Construction 4.0 in Ostrobothnia

Exploring the Stage of Digitization in Construction, Real Estate, and Public Organizations

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Abstract

This Master's thesis examines the concept known as Construction 4.0. The concept is adding value to the construction industry by offering digitalized technologies and adoption of the Lean mindset. As a way to prosper and develop operations from a project managerial perspective, the thesis is designed to investigate and evaluate the stage of digitization among a range of organizations in the region of Ostrobothnia in Finland.

The theoretical framework includes research regarding relevant principles, implementation of the concept, project characteristics, and key considerations. The empirical part of this thesis will be based on survey methodology committed as an online questionnaire. The questionnaire consisted of 14 questions with the aim to establish to what extent digitalized technologies and Lean thinking is adopted within construction, real estate, and public organizations in Ostrobothnia. The assorted actors are chosen in association with the author's current employer which is a company that offers project management services and operates in the construction industry with clients from both the public and the private sectors.

Results from the conducted questionnaire showed that Ostrobothnia is at the first steps of digitization. The general knowledge is existing but far from adequate in order to achieve requisite progress. To increase the application of digitized solutions, an increased insight is needed into the expected benefits of the technology. Lean thinking is existing to some level and results showed that some of the Lean principles were met in ignorance.

For further research I would consider a wider range of participants and also include the economical restraints as a factor. There are possibilities to gain competitiveness and reduced costs, but the introduction of these processes comes with high expenses for software as well as for training and support.

Language: English | Key words: BIM, Construction 4.0, Lean, Real Estate

EXAMENSARBETE

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Abstrakt

Detta arbete studerar konceptet Bygg 4.0 som genom att erbjuda digitaliserad teknik och implementeringen av ett Lean-tankesätt ger mervärde till byggbranschen. Som ett sätt att främja och utveckla verksamheten ur ett projektledningsperspektiv är avhandlingen utformad för att undersöka och utvärdera digitaliseringsnivån bland en rad organisationer i regionen Österbotten, i Finland.

Den teoretiska referensramen omfattar forskning om relevanta principer, implementering av konceptet, projektegenskaper och viktiga överväganden. Den empiriska delen av denna avhandling baserar sig på en enkätmetodik i form av ett online-frågeformulär. Frågeformuläret består av 14 frågor med syfte att fastställa i vilken utsträckning digitaliserad teknik och Lean-tankesättet är implementerat inom bygg-, fastighets- och offentliga organisationer i Österbotten. De olika aktörerna väljs i samarbete med författarens nuvarande arbetsgivare som är ett företag som erbjuder projektledningstjänster och verkar inom byggbranschen med kunder från både den offentliga och den privata sektorn.

Resultaten från den genomförda enkäten visade att Österbotten är i början av den digitala transformationen. Den allmänna kunskapen finns men är långt ifrån tillräcklig för att uppnå nödvändiga framsteg. För att öka tillämpningen av digitaliserade lösningar behövs en ökad insikt om de förväntade fördelarna med tekniken. Lean-tankesättet används till en viss grad och resultaten visade även att vissa av principerna inom Lean tillämpas i ovetskap.

För framtida forskning skulle jag överväga ett större antal deltagare och även inkludera de ekonomiska förutsättningarna som en faktor. Det finns möjligheter till ökad konkurrenskraft och reducerade kostnader, men införandet av dessa processer medför höga kostnader för programvara samt för utbildning och support.

Språk: engelska Nyckelord: BIM, bygg 4.0, fastigheter, Lean

OPINNÄYTETYÖ

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Tiivistelmä

Tässä opinnäytetyössä tutkitaan Rakentaminen4.0-konseptia. Tämä konsepti tuo lisäarvoa rakennusalan toimijoille tarjoamalla digitaalisia ratkaisuja sekä Lean-ajattelutavan mukaista toteuttamista. Opinnäytetyön tarkoituksena on tutkia, missä määrin rakennusalan eri organisaatiot ovat omaksuneet digitalisoidut toimintatavat Pohjanmaan alueella. Tavoitteena on analysoida miten rakennusalan toimintaa voisi edistää ja kehittää digitalisoidun projektinhallinnan näkökulmasta.

