, A
Project was profitable	D	All, excl. A
Project owners ambition was the main driver for innovation. The ambition was, however, influenced by regulations, government goals, and financial institutions	P, D	All
The digital innovation in this case had to customise their solution, competing in the contractors tender to deliver to the project	D	SWP1
Improving delivery is an important driver for innovation	D	
The risk of implementing new innovation lies with the PO and the contractor	P, D	PO, C
Procurement and investment		
Can run pilot of innovation on project	P	All
PO willing to pay for contractors digital solutions, if it benefits project in terms of cost or quality, both through the tender and directly	P, D	PO, C
Think they influence which digital tools and processes to use on a project	C	A
Collaboration and industry views		
Thinks the project owner is responsible for industry innovation goals	D	All
Exploration of new innovations are done by through project collaborators	P	C, A
Different actors using different tools leads to problems. Some have to adopt new solutions because of projects	P	All
Testing and feedback is essential to create solutions that work for the industry	P, D	All

Startups are important because they can solve the many little problems that the big actors do not address	P	SWP1-2
Projects today have increased in size, creating more noom and willingness to test new innovation	P	SWP2
Corona		
Increased use of digital tools for collaboration	P	All
Organisational level		
Innovation		
Streamlining processes is an important driver for innovation	P	C, A
Early adopters are important, as they influence the decision makers	P	All
A culture of testing is important for adopting new innovation	P	All
Innovation is important to sustain competitiveness	P, D	All
Procurement and investment		
Prefer centrally purchased solutions, of SaaS, with floating licences	P	All
Prefer support included	P	All
A barrier for adoption is procurement cost, relating to training. Depends on skilled employees to train unskilled	P	C, A, SWP1-2
Early detection of new regulations is important for developing good solutions	P	C, A, SWP1-2
Good customer relations are important for developing good solutions	P	C, A, SWP1-2
Exploration of new innovations are done by a dedicated department in the organization	P, D	PO, C, A
Collaboration and industry views		
When developing a new solution, it can't interfere with the users established work flow	P	SWP2
Development costs of new solutions are covered by the providers, exept if it is a custom solution. This is however hard to do for smaller firms and startups	P, D	SWP1-2

P/D: *Process or delivery*, La: *Linked actor*, PO: *Project Owner*, A: *Architect*
C: *Contractor*, SWP: *Software Provider*

5.3 Case Three

The third case is an environmentally ambitious and innovative project, where a central party of the project was testing a new method for prefabricated building modules. It received support from government funding initiatives, among others, which means that the project had a relatively strict and specific framework. The project was carried out as a Design Build Contract with a major preliminary project. The contract's total value was about 400-600 MNOK, and the project took place over three years, where the construction took place over 18 months. The tender process was carried out in two main stages. The architect was first selected through a "wildcard"-competition before the contractor was selected

through another new competition form. This form of competition significantly reduced the risk for the contractor and is described in more detail later in this section. As a result, the project was a successful and profitable project for all involved actors.

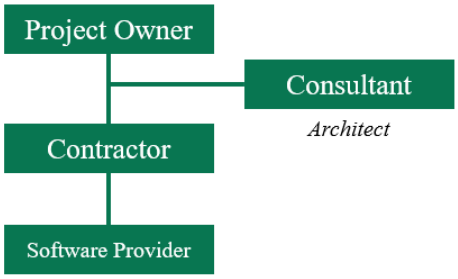

Figure 12: Design Build Contract - Case Three

5.3.1 Project Owner

The project owner of this project is a non-profit organization. In practice, they can be seen as a private developer who is quite strictly regulated by public guidelines. This industry player usually has medium to large projects within new construction and total rehabilitation. The project owner has a turnover of 300-600 MNOK annually and has 3-7 active projects at any given time. The organization has historically had a strong focus on energy and climate and is an actor that takes its responsibility in the industry seriously.

5.3.1.1 Innovation

The project owner sees themselves as an innovation-driven developer and bases this on two main points. First, that they always try to go further in relation to sustainability and the environment. Then, that they must satisfy specific cost and innovation frameworks to receive grants for their projects. If they fail to do this, they lose about 1/3 of the funding, which means that they can't do as they please. The interviewee believes that these specific and strict frameworks mean that they must think new and focus on innovative solutions and long-term goals to make it work. The project owner states that: *"If you do not have any restrictions, you can just put on lots of gadgets. Not sure it provides the best and most sustainable solution for that reason."*

The client has a strong focus on the project costs, to satisfy the strict frameworks. The interviewee also points out that digitalisation offers new opportunities. Nevertheless, they do not invest in new individual systems themselves, however, they are good at testing solutions through pilot projects. They also do not set any requirements for software in the tender. The interviewee believes that this is something they want to do in the future but it has not come this

far yet. Based on this, the client must always familiarize themselves with new software, such as web hotels, from project to project. This is not entirely fortunate, but as it works in the industry now, the interviewee believes, it's better for them as a smaller organization to get acquainted with new software than for the entrepreneur to be forced into a new system.

The interviewee highlights the tender process as a central part of their success with innovation on this construction project. They used many resources in this process and facilitated several risk-reducing measures. The process was, as mentioned, carried out in two main parts. The first part was a pre-qualification with an associated wildcard competition. Such a competition is only for smaller, recently established, architects. This increased creativity and created awareness of what was to be made. Additionally, it made future project interaction much more straightforward. The tender process for the contractors was also a competition. Here, the project owner took on much of the project's risk, so it would be easier for the contractor to prepare long-term and innovative solutions. In addition, it made it much easier to price accurately. As a result, it reduced the profitability for the project owner somewhat. However, the interviewee points out that overall it was an excellent decision and was one of the reasons why the project was so successful. In relation to digital innovation, the interviewee also believes that there is a long way to go. There is great potential in relation to design and collaboration, and sums it up as follows:

"It is not without reason that the construction industry is the least innovative and most conservative industry of all. A hammer is still a hammer. But it what happens before construction that we have a long way to go on."

5.3.1.2 Procurement and innovation

The project owner is a relatively small organization, and everyone in the development department can purchase services and products. At the project level, the project manager has the authority to do this. The interviewee points out on several occasions that they are open to testing new solutions. If they see the usefulness of it, then they test it. They primarily look at solutions that improve efficiency, risk, and documentation. They want something more long-term after such a test, and the common success criterion here is that it is easy to use, received good training, and followed up well. However, ultimately, it is a cost-benefit issue. If it goes directly to the execution of the other project actors, they can share the cost. Otherwise, it is difficult to push it since they have such a limited responsibility. In relation to this, the size of the company does not matter. It is the usefulness of the product that is crucial.

5.3.1.3 Collaboration and industry views

The interviewee believes that the industry goals are a shared responsibility, however, the client does has a greater responsibility, setting ambitions and contract model. The interviewee's personal experience is that the project gets many

known solutions if traditional consultants develop and design details. In these cases, innovation must be ordered more clearly. Using the contractor's expertise is something they see as very useful and believe it can give the best result in innovation and development. The project owner is otherwise competition-focused in relation to the fact that they want to attract the best people. Apart from this, they are not very competitive and believe that it is ultimately market forces that decide. Therefore, it is the regulatory requirements that must be stricter to force innovation and development.

5.3.1.4 Corona

They have tested a new VR solution for on-site inspections. It is in the very early stages but worked surprisingly well. Otherwise, they became much more efficient by taking digital construction meetings. Without this, they are very little affected.

5.3.2 Architect

The architect's core business is design and is characterized as highly technical architects. The company carries out most public projects on a medium to large scale. They also have some smaller projects, but that does not represent the core of the business. It's a relatively small and young architectural firm, and this project was the first with a larger order of magnitude. The company has a relative turnover of about 10-20 MNOK annually and has 10-20 active projects at any given time.

5.3.2.1 Innovation

The architect highlights the preliminary project with the project owner and the contractor as one of the most important reasons for the project's profitability and success. The form of the contract and the interaction cross-disciplinary cooperation was good. It involved an interaction model, where everyone was well involved and gained extra ownership of the project. Furthermore, the interviewee believes that the project owner is the biggest driver for innovation. It also seems that they are somewhat reluctant to take the risk of developing new innovative solutions. If they are to do this, the client must push for it, and there must be support from other actors who can part-take in the risk. This may, for example, be public support schemes, such as Enova or Innovation Norway.

It seems that the architects are very good at visualization software but care little about digitization and innovation otherwise. They care little about interaction and efficiency. They are much more focused on the risk aspect. Furthermore, it is said:

"Even though we do everything digitally, it is reality that is the product, and it cannot be digitised."

5.3.2.2 Procurement and investment

Since it's such a small organization and they mainly use the same software, it is purchased at the corporate level. The interviewee believes they are very optimistic about testing new digital solutions. Nevertheless, the interviewee is unable to come up with any examples. They purchase visualization and engineering software. Otherwise, they seem uninterested.

5.3.2.3 Collaboration and industry views

For the architect, the size of the partner does not affect a collaboration. The most important thing is that they have the same attitudes and views on what is delivered and what they want to create. Often, a collaboration works better when it's with a smaller actor, as this entails fewer people needs to be involved. This also makes interaction and communication more dynamic. Regarding competitiveness, they try to always have a steady stream of projects, to have relevant reference projects at all times. The interviewee believes that the project owner has the central responsibility in the industry for innovation and development. As a hired consultant, they lead their hours anyway, and efficiency does not matter as much. They are most concerned with the physical product and lowering risk.