Teoreettinen kehys koostuu tutkimukseen liittyvistä periaatteista; Rakentaminen4.0-konseptin toteuttaminen sekä projektinhallinnan keskeiset ominaispiirteet ja näkökulmat. Opinnäytetyön empiirinen osa perustuu kyselymenetelmään. Kyselylomakkeessa on 14 kysymystä, joiden tarkoituksena on selvittää missä määrin digitalisoituja ratkaisuja ja Lean-ajattelua käytetään Pohjanmaan rakennus- ja kiinteistöaloissa. Osallistujat valittiin yhdessä tekijän työnantajan kanssa, joka on rakennusalan projektinhallintapalveluja tarjoava yritys.

Tutkimuksen tulokset kertovat että Pohjanmaan rakennusalan organisaatiot on vielä digitalisaation ensimmäisessä vaiheessa. Yleistä tietoa on, mutta edistyminen kaipaa vielä huomattavaa ponnistusta. Jotta toimijat ottaisivat digitaaliset ratkaisut laajempaan käyttöön, he tarvitsevat lisää tietoa millaisia hyötyjä nämä ratkaisut pystyvät tuomaan. Lean-ajattelu on toisaalta jo osittain olemassa. Tulokset osoittavat että jotkut organisaatiot ovat – jopa siitä tietämättöminä – omaksuneet Lean-periaatteiden mukaiset käytäntötavat.

Lopputulokset perustuvat rajoitettuun otantaan. Lisätutkimusta varten harkitsisin siis ensisijaisesti laajempaa osallistujakantaa. Lisätutkimukseen voisi sisällyttää myös taloudelliset näkökulmat. Rakentaminen4.0-konsepti lisää epäilemättä sekä kilpailukykyä että tehokkuutta. Konseptin toteuttaminen vaatii kuitenkin laajat investoinnit tarvittavaan ohjelmistoon, koulutukseen sekä tuki- ja seurantajärjestelmiin.

Kieli: englanti Avainsanat: BIM, kiinteistöt, Lean, rakentaminen 4.0

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1 Introduction

This Master’s thesis examines the concept known as Construction 4.0 which is adding value to the construction industry by offering digitalized technologies and adoption of the Lean mindset. As a way to prosper and develop operations from a project managerial perspective, the thesis is designed to investigate and evaluate the stage of digitization among a range of organizations in the region of Ostrobothnia in Finland. The assorted actors are chosen in association with the author’s current employer which is a company that offers project management services and operates in the construction industry with clients from both the public and the private sectors.

The development of the fourth industrial revolution, or Industry 4.0, is changing many industries at a high pace and Construction 4.0 is all about adopting those processes onto construction working and management (Munoz-La Rivera, Mora-Serrano, Valero, & Oñate, 2021). Osunsanmi, Aigbavboa, Oke, & Liphadzi (2020) describes Construction 4.0 as a management technique based on innovative construction pushed by the technologies that Industry 4.0 has to offer and that introduces a foundation for smart construction sites. Although the construction industry was at the forefront when the use of information and communication technologies started back in the 1970s with structural analysis programs, the construction industry still has a lot of catching up to do when it comes to Industry 4.0 and the innovations that it entails. The lack of research and development and the fact that construction is one of the oldest industries might have some impact on its rigid culture that is somewhat resistant to quick changes. (Klinc & Turk 2019)

A designer’s work has seen some drastic changes over the decades, from using sheets of papyrus, ink, and a simple abacus to in the mid-20th century embracing Computer-Aided Design systems and calculation tools. Just as in the automotive industry with increasing optimizations, and the aviation industry with demands on lighter more streamlined aircraft to decrease fuel consumption for longer flights, the construction industry needs to embrace the use of accurate technology to keep up with customer and society demands. Fast-rising at the forefront is a methodology called BIM (Building Information Modeling) which is a design tool for 3D computer graphics (Czmoch & Pękala 2014). Its roots go back to the late

1970s and it has gradually reformed the Architecture, Engineering, and Construction (AEC) sectors worldwide (Charef, Alaka & Emmitt 2018).

1.1 Background

The construction industry contributes significantly to a country's GDP and serves as a major workforce as well as providing infrastructural development, this could be called the powerhouse of a country (Osunsanmi, Aigbavboa, Oke, Liphadzi 2020). The construction industry in Finland in the year 2017 gained € 35 billion of the GDP, which equals about 17.2 percent of the total GDP. In a matter of productivity and profitability, it is the smaller companies with less than 50 employees that show the best profitability figures while large companies have higher productivity output. Noteworthy is also that the small companies employ three out of five in the industry. The construction industry in Finland employs about 260 000 people, which covers nearly 18 percent of the total employment rate in the corporate sector. As for 2018 construction companies generated over 17 percent of the total added value that all companies operative in Finland generated, that is just over EUR 14 billion from construction companies alone. For the national economy, the importance of the construction industry has increased during the 2000s. (Finnish Government 2021)

Between the years 2000 and 2017, the productivity in the entire Finnish construction sector only increased by 3.5 percent. The real labor costs have outgrown labor productivity in the 21st century. Numbers from the last decade shows that the productivity growth in large companies has been better than in the small companies (Ahonen, Ali-Yrkkö, Avela, Junnonen, Kulvik, Kuusi, Mäkäräinen, & Puhto 2020). In the year 2019 SMEs in Finland accounted for an added value of EUR 118 billion in terms of productivity, which is an increase of 3 % from the year 2018. In Ostrobothnia corresponding statistics showed a total added value of EUR 3.6 billion of which 8.6 % were represented by construction companies, 2018 showed matching figures. Although, the gross value for construction companies in Ostrobothnia increased by nearly 14 % from 2018 to 2019. (Official Statistics of Finland, 2021)

Cost competitiveness can be seen as - who can deliver the desired product or service to the lowest price. The potential for innovation focuses mostly on production methods and since the prices for building materials are generally the same for all buyers the improvement of labor productivity remains a main competitive tool for a construction company. (Ahonen et al. 2020)

Ahonen et. al (2020) carried out an interview with 26 participants at top management from different sectors of the construction industry. Although, a few interviewees recalled that the construction industry today is far from what it was 20-30 years ago, the majority pointed out that a weak productivity development is one of the key problems in construction. Improvement of quality and productivity put requirements on clients and stakeholders. In the interviews, clients and especially clients in the public sector received a lot of criticism about their procurement expertise. Poor procurement skills and management of the construction process lead to challenges in the execution of a construction project, which is negatively reflected in the productivity and quality of construction. Munoz-La Rivera et al. (2021) emphasize the characteristics related to low productivity that the construction industry has been associated with. The indicators correlate with time, cost, and quality of projects and in particular cost overruns. These indicators have their origin in a disintegrated supply chain with various participants where none have the same vision of a common project as the other.

Digital technologies are evolving at a rapid pace at the moment. Numerous different technologies are being developed around the world that can be exploited in the construction industry. These include drones, robotics, augmented reality, machine learning, wearable technology, and blockchain technology. Utilizing these in construction may enable the emergence of new disruptive innovations in the construction industry as well. (Ahonen et al. 2020)

1.2 Problem Formulation

The problems presented by Munoz-La Rivera et al. (2021) of the construction industry focusing on interaction dynamics are describing and well affiliated with the purpose of this thesis. The development in focus has been on traditional disciplines such as the study of materials and with a little weight on information and communication technologies. The Architecture, Engineering, Construction, and Operation (AECO) industry has for some time been incorporating project management technologies to increase productivity and improve efficiency. The concept of Lean Construction is worth noting in this case, with its principles promoting continuous improvement for construction companies, reduction of waste, and an increased value of the final product by furnishing clear guidelines and management systems.

Interference of and resistance to the implementation of Building Information Modeling (BIM) and Lean Construction can arise due to lack of engagement or knowledge from project participants and poor involvement of stakeholders. Another indicator that commits interference is a fragmented implementation of the methodologies, for example, if BIM is used only for design and not for production and Lean is only implemented in one single project phase. (Dave et al. 2013)

Building Information Modeling goes further than just 3D modeling and is today extend as far as to the 8th dimension (Kamardeen 2010). Charef et al. (2018) express a need to sort out the level of uncertainty among users and the knowledge of what the 4th dimension and above really refers to. They committed a questionnaire limited to the European Union with the aim to assess the level of clarity or confusion, combined with a systematic review of journal articles of the area. Koutamanis (2020) debates whether BIM can go beyond 3D and explains the differences between the primary and derivative data that symbols in BIM contain. The results of these will be discussed later on in this thesis.