5.3.3 Contractor

The contractor on this project is a large international actor operating in Norway and abroad. The company is usually involved in Design Build Contracts within construction and infrastructure projects.

5.3.3.1 Innovation

As the other involved actors, the contractor highlights the interaction in the early phase, and the tender process, as an essential part of the project's success. No requirements for digital solutions were included in the tender, except for an operational follow-up system. This was given based on the project owner's ambitious goals and made the documentation easier along the way. Furthermore, the interviewee states that innovative delivery solutions came as a result of having high goals. The contractor focuses on technical delivery innovations rather than digital process innovations. The more interaction there is, the more need there is for digital tools. In a subcontract, where the order is very specific, it does not need interaction tools in the same way. But then, there will also be less innovation along the way.

The contractor is developing an internal system to connect all their solutions. They carry out several standardisation processes to ensure that they work equally and according to best practices. It is a so-called ERP system, which is an overarching system. In addition, they have a separate BIM department that aims to spread digitalisation throughout the organisation. The interviewee

thinks that organisational culture and efficiency are crucial drivers for innovation. The younger employees will often try out new things, but the slightly older ones, like the interviewee, hold back a bit. *"We may be a bit of an endangered breed, holding back a bit. I think it's a good balance. Some are in front and some are holding back a bit. Then we get a discussion and hopefully find the best result."*

5.3.3.2 Procurement and investment

For the contractor, purchases are usually made centrally through corporate agreements. In relation to investing in new digital solutions, the project owner and their customers largely support the choices they make. They are willing to make investments to keep up with developments, but the biggest challenge is to spread it throughout the corporation. They commonly run pilot tests on projects, and if these are successful, it is easier to make the innovation a routine. The BIM department, which was mentioned, is a result of this and is well on its way. This is also what happened with Miro, a collaboration software, which they first tested on a couple of projects, before scaling it to the rest of the company. Additionally, they feel like good solutions often come from the bottom. Their relationship to procurement does not depend on the seller's size, but rather their credibility and what they deliver. Sometimes it can also be beneficial to work with minor players, as you can expect dedication and closer relations.

5.3.3.3 Collaboration and industry views

In relation to industry responsibility, the interviewee believes that it is shared throughout and that many actors have proven their focus on moving the industry forward. The interviewee points out that the project owner has an opportunity for innovation to a greater extent than several other actors. It seems that the entrepreneur as an organization has a stronger focus on competitive advantage, in ensuring a sufficient delivery, according to the project owners requirements.

5.3.3.4 Corona

Corona forced needs for new collaborative tools. The contractor carried out several interaction processes which they did not think they would achieve without meeting physically. They started using Miro to combat this issue.

5.3.4 Software Provider

The software provider interviewed in relation to this construction project is a medium-sized software provider. They work specifically with the construction industry, where they have had great success and are well-established.

5.3.4.1 Innovation

The software provider is developing off-the-shelf products, and they started by digitalising physical information. The development of innovations has been based on extensive industry knowledge and in-house competence in software development. Their primary customers are the contractors. They have been 2-3 years ahead of the new regulations, and the interviewee says they have always pushed for legislation which the contractor has not been able to handle themselves. This applies at both the company level and project level. They state that they are the industry's useful nerds, but this is still debated.

Despite some controversy around pointing out legislation, they have had great success, and that is mainly due to two things; First, that they have become very familiar with the legislation. Second, that they have created good solutions together with the users, through focus groups, where they essentially get help from the market. They have always had a strong focus on internal knowledge and want to build knowledge with the contractors. The advantage of being in the driver's seat of the regulations and participating in working groups is that you are developing the regulations yourself. Then you can also develop solutions based on this.

The interviewee also emphasizes that there have been challenges associated with the user groups. To begin with, they struggled with not making everything the customers asked for. Then they came up with many different solutions which turned out to be problems only for the individual. As a result, they have become much better at prioritizing what solutions are best suited for the vast majority of people.

5.3.4.2 Investments and goals

Three people started the company with both development and industry knowledge. This allowed them to develop the first products internally and has meant that the company has never had investors. They have never taken dividends, and all the money has gone back into the company. They have always had a very healthy economy, and the only thing they make money on is selling their own services. From the very beginning, they have had a focus on acquiring a strong market position. They have their own people who are specialists in soft funding and have been very good at "skattefunn", a Norwegian tax-subsidiary. In addition, they have received support from the EU on several occasions. They have over 100 developers abroad, which entails that they always have a capacity for development. They have achieved their goals through step-by-step innovation by constantly developing new solutions and modules. Built the company slowly but surely.

5.3.4.3 Price model and customers

The user groups mentioned above have also been involved in creating the company's price structure. The price model has taken into account the forms of

contracting on the various projects and is mainly based on the turnover of the various companies. They do not earn much on the basic license, but on the additional services and modules. They have always been committed to creating a fair model for all parties.

"It has never been a problem for customers what it costs, but that you are forced into a new system. Because it is the regulations that say it. In a way, you have no choice."

To begin with, they made outreach sales, but when they managed to create an industry system, the user groups and the contractors themselves actually became the best sellers. They have had much focus on implementation, training, and support. They have gone out on the projects and helped them get started. They have their own support department, which is practically free, and the only thing that costs money is if they are to hold their own courses. They want customers to understand the legislation and what they are doing.

The interviewee believes that the industry can no longer make a living from pdfs. They need to be more computer-driven, which has worked well abroad. In England, for example, there are much stricter rules in relation to this, and there it is much easier to come up with new solutions. In Norway, on the other hand, things take much longer because you leave it to the industry. Otherwise, it is a lot about change management and dares to try. It is super essential for innovation. No matter how digital we become, it is ultimately about people.

"The biggest drivers in the construction industry are market requirements and the environment. But I do not think everyone works towards the environment because they are so environmentally friendly, but they make money from it."

5.3.4.4 Corona

Software providers have been well of during the corona, and overall, sales have probably gone up, according to the interviewee. They have been affected somewhat though, as they have many employees abroad and the euro has been very high due to the pandemic, which has meant that they have paid higher wages.

5.3.5 Case Three Summary

Overall, the project was a profitable project for everyone involved. Innovations in the project were associated with the tender process and the strict framework from the project owner. The most significant drivers in the industry are related to market requirements. Table 8 summarizes the findings from Case Three.

Table 8: Summary Case Three

Findings	P/D	La
Industry level		
Innovation		
Tender requirements can facilitate innovation	D	PO
Public funding and financial institutions is a driver for project innovation	D	PO
The preliminary project with its collaboration was a driver for project innovation and results	D	PO, C, A
Using contractor through a competition is more effective for innovation, than using consultants in the early phase	D	PO, C
Type of contract is an important factor for delivery innovation	D	PO
Larger and more complex projects are a driver for process innovation	P	All
Delivering innovation based on coming regulation is a good strategy to ensure adoption	P, D	SWP
Procurement and investment		
There is a low barrier for testing new solutions as pilots, on projects	P	PO, C
High bar for making a solutions a system wide routine, as pilot success has a high bar for usability	P	PO, C
Collaboration and industry views		
Government legislation and market requirements are responsibele for reaching industry goals	D	All
Project owner has the responsibility to implement change, through their ambition	D	PO, C
Corona		
Positive effect due to increased use of digital collaboration solutions	P	All
Tested new solutions for interaction and inspection, remotely	P	PO, C
Organisational level		
Innovation		
Very delivery oriented approach to innovation	D	PO, C
Contractor has developed an internal ERP-solution, connecting all their systems	P	C
Innovation is driven by competitiveness	P	C, A
Innovation should be developed in collaboration with users to ensure usability and usefullness	P	SWP
Early adopters are important in influencing decision makers	P	C, SWP
Procurement and investment		
Prefer central corporate procurement, with floating licences	P	All
Prefers included support and training	P	All
Hard to routinise solutions in large organisations, after initial testing	P	C

Invest all profits into future innovation development	P	SWP
Collaboration and industry views		
Positive towards working with smaller actors, as long as the product is usefull, and the people behind it are trustworthy	P, D	All
Prioritises risk reduction and visualising the delivery over efficiency	P, D	A
Attitude and scepticism, as a symptom of age is a barrier for innovation	P	C
Individuals don't like to diverge from the usual work flow	P	C, A
Corona		
Profits has increased	P	SWP
Increased costs, due to foreign software developers and a higher Euro cost	-	SWP

P/D: *Process or delivery*, La: *Linked actor*, PO: *Project Owner*, A: *Architect*
C: *Contractor*, SWP: *Software Provider*

5.4 Case Four

This last case is still ongoing and estimated to last for five years in total. The project was issued as a tender, and structured as a Design Build Contract. This entails that the Project owner hired a contractor, which made all subsequent hires. It s large project of more than 1 BNOK and has high ambitions relating to sustainability. Additionally, one of the software providers in this project is the authors' company, Kvist Solutions. Therefore, this case is discussed from the perspective of Kvist, despite containing data from interviews.

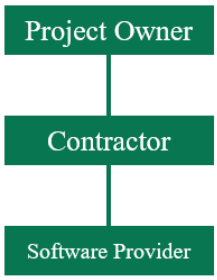

Figure 13: Design Build Contract - Case Four

5.4.1 Project Owner

The Project owner is a public actor, tasked with the management and operations of public property. They usually have one large and tens of smaller projects yearly.