In a systematic literature review of Lean Construction and BIM in small and medium-sized enterprises in construction, it was found that the current literature of LC and BIM is rather inadequate regarding both the number of publications and content of publications. The review presented a compilation of the number of publications per country of origin over the period 2003 – 2018. The review comprised 25 countries, Finland came in among the last with only one single publication as our neighbors in Sweden placed second with a total of 10 publications, the United Kingdom topped the list with their 39 publications regarding the subject Lean Construction and/or BIM in small and mid-sized enterprises. (Tezel, Taggart, Koskela, Tzortzopoulos, Hanahoe, and Kelly, 2020)

Implementation and utilization of BIM, particularly in relation to small companies, meet barriers related to the cost of software and training. User-related problems are often incapacity or unwillingness to adopt BIM, closely connected to lack of knowledge in the subject (Koutamanis 2020). BIM implementation comes with a set of challenging expectations that are not always fulfilled. These challenges often relate to the uneven competencies in BIM, cultural resistance, and lack of client demand (Vass & Gustavsson 2017). The degree of BIM implementation is accompanied by the size of the company; smaller firms tend to see BIM barely as 3D modeling while in larger firms it is appreciated as a tool for project management. Thus, the serious gains are likely incorporated by larger companies (Ghaffarianhoseini, Tookey, Ghaffarianhoseini, Naismith, Azhar, Efimova, & Raahemifar 2017). An article about the problems that arise in a construction project with a wide-range use of BIM by Kerosuo, Miettinen, Paavola, Mäki, & Korpela (2015), encapsulates the main challenges between different actors in the supply chain from a BIM point of view. From 25 conducted interviews and participation in various construction project meetings, the authors could establish that - to many end-users, the practice of BIM is primarily for building presentation. Between different design actors integration of the model was an issue and also that BIM often is implemented without convenient information for the construction site. Furthermore, is BIM seldom compatible with tools used for building maintenance. The National Building Specification (NBS) listed in their 10th annual BIM report common barriers to using Building Information Models, the four most common obstacles among the respondents yet to adopt BIM were *no client demand, lack of in-house expertise, cost, and too small projects.* Among those who have comprehended BIM in their managerial and operational processes 68 % announced a successful implementation, and of those who have not yet implemented BIM 58 % said that adoption is crucial to not get left behind. NBS (2020).

1.3 Purpose of the Thesis

This thesis will examine the overall stage of digitization in Ostrobothnia associated with construction companies, real estate organizations, and public sectors with the goal to establish some common ground for the local use of Construction 4.0 channels and find valuable add-ons, from a project management perspective. By conducting a survey among a variety of construction companies in the SME category, real estate organizations, and public sectors with the ambition to get hands-on examples of the current situation the aim is to answer the following research questions:

How far adapted is digitization in Ostrobothnia today; Is there general knowledge in the subject? What are the experienced or expected benefits and opportunities?

1.4 Delimitation and Structure

The thesis is limited to investigate only construction, real estate, and public organizations, that is the intended users on the demand side of the subject Construction 4.0 and its means BIM and Lean Construction. To maintain clear boundaries designers and suppliers were left out of the scope. The economic aspect of implementation and digitization will not be considered as a factor due to the diffuse borders and the fact that it could negatively influence the response rate in the survey.

The construction of the thesis is founded on six chapters. Chapter 1 introduces the reader to the background, presents known problems, and explains the purpose of the thesis. The 2nd chapter reviews existing research about the concept of Construction 4.0. By opening with a presentation of known problems in the construction industry it further goes through the how and the why to implement digitization and Lean thinking, relevant principles, to round out with a brief presentation of what to consider for different actors. Chapter 3 introduces the methodology and explains the survey method, a questionnaire, and brings up convenient benefits as well as identifies difficulties such as low response rate. The 4th chapter begins with a result summary of the received responses followed by an analysis of the answers in connection to the theoretical frame of reference, to be rounded out with a non-response analysis. In chapter 5 conclusions are drawn to the result analysis and the research questions are answered based on the outcome. Lastly, in chapter 6 are general considerations discussed and proposals for future research presented.

1.5 Definition of Terms

In Table 1 in this sub-section, various terms used in the thesis are listed along with their abbreviations.

Table 1. Definition of terms

Term	**Abbreviation**
Artificial Intelligence	AI
Building Information Modeling	BIM
Building Research Establishment Environmental Assessment Methodology	BREEAM
Computer Aided Design	CAD

Enterprise Resource Planning	ERP
Gross Domestic Product	GDP
Integrated Project Delivery	IPD
Internet of Things	IoT
Leadership in Energy and Environmental Design	LEED
Lean Construction	LC
Machine Learning	ML
Return on Investment	ROI
Small and Medium-Sized Enterprises	SMEs

2 Theoretical Framework

This chapter begins with a presentation of known problems in the construction industry, it further goes through the how and the why to implement digitization and Lean thinking, relevant principles, to round out with a brief presentation of what to consider for different actors. These are all important elements to understand when considering the utilization of Construction 4.0 technologies and concepts.

When it comes to Construction 4.0 it is safe to say that Lean Construction (LC), the continuous progress of Building Information Modeling (BIM), and Integrated Project Delivery (IPD) are the main trends (Munoz-La Rivera et al. 2021). The main focus of this thesis will be on BIM and Lean Construction. Even though Lean Construction and Building Information Modeling are two different initiatives they both have a great impact on the construction industry. Lean Construction has more of a visionary approach to project and construction management while BIM is transformative information technology. (Sacks, Koskela, Dave, & Owen 2010)

The term Lean Construction actually originates from the Toyota Production System (TPS) and refers to the application and adaption of its underlying concepts and principles to the construction industry. Many of the tools and principles of the TPS are applicable as such in construction and its main focus is on waste reduction, increased value to the customer, and continuous improvement (Sacks et al. 2010).

Building Information Modeling results in a digital machine-readable model that contains all necessary documentation about a model, such as its performance, planning, construction, and also its operation and lifecycle. An appropriate implemented BIM model facilitates a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration. With this pattern, BIM is predicted to serve as support for several of the results that Lean Construction is expected to deliver (Sacks et al. 2010). As gratitude of receptivity BIM can stimulate a deeper adoption of digitization, it supports collaborative working, integration, communication, visualization, automatic generation of documents, building simulations, and management throughout its life cycle (Munoz-La Rivera et al. 2021).

2.1 Known Problems in the Construction Industry

The problems addressed in Munoz-La Rivera et al. (2021) of the construction industry are very actual and describing. The problems are further presented in Table 2.

Table 2. Problems in the construction industry (based on Munoz-La Rivera et al. 2021)

Problem	Description
Budget overruns and delays	A far-reaching problem including technical, administrative, and legal difficulties. Interference with competitiveness.
Low interaction with suppliers, although high reliance	Despite the high reliance on external suppliers, a systematic interaction is lacking. Resulting in a growth focusing on incorporation instead of external innovation and learning.
Inadequate expertise from management	Due to limited communication and access to knowledge from previous projects the lessons learned fall short and often remain individual.
Traditional methods in focus	Absence of innovation and learning new techniques due to limited information.
Regulations in conflict with innovation	Standards related to safety and consumer protection or technical and environmental regulations can hinder changes in the sector due to distortion.
Fragmented supply chain	Fragmentation in the production process generates a hierarchy that leads to conflicts between contractors.
Low-skilled workforce	Due to safety, wage, and working conditions have the sector has become unattractive to young and trained workers, this is rising the average age of employees with a high job rotation and low turnover.
Poor financial and asset management	Financial management problems impact the company’s payments to employees and sub-contractors, which in turn generates problems with credibility, bad practices, and problems in the schedule.
Modifications and changes during construction	Adjustments and changes in design during construction caused by inconsistencies, client modifications, and economic balance tend to delay processes and increase costs.
Weak planning	Delays and rework due to poor planning and programming is a common issue in construction.
High accident rate	Low-trained and unmotivated personnel generate an accident-prone environment.

In a manifesto stated by the European construction industry federation, we can read: *"BIM is a part of the overall digitalization of the construction industry and Industry 4.0"* (FIEC, 2017). It explains BIM as a process-driven working and management method that is based on collaboration and data sharing throughout the entire construction value chain, including clients and final users. According to Schönbeck, Löfsjögård & Ansell (2020) construction project management starts with analyzing large amounts of functional data, which in turn has to be transferred to interpretable information before the design stage can start.