5.4.1.1 Innovation

The project manager describes the company as very innovative, and they are currently involved in three research projects, together with contractors. They feel the communal responsibility as a public actor. They also emphasise that they want ambitions contractors in tenders, so that less innovative ones are weeded out. However, their main motivation for innovation is to improve their own constructions. *"Everything is market driven in the end. It's controlled by rental prices"*

The biggest challenge in innovation is training and the cost of implementation. The project manager argues that initial training results should be measurable, so one can calculate the effectiveness and value of the training. Without such practises, there is no way to quantify if the time spent on courses and training was worth it. Additionally, peoples unwillingness to change is a major obstacle, where *"Attitude and age is a challenge. The attitude is a product of older age, I think, actually"*, according to the product manager. By extension, the main reason why they don't start using a service is that its to complicated, as you have to get everyone on board.

5.4.1.2 Procurement and investment

All purchases are controlled by the firms management, at the corporate level. However, on projects they use other solutions, purchased by the contractor. If they want a certain technology on a project, they will just add that as a requirement. However they wont add specific software requirements, as this forces the contractor to use a service which they might not like. *"We did that on this other project, where we forced them to use a software they didn't know how to use, and it worked out poorly... It's a very slow ecosystem, which takes a lot to change. It's more effective to leave them be"*. In this case, however, they added a requirement to include a digital twin of the construction, without any specific software in mind.

5.4.1.3 Collaboration and industry views

Their view on competitiveness is to always try to be the best at what they do and deliver on promises. They also do a lot of collaborations with students and smaller startups, to try and be a part of whats happening in the industry. As such, they are positive to working with smaller actors, as this gives them more influence over the services they use. The Project owner argues that themselves and the contractors each share the burden 50/50 when it comes to pushing new digital solutions. They also add that the responsibility for the industry reaching its sustainability goals mainly rests with the Project owners, as they are the ones in charge.

5.4.2 Contractor

The contractor of case four is one of the largest in Norway, with a presence in several other countries. They participate in about 5 larger projects and 30 smaller ones each year.

5.4.2.1 Innovation

The Contractor is eager to find the best solutions for their employees. They have a department tasked with finding new solutions, however, they are very concerned with the usability of their innovation. The Contractor where the ones to bring Kvist's software, called Init, into the project. This is done as a pilot, and is how they usually test out something new, before purchasing in larger scale.

Their motivation for innovation is to stay competitive, and they usually push for innovation internally themselves. In this case, however, there is also the requirement, from the Project owner, for a digital twin. When adopting new innovation they look at the usefulness and the usability of the solution. Additionally, the attitude throughout the company and with subcontractors is a hurdle, as the level of technological competence is varied.

5.4.2.2 Buying orientation

As mentioned, they contractor can try out new solutions on projects, however, if they wish to purchase something after completion, it has to be done centrally, by the responsible department. As a result, they prefer floating or company-wide licenses, but can also sometimes purchase personal licences for certain services. Additionally, support is important for them, where they like to have the security of always being able to call for help, without concern for added costs.

5.4.2.3 Competitiveness and industry views

To stay competitive, the contractor continuously invests in new technology, responding to industry standards. They also focus on hiring personnel with technical competence and try to improve their organisation's overall preparedness for innovation. In regards to the industry goals, they feel like it is a communal responsibility, where the market and regulations, shape project owners ambitions.

5.4.3 Software Provider - Kvist Solutions

Kvist is as mentioned the authors' company. Thus, an interview haven't been conducted, however, relevant views on the interview topics are presented in this section.

Kvist is a start-up company which delivers digital solutions for environmentally ambitious building and construction projects. The company was founded in

June 2020 and stemmed from a problem, which one of the authors discovered when he worked for one of Norway's leading construction companies in 2018. Kvist consists of eight employees with strong technical expertise in software development.

5.4.3.1 Innovation

Kvist has a very user centred approach to their innovation. This is based on the industry's focus on having high usability, to get everyone on board. Additionally, Kvist's goal through the pilot in this case, is to get feedback on which features work, and which don't. The solution will be a general solution, but it has to take into account all the different actors' technological competence. Thus, the results from this case will shape the solution into something which hopefully satisfies the industry's demands.

5.4.3.2 Investments and goals

Kvist is a private initiative, currently funded through different soft funding initiatives. In may of 2021, they had secured 1.6 MNOK through such measures. The goal is a commercial launch, in January 2022, upon completion of the pilots.

5.4.3.3 Price model and customers

According to plans, Init were to be a SaaS, aimed at the contractors. However, this was still an uncertainty, at the time of writing. The contractors are the primary customers, both because they are responsible for the process of environmental certification and they are commonly the ones tasked with purchasing the process software through tenders.

5.4.4 Case Four Summary

As case four is still ongoing, it's outcome is yet to be decided, despite everything having gone according to plan, in the initial faces. Thus, the results from the two aforementioned innovations are not yet conclusive. However, the drivers and motivation for trying to adopt these innovations still presented some insights. First, there was the digital twin innovation, which was a result of the project owner's ambition. This innovation is directly linked to the delivery, in which it should be accompanied by an accurate digital version, for the owner to utilize post construction. Secondly, the contractor has initialised the Kvist-Init pilot, on their own accord, as a response to their own need for efficiency and management. Thus, this is directly related to the contractor's own process, but also to the project owners ambition, concerning the environmental certification.

Table 9: Summary Case Four

Findings	P/D	La
Industry level		
Innovation		
Tender requires technology innovation; possibly leading to process innovation	D (P)	PO
Project ambition set in Project owner, based on market price	D	PO
Think they are responsible for project process innovation	P	PO, C
Thinks innovation is driven by project ambition	D	All excl. SWP
The biggest issue is training and cost of implementation	P, D	PO
Procurement and investment		
Budget for innovation on project	D	PO
Can run pilots on project	P	C
Collaboration and industry views		
Think PO's are responsible for sustainability goals	D	PO, C
Think industry goals are a communal / public / government responsibility	D	PO, C
The industry is unprepared for technically advanced innovation	P	PO
Attitude and age are the biggest hurdles currently	P	C
Corona		
Increased use of digital tools for collaboration	P	All
Organisational level		
Innovation		
Driven by competitiveness / to better compete on tenders through efficiency	P	C
Worried about complexity (Usefullness and ease of use)	P	PO, C
Sceptical and conservative	P	C
Requires linkes to exsisting systems or formats	P	C
Environmental certification software, Kvist Init, to improve process	P	C
Procurement and investment		
Prefers corporate procurement	P	All
Centralised procurement	P	All
Prefers included support	P, D	C
Prefers personal licences if the software is abnormally expensive	P, D	C
Collaboration and industry views		
Positive to working with smaller actors	P, D	PO, C

P/D: *Process or delivery*, La: *Linked actor*, PO: *Project Owner*, A: *Architect*
C: *Contractor*, SWP: *Software Provider*

6 Cross-Case Analysis

In this section, a cross-case analysis is presented, investigating patterns, and strategic or operational resemblances and dissimilarities between the cases. The analysis was carried out by highlighting the topics which were shown to be prominent throughout the within-case analysis. First, a table is presented, summarising the key findings and which cases they relate to. Subsequently, the themes or subjects that have shown to be salient on the projects are discussed. The findings have been be categorized according to the relevant level, and by its strategic or operational characteristics.

6.1 Overview

An important discovery is the distinction between *delivery* oriented innovation, e.g. an energy efficient power grid in the building, and *process* oriented innovations, e.g. a new project management system. While these orientations are interconnected, where the internal processes actually leads to the a delivery, it still is a useful distinction considering the motivations and challenges are very different. All involved actors are focused on the outcome of the project, however, they have different motivations to focus on the processes that ensure delivery. These orientations will simply be referred to as either delivery or process innovation, henceforth.

Table 10: Cross-case analysis

Industry level	S/O	P/D	C1	C2	C3	C4
PO determines goals and criterias for delivery oriented innovation	S	D	X	X	X	X
PO has the main responsibility to push the industry in terms of innovation	S	D	X	X	X	X
Tender does not promote / requires process innovation, however it does promote delivery innovation through ambition	S	D	X	X	X	X
PO's Project ambition influenced by government goals	S	-	X	X	X	
Pilot test one one project, then transfer product to other projects	O	P		X		
Innovations are easily transferred from one project to others	O	P		X		
The project's contract form positively affects innovation	S, O	P, D	X		X	
Adoption drivers						
Market requirements and statutory regulations	S	P, D	X	X	X	X
Industry goals and ambitions	S	P, D		X	X	
High complexity on project	O	P			X	

Adoption barriers						
Cost and risk distribution	S	P		X	X	
Varying level of technological knowledge and integration on a project	O	P	X	X	X	X
Low margins and high risk on projects	S	P, D	X	X	X	X
Different actors have conflicting incentives on projects, in order to nurture innovation	S, O	P, D		X	X	X
Organisational level	**S/O**	**P/D**	**C1**	**C2**	**C3**	**C4**
SW is bought centrally if widely used	S	P	X		X	X
New innovations must be integrated with existing SW	O	P	X	X	X	X
Adoption drivers						
Word of mouth - usefullness	O	P	X	X	X	X
Customer/partner use it on project	O	P		X		X
Testing culture	O	P		X	X	X
Aligns with company strategic goals	S	P	X		X	X
A need to improve efficiency, reduce risk etc (competitive advantage)	S	P, D	X	X	X	X
Early adopters / Champions	O	P		X	X	X
Good practises for routinization of tested innovation, sharing new processes throughout	O	P			X	
Regulation / Legislation	S	P, D	X		X	X
Adoption barriers						
Implementation cost and training	S, O	P, D		X	X	X
Complexety (high bar for usability)	O	P	X	X	X	X
Technical competence	O	P	X	X		X
Attitude and age	O	P	X	X	X	X

S/P: *Strategic or operational*, P/D: *Process or delivery*, C"n": *Case "n"*

6.2 Industry level

On complex construction projects, the Design Build contract is close to an industry standard. The involved corporations are all specialized on this type of project delivery method. The contract form is associated with some pros and cons which, amongst other subjects, are discussed in the following segments. Furthermore, statutory regulations influence both drivers and barriers for the various actors, being an important influence for strategic and operational circumstances.