Separating design from building often leads to twice the work in the construction phase which lowers the productivity. In addition to this, it is not unusual with last-minute changes to buildings that cause redesign and rework. Efficient flow of information in the supply chain is seen as a way to improve productivity and for this, the Building Information Modeling system is a strong candidate, particularly if integrated throughout the whole construction project. (Ahonen et al. 2020)

In the interviews conducted by Ahonen et al. (2020) an interviewee from a consulting company pointed out that for the industry to evolve the demands must be set from start with the aim to enhance new technologies. Those demands could preferably come from clients in the public sector. Although it can be seen as an advantage to those who already have such technologies implemented in their organization and can take part in the competition to offer, compared to those who have not yet implemented any. For progress to develop, demands are required.

The interviews highlighted a number of issues related to productivity and arguments for the low productivity activity. According to the interviewees the main reasons for the weak productivity development in the construction industry are (Ahonen et al. 2020):

- Extended supply chain
- Strong regulations
- Individual projects that make each project its own prototype
- Lack of data management in construction and absence of data integration (data modeling)
- Public sector procurement practices

- Rigidity in collective agreements
- Overall complexity and design changes during the assembly phase.

As a counterpart to the stated problems in productivity the interviews revealed various suggestions to improve productivity output (Ahonen et al. 2020):

- Development of prefabricated elements
- Standardized solutions for school buildings
- Supply chain integration
- Integration of design and production (data modeling)
- Collaboration in construction
- Product-oriented development to support last-minute changes
- Cooperation between public and private sectors for a regional development
- Flexibility in collective agreements
- Development of construction logistics

2.2 Implementation of the Concept

The Industry 4.0 visions agree with the construction industry's principles and practices, that is, they can be well aligned. The utilization of this implementation is not that far evolved and digitization and automation in construction mainly focus on single-point solutions instead of improvements for the value chain, productivity, and sustainability.

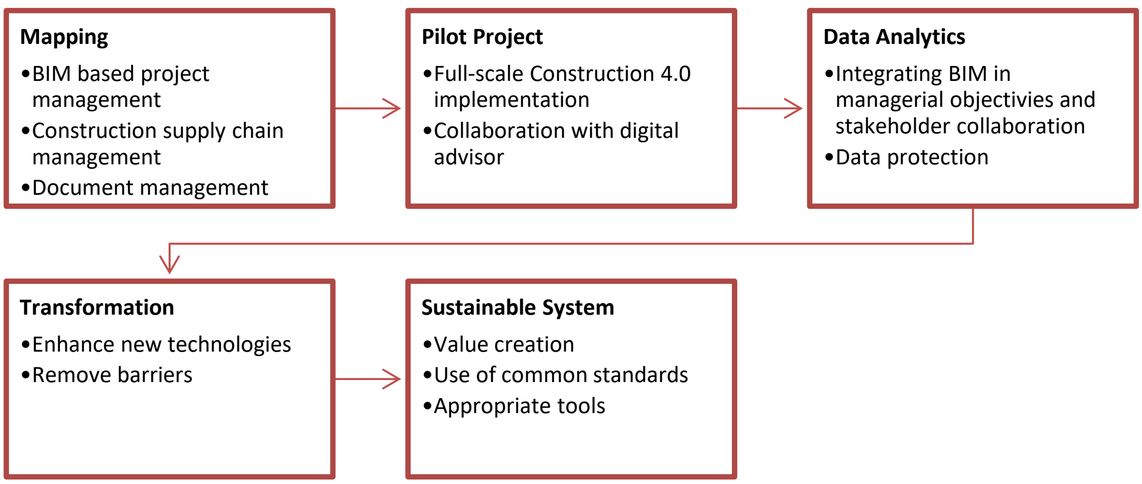

Figure 1. Implementation through a pilot project (based on Hossain et al. 2019)

Hossain & Nadeem (2019) presents a framework for implementing the Construction 4.0 concept in construction companies, visualized in Figure 1. The first step of implementation starts with an evaluation of the current digital maturity of the company and drafting a five-year plan with milestones to achieve. As BIM is the digital planning method in the construction industry it is exceptionally important that the company's BIM-based project management system is well executed. Standardized document management systems, automation in the construction process, and construction supply chains built by the means of Industry 4.0 are all important measures to take into account when digitizing a company for Construction 4.0. A pilot project should be selected to convert theory into practice. Here the company needs to address the business value and cooperate with outside qualified experts of the field to stimulate digital innovation. Lessons learned are a valuable part of pilot projects that need to be assimilated for further development of strategies and new technologies. For analyzing large amounts of data IoT techniques such as Artificial Intelligence (AI) or Machine Learning (ML) can be used, in consideration with data protection, cybersecurity, and ethical questions. To maintain the digital era a sustainable system has to be formed for developing complete products and solutions for customers. The model can be sustained by the use of appropriate tools and standards, building suitable partnerships, and adapting to a new safety culture for Construction 4.0.