6.2.1 Strategic driver and barriers

On the large complex projects, the Design Build contract appears to be a requisite for a project owner to initiate the project, as a lot of risk and operational responsibilities are delegated to the contractor. The DB contract eases the pro-

cess of commencing these projects, which is important as these are the projects that pushes the industry, in terms of innovation. A clear consensus from all informants is that, the project ambitions in terms of delivery innovation starts with the project owner, and the criteria set in the contract naturally affects the entire project. Innovations which relate to the final delivery, are financed by the project owner. In this regard, the project owner is the key driver of innovation.

As the project owners in the four cases were of different types, i.e. private and public, the cases had different strategic drivers. A private project owner is driven by profitability and market trends. Profitability arise from good customer or tenant satisfaction and efficient project processes. Furthermore, on case two, the project owner listed on the Oslo Stock Exchange, which puts a pressure on the company in terms of reputation with the investors. Thus, the company must prioritise sustainability and other digital market trends, in order to maintain a market leader status. The other cases have public project owners, with large variations in organisational structures. Regardless of their structure, they are public organisations with a purpose set by government actors. These goals are characterised by societal benefits, in addition to the market incentives. Nonetheless, industry regulations and criteria set by financial institutions are important factors for innovative activity of both types. Some industry regulations, such as, criteria for documenting sustainability on projects, forces the actors to deliver. For example, case one adopted a digital management tool for handling personnel in conjunction with the corona pandemic, in the middle of the project, without delay, due to the requirement. Other laws can be limiting in terms of innovation, e.g. ambiguity in the regulations on reuse of building materials. However, all the software providers highlights that being able to make software that fulfills new criteria by the government is a success factor to them.

The DB contract form is associated with some inevitable consequences, which dramatically mitigates the potential for innovations on ambitious projects, i.e. conflicts of interest. As the contractor and the project owner desperately tries to keep the costs low, consultants and other service providers make their living on expensive hours. This is highlighted as a major flaw of the DB contract, especially in case two, which can be correlated with the project's extraordinary innovation ambitions. Case one, three and four underline the importance of the contract form to stimulate innovation, but did not experience any conflicts with DB on the respective projects, as they had consultant tenders which focused on delivery, rather than hours. Case two, in contrast, points out that the risk of conducting innovative activity is poorly distributed between the actors, and in combination with the conflicts of interest that occur from the contract, the foundation for innovation is bad on large complex projects. The conflicts of interest led to some operational barriers, which are discussed in the next segment. Moreover, neither of the tenders included any criteria for process innovation, only addressing delivery innovation.

In many cases, with private project owners, the different actors have large frame-

work agreements, which lay the foundation for the terms in the project contracts. In practice, it's a competition between the actors which the project owner has organizational agreements with, which could potentially be sub-optimal candidates for the project. Furthermore, the framework agreements could impact innovations negatively, as the tender processes does not provide fair competition between all relevant actors. Public project owners have a similar problem, relating to public procurement. They have to issue tenders for everything, based on regulations, which as stated in case one, could lead to sub-optimal actors winning, based on price, while not being the highest value solution.

6.2.2 Operational driver and barriers

The DB contracts limit the potential for innovation processes as it is function based, and well delivered results are recompensed. Thus, the processes are neglected as a part of innovation, and by law, the project owner has to approve all minor changes. In practice, the actors do not work towards the same goal, as product suppliers want to sell units, the consultants bill hours, and the project owner wants low costs. The project owners are called out as being too result-oriented to bring forward innovations, as innovation requires a thorough process. Still, the complexity of large projects stimulates a need for good systems in order to facilitate efficient construction, hence, the larger project participants often push for process oriented innovations, despite being mostly focused on the delivery.

The environment in which a company operates, greatly affects their willingness and ability to explore and adopt new solutions. On large projects, it's not uncommon for actors to work with different tools, and have various levels of technological competence. Therefore, in order to collaborate effectively, the actors prefer to work with the same tools on projects, however, this is a well-know industry challenge. The consultants are a huge influence on projects, in terms of which digital tools to use, but ultimately it is the contractors and project owners who decides which collaboration tools are to be used in a DB. Nonetheless, adopting new tools are experienced as costly and time consuming, which will be discussed further on the organisational level. If a tool or innovation is successfully tested on one project, the process of transferring it to another project is not a large barrier. Word of mouth is a powerful force, and good technology is implemented swiftly if the users actually *like it*. In fact, many of the actors have a routine to test an innovation on a pilot project, to later apply the technology on the other projects. However, routinisation is a comprehensive process, which also will be elaborated in the organisational context.

All the cases underlines that innovation must be included in the project from commencement, in order to succeed. This is important for several reasons. Since every project is a temporary collaboration with many contributors from different organisations, building a strong culture to achieve the desired goals is a crucial part of a successful innovation project. If the innovation and the innovative goals are included from start, the different actors will have a more

decisive expectation of what the goals of the project are. Furthermore, having clear innovation goals to work towards from the beginning, makes the innovation process more streamlined, as uncertainty and indistinct objectives will disturb the process of developing good results. In case two, the innovation projects started after the construction phase had begun. The involved actors had to make a separate contract from the DB contract, with unclear goals. This resulted in a conflict which is still ongoing.

6.3 Organisational level

On the organisational level, it is more relevant to focus on process-oriented innovations, as opposed to delivery oriented on the industry level. A general finding is that after an innovation is tested on a project, the organisation will purchase it centrally, through a corporate agreement. The two key concerns for the organisation at this point is; (1) Interconnectivity, where the added innovation must either be exportable to or integrated with existing solutions, and (2) It is preferred to have floating licences, as to not create a barrier for more employees adopting the solution.

6.3.1 Strategic driver and barriers

Strategically, there are two drivers which were emphasised across the board, too be crucial for an innovation to be adopted. First, the innovation should align with the organisation's strategic goals, meaning that if there is a solution that responds directly to the management's business targets, it is pursued centrally. Subsequently, it should increase competitiveness, either creating a competitive advantage for the organisation, or keeping up with other industry actors. This entails pursuing solutions providing cost-savings, risk reduction, increased efficiency/productivity, or other strategic goals, such as sustainability.

Regulation is perhaps the most effective strategic driver, forcing actors to change their processes, consequently, creating a strong incentive to adopt helpful solutions at the same time. Hence, tools which delivers an output, or tracks a process, required by law, have demonstrated a high probability for successful innovation adoption, by many of the software providers. Examples of this were demonstrated in both case one and two, where the contractors weren't necessarily happy with the change in routine due to new regulation. However, they were forced to comply, and wanted the best tool available for the new process.

The largest organisational barrier for adoption, on the strategic level, is the cost of implementation. In addition to procurement costs, there usually has to be coursing of employees, and a support service (which as a result is preferred to be included). Additionally, there can also be significant costs related to the logistics and time spent on moving systems and developing new internal routines. In case four, the measurability of employee training success was argued to be a missing element, as there is no way to know how effective the training actually is, and thus, if it's worth its cost. However, these aren't the organisational barriers

which are emphasised in any of the cases, despite being a strategic concern. The reason for scepticism more often comes from the operational perspective, which then influences the strategic cautiousness and focus on implementation costs, as a failed adoption is a significant risk. In essence, if a solution aligns with an organisations strategic goals, there aren't many strategic barriers to prevent it, but as discussed in the next segment, there are still many barriers to consider.

6.3.2 Operational driver and barriers

Operationally, *usefulness* was a metric which was used to describe key drivers, in all four cases. This seemed to be a term relating to users' perceived value of a solution. This was also the most important factor for an innovation to be shared with colleagues and partner organisations through word of mouth. However, as this is a sort of catch-all term, there seems to be several additional drivers and absent barriers needed to gain this description within the industry.

There are three central barriers for innovation, appearing in all or most cases. These are largely connected, as different aspects of the same issue, namely the organisation's technology readiness. First, there is the internal *technical competence*, which states that employees do not necessarily have the skill and knowledge to pick up new innovations. This is outlined as an age related issue, where the younger generation is generally more prepared for change. As was pointed out in case one, pairing up new employees with technical competence, and employees with experience, is one way they can deal with their lack of skilled workers. This demonstrates the slow process of actually getting the organisations as a whole to the same level of technology readiness.

The second barrier, is employee *attitude* towards innovation and change. In all the cases, words like *conservative* and *sceptical* were used to describe employees. By some, this was even directly attributed to older age, connecting it to the aforementioned issue of technological competence. However, this scepticism could also be tied to the the employees fear of redundancy, considering automation of tasks.

The final operational barrier, could perhaps be considered a result of the first two, as mentioned above. This is the *complexity* of the innovation or rather the users extremely high bar for usability, across the board. The general attitude is that anyone must be able to use it, without issue, or it wont work. These barriers essentially limits technical innovations, for organisational processes, to a very incremental progress. The users want innovations to imitate their established processes, and there has to be required little to no learning curve. Hence, a demand for simplicity in solutions emerges. This seems like a logical consequence of low technology readiness, and the large ecosystems of actors and individuals that have to participate in the progress.

Early adopters, are pointed to as crucial for initiating an adoption process, within an organisation. These are pointed to as the drivers, both in influencing

procurement, but also, for bringing in new solutions for testing on projects. In relation to the strategic point of implementation costs, these early adopters are also pointed to as important operational drivers, as they can help train and organise the other employees in new systems and routines. They are also pointed to as important for motivating others within the organisation, and help change the sceptical attitudes.

One key finding, is that a corporate culture for *testing* new solutions is important for discovering innovations, and by extension, successfully adopting at a higher frequency. This should entail good systems and low barriers for running a pilot test, however, in many cases these test's initiation relies on the aforementioned champions and approval from management. For example, in case four the project owner had the ability to include an innovation in the tender, however, this was linked to the delivery, where a digital twin was a requirement. Process innovation by the contractor and consultants, usually has more rigid systems of central procurement in place. Several actors in these complex projects have taken steps to improve their corporations testing culture, through standardised initiatives for discovering innovation. This is done through departments tasked with exploring and initiating new solutions. If they can act autonomously in procurement, and facilitate pilot tests, this can help in lowering the barrier for trying out new solutions.

After a pilot test of a solution is completed successfully and the solutions is evaluated useful, the actual adoption and *routinisation* of the innovation can begin. However, it can prove difficult to take the lessons from a pilot and apply them to the organisation as a whole. Additionally, sharing the benefits of the innovation, to get employees on board is also pointed to as crucial. Case three addresses this, through defined operational systems and practises for routinisation of innovations, and sharing of experiences throughout the organisation.

7 Discussion

This thesis contributes to filling the knowledge gap on innovation drivers and barriers on large complex projects in the Norwegian construction industry. The project thesis concluded that there seems to be some structural problems with the industry for innovative activity to thrive. This study has further investigated how successful innovations emerge within the industry, with findings that both contradict and confirm literature on the matter.

In this section, results from the cross-case analysis will be discussed in light of the relevant theory. First, a review of the key findings related to drivers and barriers on the four large complex projects will be presented. Second, the thesis will highlight requisites and criteria for successful innovation adoption in the industry, based on the empirical results.

7.1 Drivers & barriers for innovation on complex projects

7.1.1 Industry level

Not surprisingly, and in line with the emprical studies of Bygballe & Ingemansso's and Blayse & Manley, the project owner is brought up as the initiator and responsible actor to push the industry in terms of innovation by all informants [7, 8]. Nonetheless, the industry as a whole appear as severely focused on the delivery of the project, and innovations related to it. To benefit from the study, the term innovation had to be divided into two categories, that is, delivery and process innovation. The alarming difference of focus on the two types of innovations needs to be addressed, as digitalisation of the slow processes within the construction is highlighted as one of the most contributing factors in order to transform the industry [3].

7.1.1.1 The project owner and government

In terms of delivery innovation, it is evident that the project owner sets the criteria for the project results. The entire industry acknowledge this finding. However, as the project owners goals and ambitions are highly influenced by government regulations and financial conditions, the government can implement several measures that would accelerate the industry's transmission towards productivity and sustainability. The problem is not to bring forward new innovative buildings, but to do so in such an efficient and profitable manner, that it is lucrative to more actors.

The competitive industry environment is at a level which mitigates innovation adoption, according to Zhu et al [42]. The competitiveness creates financial stress and risk aversion which leads to the project members' scepticism for adopting innovations. The bar must be lowered to test new technology, as the managers from different companies experience that innovation is too risky as it may affect the project's profitability. This study examines large and complex

construction projects, which usually is the early adopters in the industry, as the complexity requires innovation and the budgets account for it. However, the low innovation companies, that is, the late adopters, should take part in the digital transformation. Creating an increased demand for new innovations through regulations are suggested by several reports as an effective measure [21, 63]. A comment from one of Norway's largest project owners highlights that ambiguous regulations can makes it difficult to be innovative on certain areas, such as, reuse of building materials. The industry leaders are more than ready to create a circular economy for construction to be sustainable, but the laws on reuse are too strict to allow sustainable to be profitable. [86]

7.1.1.2 The Design Build contract

The way that the DB contract has evolved is a requisite for the project owner to initiate a large complex project, since the risk is partially transferred to the contractor. However, the major conflicts of interest which characterizes the entire industry reduces the potential that lies in new innovations, which also Pärttö & Saariluoma concludes with [9]. This can be solved by incentivising the actors to use new process technology through specific result requirements. On projects with high ambitions, a separate innovation contract is a proper solution to bring forward delivery innovation, if it is executed correctly. This study reveals that innovation contracts should be less function based, and more focused on the process of bringing forward innovations. This is in line with the results from Bygballe & Ingemansso's study. Innovation will increase with a more demanding project owner [7]. Implementing measures involving risk increases the likelihood of a conflict. By mitigating conflict levels, as this is both a costly and exhausting for the involved parts, the fear of adopting innovations is addressed. This is the project owner and the contractor's responsibility. The project owner must facilitate a tender process of high quality, incentivise for rapid clarifications and require better documentation of the entire project process. The contractor needs to declare uncertainties early and sustain a good collaboration with all involved actors. The conflict level works as a barrier for the industry to adapt OI principles. On the high innovation project of Case Two, every actor mentioned conflict as costly and unnecessary. This corresponds well with the barriers of delegating resources to find the correct partner, as stated by by Enkel, Gassmann & Chesbrough [49].

7.1.1.3 The Project environment

As a project is a temporary phenomena, there is a unique composition of companies working together on each project. The entire industry is project-based which, by the principle of Open Innovation, should stimulate to bring forward innovations [38]. The results from the analysis indicates that this is true, in relation to the project delivery. The actors collaborate broadly and deep for a short period of time to deliver the best result. This can be seen by the spectacular buildings that surround us. In terms of process, however, the situation

is quite different. The different companies develop their own internal tools for different tasks, which is a result of the competitiveness in the industry. As per today, these tools provide some level of competitive advantage to the firms, but in order to stimulate productivity growth throughout the industry, the companies would benefit from a more Open approach, as Chesbrough and several empirical studies suggests [7, 8, 87].

Applying Open Innovation principles may not be as simple as Chesbrough and the other innovation theorists suggest, specifically to the construction industry. The studies of Bygballe & Ingemansso's and Blayse & Manley imply the many studies which analyse the innovation activity in industries, utilize parameters which may not catch the entire industry situation as a whole [7, 8]. Many traditional frameworks for innovation focus on R&D, patents, and new products or services. However, in construction most innovation is connected to deliveries. Hence, it may cause implications to draw conclusions based solely on innovation literature, as the industry is more complex than the results from innovation literature suggests. Frameworks adapted to the immense competition, seen within construction, could probably serve a better analysis.

The temporary circumstances combined with the competitiveness which permeate the industry, creates not only conflicts of interest on projects. The projects become hasty and hurried, which creates limited room for innovations.[9] This combination creates tender processes that are more focused on the lowest price, rather than processes. This is drawn out as a problem by the project owners on Case One (public) and Two (private) as well, which state that the tender processes may not provide the best candidates for innovation. This underlines the aforementioned point of incentives for innovation in the tenders.

Tatum states that incremental innovation succeeds more often than radical [60, p.180-190]. This is unquestionably the case in industry, based on the informants statements. Moreover, as broad collaboration culture promotes more incremental innovations, the construction industry has a large potential to successfully innovate incrementally [67, 68]. As collaboration breadth involves diverse input from various collaboration partners with different perspectives, it stimulates creativity and exploration of new opportunities. Moreover, breadth increases the ability for an innovation to reach and establish in the market, as there is a network of partners who have collaborated in the development [66]. Nevertheless, the industry seem to be facing challenges with adopting even incremental solutions, due to the aforementioned web of interconnected solutions, high demands of usability etc. Although there are challenges in terms of technological integration and readiness, the different actors needs to be proactive, and abstain from simply blaming the project owner.

Due to the aforementioned collaboration breadth, the different actors seems to be good at exploring new opportunities, once the innovation is approved by someone in the industry. Concluded from Case two and Four, word of mouth in the industry is a important contributor to the diffusion of an innovation. After a tool is tested on a pilot project, the companies seem to have procedures

to transfer the tool to other projects. However, this procedure is demanding in relation to routinisation. Certain software providers acknowledge that the transfer to other projects is partially their responsibility. This has been experienced as resource-intensive by the author's own venture through Case Four as well.

7.1.1.4 Corona

The ongoing Corona pandemic also gave some interesting results. First, all informants had, not surprisingly, migrated to digital tools for planning, management, and meetings. However, this was generally pointed to as a positive experience relating to the tasks at hand, possibly increasing efficiency for some. Additionally, several actors made procurements as a direct result of the pandemic, both as a result of regulations, but also general innovations relating to the construction process. Furthermore, the software providers, who feared a decline in revenue, actually had more growth than expected. This further emphasise the impact this event had on the industry, pushing them to become slightly more digital. As the pandemic struck Norway, The Norwegian Prime Minister, Erna Solberg, spoke to leaders from the fifteen largest Norwegian corporations. All leaders where afraid that Norwegian companies would focus on their core business, and downgrade innovation focus as the pandemic would shake the international economy. The government introduced grants and funded projects, such as "Green Platform", to sustain innovation activity in the country. The Prime Minister argues that the government initiatives have produced very positive results [88]. This could have been a contributing factor to the growth experienced by the software providers.

7.1.2 Organisational level

7.1.2.1 Organisational structure

On the organisational level, the actors from the case studies all had a relationship with innovation, despite being somewhat vague; describing ambition, without concrete goals. According to Miller's theories on types of firms, this is a common problem for Planning companies, where vague strategies for innovation, leads to a focus primarily on the core business [85]. Thus, structural changes has to be made to achieve a greater degree of ambidexterity, and to incorporate the proper drivers into their operations.

The central barriers outlined in the cross-case analysis, i.e. technological competence, conservative attitudes, and fear of complexity, has lead to a an overly slow and sceptical environment within organisations. Consequently, organisations only apply what could be categorised as incremental innovations, based on Norman and Verganti's definition[43]. However, even these incremental innovations are met with the same barriers, to a much larger degree than organisations in other sectors, as illustrated by Rogers [51]. One contributing factor is how organisations within construction are struggling, due to their large apparatus.

This is consistent with Wernerfelt's arguments about the Resource-based view, where larger firms have the resources, but lack the prosper structure for innovation [75]. Additionally, the different levels of technology readiness between employees and projects, as described by Zhu et al. [42], combined with weak internal operational systems for innovation, are contributing factors, further demonstrating the need for change in organisational structure. However, as seen in these complex projects, some measures have been taken, which in time could improve the process of adoption. These measures will be discussed further in the next segment, Successful adoption.

7.1.2.2 Prerequisites for innovation

The aforementioned barriers were the variations in technological competence and attitudes towards innovation. This led to the requirements for extremely low complexity in innovations, and a very incremental progress. The issues of *complexity* is highlighted in by Rogers as an essential attribute for innovation adopters [53]. The organisations' worries of usability are consistent with this, as they depend on services everyone can use. While one part of the issue stems from the lack of technology readiness within the organisations, this should also be seen as a criteria by innovators, where their solutions should address these barriers.

It's understandable that employees are reluctant to change their established processes, as long as the discrepancies in technology readiness are present, and their focus remains exclusively on deliveries. Thus, to enable the organisations to be more effective in adopting incremental innovation, as well as having the possibility of successfully adopting radical innovations, these underlying issues has to be addressed. One barrier demonstrating progress in the industry, is their focus on *interconnectivity* in new systems, or as described in Rogers' findings, *Compatibility* [51, 53]. This is closely linked to a company's level of, what Zhu et al. describes as, *technology integration*, which has traditionally been low within the industry [42]. However, a core focus in all the cases were the possibility of integration of new systems, signaling progress.

7.1.2.3 Regulation

A major driver for innovation within the industry has been government regulation. New requirements which organisations must adhere to, gives them a very clear goal which has to be achieved, much in the same way tenders define delivery goals. Stricter requirements in the Norwegian industry, could accelerate progress, as argued in case three which pointed to the stricter British regulations, making innovation lucrative, as in Bygballe & Ingemansson's findings [7]. The corona-pandemic showed it in practise, such as in case one, with the personnel tracking software. Additionally, financial incentives such as subsidiaries and tax breaks has proved effective relating to deliveries, however, such measures could also be utilised relating to process innovation, pushing the organisations towards

their goals, without worrying about if the additional initial cost on projects, will make them less competitive before they manage to increase productivity. [63]

7.1.2.4 Champions

In the cross case analysis, perhaps the most emphasised driver for innovation were the organisations' lead users or *champions*. Whether in relation to helping train others, influencing attitudes or introducing new systems, these champions were pointed to as crucial drivers of innovation. While they clearly have played an important part, this large role in the organisations innovation ecosystem, could perhaps be linked to the otherwise weak operational systems for innovation. This is the issue the actors in the cases are trying to address with their other drivers, relating to better systems for testing and routinising innovation, which will be elaborated on in the next segment. [79]

7.2 Successful innovation adoption

7.2.1 Industry level

A key factor for successful innovation, both related to the delivery and process, is the early statement and implementation of relevant goals, tools and processes. If the case of a delivery oriented innovation, every project participant must cooperate to achieve particular goals, which is set by the project owner. These goal must be presented and facilitated from the commencement of the project. That being said, ambitious project owners certainly push the project, in relation to delivery innovation. This is highlighted in the previous segment.

Process oriented innovation should be viewed as just as important, as delivery innovation. Incremental innovations were discussed in the previous section, and to increase the likelihood of successful adoption, new innovations should be incremental due to interdependencies and the incremental culture that permeate the industry [7, 60]. The processes are not solely the project owners', nor the government's responsibility. In terms of bringing forward process oriented innovations which can streamline the workflow for the different actors, the actors themselves have a responsibility to participate in innovation activities, collaborate with partners and startups to stimulate a culture for developing new tools. This is a shared responsibility, although most informants claims that it is the project owners'. Although there is a broad collaboration culture on the projects in the industry, the different actors could benefit from investing resources in deeper collaborations, in parallel with the temporary projects. This should not be done to develop radical innovations, but rather increase the industry's ability to exploit all the opportunities which are present. [50]

In the case of a complex project with high ambitions in terms of innovation, creating a separate innovation contract from DB contract can benefit the processes. These innovation contracts must focus on incentivation of the different actors to contribute to the innovation to avoid conflict of interests. The conflicts

of interest have shown to be costly and devastating for innovation, and conflicts should be avoided to successfully adopt new solutions. Several informants involved in the conflict in Case Two suggested that the risk of the innovation project should be shared by all participants. Moreover, the the reward of a successful project should be distributed according to risks taken by the respective actors. Everyone must work towards the same goal, and the way to successfully achieve that is through proper incentivation.

7.2.2 Organisational level

Two central stages of innovation adoption, as described by Zhu et al., are initiation and routinisation [42]. In the context of these cases, i.e. complex projects, this usually entails initiation through testing an innovation on a project, and routinisation through central procurement and employee training. The initiation has been partially solved by a culture for testing within the companies and increasingly also internal departments working with initiating such projects. Historically, the largest hurdle has been getting the solution approved centrally, however, these departments helps to lower the bar for initiation. From the innovators perspective, this is a something which should be considered through what was defined as *trial-ability*, by Rogers [51, 53]. This entails creating solutions which are easy to test for the organisations.

When it comes to routinisation, it isn't as clearly defined as initiation within the organisations. Better routines for transferring knowledge and processes, from the tests, to the corporation, could improve routinisation significantly. The aforementioned departments cold perhaps play a role in this, standardising the process and training, decreasing the need for champions to lead opinions and pass on knowledge. Regarding employee training, the project owner in case four's request for measurability is also something which should be considered. This can be seen in relation to the *observability* which according to Rogers, states that if the results of an innovation are visible to others it has a positive effect [53]. Thus should be considered from the organisational perspective, where, the organisations can encourage communication between departments. However, due to the project centred nature of these organisations, this could prove difficult. Additionally, if training results, from the initiation, can be quantified, they can include this in operational goals, creating an actual incentive to increase their employees technology readiness through training goals. Creating a decentralised structure for knowledge sharing, and creating measurable incentives, could help make successful adoption both more effective and frequent, through observability. [42]

While the organisations interviewed in relation to this thesis are hiring young and technical employees, a large part of their workforce lacks the skills necessary for utilising new digital solutions. This entails a renewal rate dependent on age and retirement, which slows the process of companies increasing their technology readiness dramatically. Additionally, most of the processes and tools used are created internally by experts, to help with competitiveness. These are two key

elements of closed innovation, as described by Chesbrough [48, p. xxii]. Both improved knowledge sharing between employees, such as in *organic companies*, and possibly also between organisations, such as in open innovation, could be necessary to improve this slow rate of progress. [85]

While there are a lot of structural changes to be made within the organisations, one should also consider the drivers and barriers from an innovators perspective. The central finding of a demand for low *complexity*, within the organisations is, according Rogers [51], the only adopter's attribute which will impact the innovation negatively. It describes the degree to which the innovation is perceived as challenging to understand, and if this isn't addressed by the innovators, the solution will fail. Thus, this should be a careful consideration for innovators, creating solutions aimed at the construction industry. To create solutions that the organisations are comfortable with, a user-centred approach should be adopted, as outlined by von Hippel, in order to address the employees' concerns and limited technological readiness [81]. [42, 53]

8 Conclusion & Implications

8.1 Conclusion

This thesis has aimed to examine existing drivers and barriers for successful innovation adoption, within the construction industry. The research is based on empirical data, combined with entrepreneurship and innovation theory. When appropriate, the authors have supplemented with experience from their own venture or other perspectives. Four construction projects have been investigated, divided into 17 in-depth interviews. A triangulation has been carried out with a 360-degree perspective from different actors, on each individual case. Initially, two research questions were posed regarding innovation adoption drivers and barriers in the construction industry. The following conclusion is structured based on the research questions.

- *What drivers and barriers for innovation adoption exist in complex construction projects?*

The study reveals drivers and barriers for innovation adoption on the industrial and organisational level, and the complex interdependencies between them. The industrial aspect largely affects the organisational circumstances and vice versa. The influence governmental regulations, and the project owner's ambitions, have on innovation performance in the industry is immense, as a clear result extracted from both the literature and the empirical studies. During the study, however, it became clear that there are distinct differences between delivery and process oriented innovation within construction. While the industry produces strong deliveries with innovative content, innovation related to processes are lagging behind both on the organisational and the industry level. This is partially due to the strong focus on projects, within the industry, where nearly everything is tied to a specific delivery.

The more ambitious the project owner is, the more innovative the project's delivery will be. While, this does not necessarily correlate with process innovation, it may sometimes encourage new processes through the strict frameworks. To fully understand the drivers and barriers of a project's tender, the market and regulatory conditions must be addressed. Both public and private project owners are heavily influenced by market trends, regulations and industry strategies. The government can stimulate the market in such a way that the project owner is incentivised, or even required by law, to implement sustainable, digital or process related measures. Additionally, financial incentives are detrimental, in determining ambition.

A culture for pilot testing has a positive impact on innovation adoption, and this is something the industry does regularly. However, the routinisation of innovations, after a test, is resource intensive in terms of training, knowledge transfer, and developing new processes, thus, creating a barrier through cost of implementation. Even though some construction companies have procedures to communicate between projects, better routines are required for routinisation in

order to accelerate innovation. The intense competitive situation, within the industry, has led to low technology readiness, sceptical attitudes, and slow internal structures in the larger firms, where even incremental innovations face challenges in terms of industry adoption. However, focusing on incremental solutions is likely to benefit the progress of industry innovation, as this will require these issues to be addressed. Currently, these issues results in the immense caution in terms of *complexity*, which then becomes a central barrier. Additionally, the requirements for compatibility with established systems and processes, is also an eminent barrier.

The internal drivers for innovation adoption, related to processes, are primarily competitive factors. From the operational standpoint, this includes factors like increased productivity, cost reduction, and risk management. However, from a strategic standpoint, innovations relating to organisational ambitions, such as sustainability, image and other strategic goals, are also added. Additionally, the internal champions or lead users, are a crucial driver for successful adoption.

- *How can complex construction projects successfully adopt new technological innovations?*

When the results from the cross-case analysis is interpreted, the need for a solid contract presents itself. Having a contract which incentivates all parts will lead to a collaboration in which all project members work towards a common goal. If not, conflicts of interest arise which heavily mitigates the innovation potential. Poor contracts nurture the conflict-based culture in the business, hindering a more open and collaborating approach, that the industry desperately needs.

Involving lead users in the development is an important factor. As technological competence varies to a great extent throughout the project and within the organisation, having a champion which sees the potential and can assist in the adoption process with training and user testing significantly increases the chance of success. Moreover, as the champions provide valuable insight on user needs and usability, they can help the innovation to reduce its complexity, which should be a key concern for the innovator. Additionally, a user-centred approach to designing innovation for the industry, is crucial to address the demand for usability. This could also help to ensure the industry's wish for *usefulness*.

Organisations should focus on creating a culture for testing new solutions, through flexible systems, without central and rigid procurement processes. Additionally, there should be a greater focus observing measurable innovation results, as well as knowledge and process transfer, to better spread new solutions between projects. This also entails a more organic corporate structure, with cross-project communication, and structures enabling work related to process innovation. From the innovators perspective, this entails a focus on trial-able and observable solutions, which makes it easier for organisations to evaluate them. Additionally, the industry's demand for compatibility has to be addressed, through solutions which communicate, or are formatted, as existing solutions.

Starting early with innovation on projects is a key factor for a positive result. If innovation is involved after commencement, the project members will have to alter their routines for the innovation activity, which will be met with resistance, negotiations and unnecessary delays.

Although construction has historically proven to struggle in bringing forward new innovations, there is a huge potential to transform the industry. The actors appear to have the motivation, and the willingness to renew and change behaviour is increasing due to the escalating urgency to become sustainable in light of climate change. The industry culture is permeated with collaboration, which lay a solid foundation for innovation. With relatively small alterations and tangible measures, the industry has all the prerequisites to succeed with the necessary transformation it faces the upcoming years.

8.2 Implications

This thesis has aimed to broaden our understanding of the state of innovation, within the Norwegian construction industry. We hope that the findings can contribute to unfolding the barriers that continuously discourage innovation, as well as the underlying drivers which progresses the industry. Based on these insights, we hope to assist decision-makers and leaders to begin exploring which opportunities actually lay beneath these barriers, to start building tomorrow's sustainable and competitive construction industry. In this segment, we present various suggestions that could contribute to accelerate the industry transformation, or at least, which should be further evaluated. Our suggestions substantiate the propositions in the digital road-map prepared by BNL, to a great extent [24].

8.2.1 Suggestions to the policy makers

As mentioned, the competitive industry environment creates financial stress and risk aversion which leads to scepticism for adopting innovations. There are several measures that can be implemented by policy makers, which are listed below.

1. Subsidize innovative projects, both related to delivery innovation and process innovation. The government can create an arrangement where potential financial costs of failed testing of new process innovations will be covered or subsidised by the state. This way, the bar would be lowered for testing new technology, as the project's profitability would be unaffected, unless it has a positive effect.

2. Create stricter regulations, related to the processes and deliveries in a construction project. The government can set stricter criteria, to promote innovation, e.g. digital documentation of the project's emissions. This will lead to both raised awareness on important issues and new digital tools. This example has already been implemented and proved effective,

however, the government could expand strategy this to other parts of the industry.

3. Adjust the ambiguous regulations which makes it difficult to be innovative on certain areas, such as, denying reuse of building materials. In some cases, regulations acts as a brake for innovations, especially in terms of sustainability and reuse of materials.

The policy makers should also reflect on the situation in which the industry actors operate. To accelerate the productivity growth and ultimately sustainability , the government has to contribute with regulations that stimulates innovation. Furthermore, grants and financial incentives which promotes innovation and digital solutions must be implemented to catalyse the change which is needed. The governmental activities during the pandemic have proven that governmental grants and funded projects provide results, hence, these measures should be adopted to the construction industry.

8.2.2 Suggestions to the industry actors

The study suggest that project owners should consider their great responsibility and opportunity to push the industry in terms of innovation. Project owners can prepare tenders to incentivise collaboration and interaction between the project members, rather than price competition. Furthermore, in projects with high ambitions, stricter requirements to the project participants have proven to stimulate better delivery innovations, so this should be a prerequisite for these projects.

Although there was a consensus that a lot of the responsibility for innovation lies with the project owners, especially regarding deliveries, we encourage contractors, consultants and other industry actors to partake in the industry transformation. Some suggestions to specific measures follows.

1. All companies should develop an organisational structure designed to explore, initiate and routinize new innovations. One way is to create more organic organisations, with flatter structures and communication and knowledge sharing between projects. Alternatively, creating a small innovation department or a joint venture with strategic partners.

2. The companies should find strategic partners to develop solutions which benefit the entire industry, rather than spending resources on creating internal tools. We have experienced through our own venture how rewarding it could be to collaborate with large industry actors, and the result was a tool which out-performs our partners' internal solutions. This demonstrates the positive synergies which could be achieved through such ventures.

3. Join innovation Clusters, such as Construction City. This is an arena to contribute with knowledge and other resources to help the entire industry.

Clusters requires small amount of resources from the individual firms, but heavily stimulates an innovative culture.

4. There should be a focus on measuring the impact of technology training and new processes, while testing novel solutions, to enable better decision-making for innovation adoption. Furthermore, there should be structures in place, such as the aforementioned departments, to facilitate the sharing and routinisation of new these new processes.

8.2.3 Suggestions for innovators

Innovators has to approach the industry with all the preconditions for innovation in mind. This entails addressing the industry's concerns while developing new solutions, especially considering the rigid processes and incremental nature that is present. This can be pursued through the following measures.

1. The innovator has to create solutions which adhere to the industry's demand for low complexity, through a user centred design approach. This entails a focus on improving the established processes in the industry, through solutions everyone manages to use, due to the . This also addresses the concern of low technology readiness to some degree.
2. The compatibility of new solutions has to be considered. The industry has low acceptance for tools that does not integrate, or at least communicate, with preexisting solutions.
3. There should be a focus on creating solutions which can be easily tested in pilot projects, in addition to giving measurable results which can make the solutions' potential and procurement cost evident.
4. Providing proper support, training and gaining customer trust is essential.
5. Including champions from the start, preferably through developing a network in the industry which provides multiple perspectives on the solution. This will also provide insights on the customer's future needs.
6. Additionally, some innovators who focus on legislative solutions, could benefit from staying ahead of new or future legislation, to create solutions for coming industry demands. This could also entail playing a part in new legislation through suggestions or advising the policy makers.

8.2.4 Theoretical implications and further research

This thesis has provided research on a particular domain which is relatively unexplored. In a time where the industry is persistently blamed for low productivity, there is a desperate need for research on how to improve innovation performance in the conservative and analogue sector, i.e. the Norwegian construction industry.

Combining the results from the empirical study with innovation literature has provided unique insights on the industry's drivers and barriers. Although there exists many traditional frameworks for innovation, it may cause implications to draw conclusions based solely on innovation literature, as the industry is more complex than the results from innovation literature suggests. This may be due to the traditional frameworks valuing R&D, patents and new products and services, in more open industries. Frameworks adapted to the immense competitive environment, seen within construction, or to look at innovation in projects or deliveries, could probably benefit future analysis. In terms of further research, we hope that this thesis could provide a step into the research domain, and encourage adaption of existing innovation frameworks to suit the conditions within the construction industry.

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9 Appendices

Appendix A - Intervjuguide 1

Intervjuguide for Byggherre, Entreprenør og Konsulent

Rammer for intervjuet

Intervjuform: Semi-structured
Estimert tid: 40-50 min

Introduksjon til intervjuet

Vi er tre studenter fra NTNUs Entreprenørskole. Vi jobber også i en startup ved navn Kvist, som utvikler programvare til byggebransjen. Med denne masteroppgaven ønsker vi å se nærmere på suksesskriterier for adopsjon av innovasjon, i byggebransjen. Det vil si, hva som må til for at ny programvare og lignende skal bli tatt i bruk i arbeidshverdagen til byggeprosjekt. Med dette ønsker vi å bidra til mer innovasjon og økt produktivitet i bransjen. Vi kommer til å gjøre opptak av intervjuet, med all personlig data vil bli anonymisert. Det eneste som vil gjengis i oppgaven er stillingstittel og størrelsesorden på prosjekt og selskap. Vi ønsker å basere intervjuet på "Prosjektet", så gjerne trekk paralleller der det er relevant og hvis ikke så kan du svare generelt basert på erfaring.

Intervjuspørsmål

1. Introduksjon

- Navn, alder, utdanning
- Hvilken stilling har du per dags dato? Andre relevante stillinger? Hvor lenge har du hatt denne stillingen?

2. Bedriften

- Kjernevirksomhet og hovedfokusområder
- Antall prosjekter årlig

3. Prosjektet - Bruk dette som utgangspunkt for resten av intervjuet.

- Prosjektnavn
- Kan du gi en kort intro til prosjektet? (Kontraktssum, entrepriseform, årstall, varighet)
- Hva var det som var spesielt bra? (Noen spesielle tiltak/løsninger dere gjorde/brukte?)
- Kan du trekke frem noe med prosjektet som ikke har gått som planlagt? (Hvorfor gikk det ikke etter planen? Hvordan kunne det vært unngått?)

- Hvor lønnsomt var dette prosjektet for dere?

4. Anbud

- I anbudsprosessen for prosjektet, legges det ned krav for bruk av programvare, tjenester eller annen innovasjon? (I så fall, hvilke? Hvordan stilles kravet?)
- Var det et mål å gjøre de involverte mer effektive gjennom anbudet?(Hvordan blir det tatt høyde for?)

5. Investering

- Hvem sitt ansvar er det at bransjen skal nå sine mål?
- Føler dere et ekstra ansvar for å drive innovasjon? (Evt hvilke deler av ansvaret for å drive innovasjon hviler hos dere?)
- Kunne dere investert/investerer dere i teknologi, med mål om å gjøre entreprenørene mer effektive / lønnsomme? (Hvis ja, hva skal til for at dere velger å gjøre dette?)
- Hvilke faktorer/insentiv vil være avgjørende (og legge til rette) for at dere skulle investert/tatt i bruk en programvare? (Kostnad, betalingsmodell, tid, produktivitet, risiko, eksklusisivet, subsidier)

6. Innkjøp og implementering

- På hvilket organisasjonsnivå foregår innkjøp av digitale produkter/tjenester? (Hvordan påvirker entrepriseformen implementeringen av disse?)
- Hvordan foregår slike innkjøp hos dere? (Hvem er beslutningstaker? Hvordan går dere frem? Hvem er initiativtaker ved innføringen av nye digitale verktøy? Er det noen problemer med dagens modell?)
- Kunne dere kjøpt inn tjenester på vegne av andre aktører?
- Hva vil du si er de største utfordringene som har oppstått ved innføring av nye digitale løsninger? (Implementeringskostnad, opplæring, holdninger?)
- Hvordan type avtaler har dere med leverandører av teknologi? (Per prosjekt/per bruker, konsernavtale? Hva foretrekker dere? Hva betaler byggherre for og hva betaler entreprenør/rådgivere?)
- Hva er hovedgrunnen til at dere tar/ikke tar i bruk ny teknologi? (Hvilke effekter ser dere?)

7. Samarbeid og holdninger

- Hvordan opprettholder bedriften konkurransedyktighet? (Har dere noe forhold til det?
- Hvordan stiller dere dere til samarbeid med nye, mindre aktører?

- Har dere noen samarbeidsprosjekter (innovasjonsprosjekter) med andre selskaper om utvikling av nye løsninger? (Hvis ja, hvilken type? Hvor ofte blir dere kontaktet av eksterne selskaper som ønsker å samarbeide om et utviklingsprosjekt?)
- Hvordan er holdningene til innføring/utvikling av nye digitale løsninger? (Er det forskjell på holdningene i de ulike organisatoriske nivåene? Forskjell fra prosjekt til prosjekt?)
- Har dere fokus på innovasjon i bedriften eller på prosjekter? (Konkrete tiltak/krav? Format/hvordan?)
- Hva er driverne for innovasjon?
- Har du noen eksempler på innovasjon i prosjektet?
- Er noe av innovasjonen siktet mot deler av bransjen, dere outsourcer?
- Hva er deres forhold til klyngesamarbeid i bransjen for innovasjon? (som f.eks. Construction City)

8. Oppsummering

- Hva vil du si er de største barrierene for å investere i nye softwareløsninger?
- Hvilke råd ville du gitt til et softwareselskap når de skal selge inn nye digitale løsninger?
- Hvilke digitale løsninger savner du? Hvor er det størst behov for digitalisering?
- Hvordan har corona påvirket noe av det vi har tatt opp?
- Er det noe annet du vil legge til?
- Kan jeg kontakte deg for noen oppfølgingsspørsmål om nødvendig?

Appendix B - Intervjuguide 2

Intervjuguide Software leverandør

Rammer for intervjuet

Intervjuform: Semi-structured
Estimert tid: 40-50 min

Introduksjon til intervjuet

Vi er tre studenter fra NTNUs Entreprenørskole. Vi jobber også i en startup ved navn Kvist, som utvikler programvare til byggebransjen. Med denne masteroppgaven ønsker vi å se nærmere på suksesskriterier for adopsjon av innovasjon, i byggebransjen. Det vil si, hva som må til for at ny programvare og lignende skal bli tatt i bruk i arbeidshverdagen til byggeprosjekt. Med dette ønsker vi å bidra til mer innovasjon og økt produktivitet i bransjen. Vi kommer til å gjøre opptak av intervjuet, med all personlig data vil bli anonymisert. Det eneste som vil gjengis i oppgaven er stillingstittel og størrelsesorden på prosjekt og selskap. Vi ønsker å basere intervjuet på "Prosjektet", så gjerne trekk paralleller der det er relevant og hvis ikke så kan du svare generelt basert på erfaring.

Intervjuspørsmål

1. Introduksjon

- Navn, alder, utdanning
- Hvilken stilling har du per dags dato? Andre relevante stillinger? Hvor lenge har du hatt denne stillingen?

2. Bedriften

- Kjernevirksomhet og hovedfokusområder (Produkter/tjenester? Lager dere hyllevarer eller custom software til ulike kunder?)
- Status? Lønnsomhet?
- Inntjeningsmodell/prising (Produkt, support, annet?)

3. Investering og finansiering

- Hvordan gikk/går dere frem for å hente investeringer til deres innovasjon? (og nye produkter)
- Hvem investerte i prosjektet i tidlig fase?
- Hva var responsen fra bransjen i tidlig fase?
- Hvilke faktorer opplever du som avgjørende for å lykkes? (Kostnadsbesparelse, kreativitet, tidsbesparelse, risikominimering, andre?)

4. Salg og implementering

- Hvilke bedrifter er deres kunder? (Sekundærkunder)
- På hvilket organisasjonsnivå foregår innkjøp av deres produkter/tjenester? (Hvordan påvirker entrepriseformen implementeringen av disse?)
- Hvordan foregår slike innkjøp av deres tjenester? (Hvem er beslutningstaker? Hvordan går dere frem? Hvem er initiativtaker ved innføringen av nye digitale verktøy?)
- Hvordan type avtaler har dere med kunder? (Per bruker/per prosjekt? Konsernavtale? Hva foretrekker dere?
- Hvordan forhandler dere med kunder? (Hvor ofte?)
- Hvor mye tjener dere på en kunder per år?
- Hva vil du si er de største utfordringene som har oppstått ved innsalg?
- Hva er hovedårsaken til at prosessen gikk bra/dårlig? (Hva kunne vært gjort bedre/annerledes?)

5. Samarbeid og holdninger

- Hvordan opprettholder bedriften konkurransedyktighet? (Har dere noe forhold til det?)
- Hvordan skaper dere kredibilitet i møte med store aktører? (Samarbeider dere med andre selskaper for utvikling av nye produkter?)
- Har deres kunder fokus på innovasjon? (Har du noen eksempler på dette som har vært positivt/negativt for dere?)

6. Oppsummering

- Hva vil du si er de største barrierene for å selge i nye løsninger til bransjen?
- Hvilke råd ville du gitt til et softwareselskap når de skal selge inn nye digitale løsninger?
- Hvordan har corona påvirket noe av det vi har tatt opp?
- Er det noe annet du vil legge til?
- Kan jeg kontakte deg for noen oppfølgingsspørsmål om nødvendig?