2.2.1 Benefits from Project Implementation

Dave et al. (2013) categorizes the key drivers for implementing Lean and BIM in a push and pull system, see Figure 2. On the push-side are external factors that initiate implementation, e.g. competitors and the threat of being left behind which leads to decreased competitiveness. The pull-side is represented by internal factors that contribute to a company's or organization's own self-assurance and influences their market advantage.

Figure 2. Push-pull system (based on Dave et al. 2013)

The application of new technologies in combination with cooperative processes contributes to higher productivity, eliminates collisions in design discovered at the worksite, reduces waste, and prevents delays. Noteworthy is, so be it a technological or process change, that any unfamiliar adoption will either breakeven or be at a cost the first three projects. A Return on Investment (ROI) is however eventually realized, this, of course, revolves around the effectiveness of implementation. To fully benefit from any new technology, generally requires investments in process development and technology acquisition and learning. The boost in productivity is typically seen already after the first or second project and a considerable long-term ROI can be expected. (Dave et al. 2013)

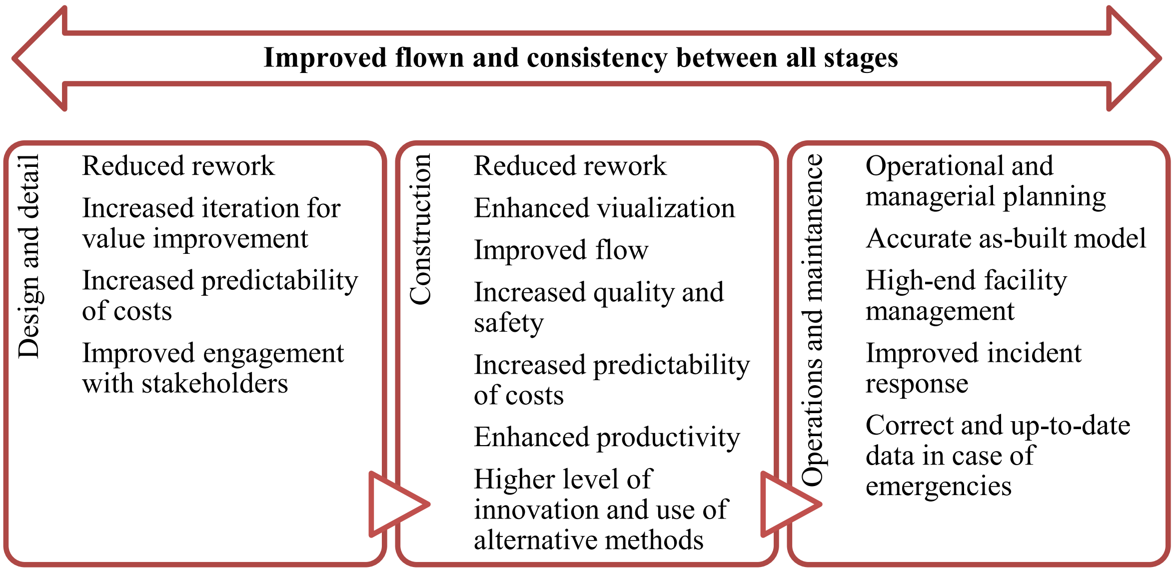

Figure 3. Benefits from incorporating Lean and BIM (Dave et al. 2013)

2.3 The Transformation

A digital company with definite leadership and engagement from all stakeholders and a continuous search for new technologies can gain a competitive advantage in the market. The transformation is intended to bring positive changes to the construction industry, for example, improved productivity, efficiency, quality, and integration of processes. It also has the ability to remove obstacles that may hinder the digitization of the construction industry. This transformation will of course be faced with drawbacks from outside such as political, economic, technological, environmental, ethical, and legal influences. The lack of clarity regarding costs and benefits for BIM adoption has since the beginning of this millennium witnessed restraints in terms of organizational culture and work practices. (Hossain et al. 2019)

For a digital transformation to become genuinely absorbed and business as usual it is important that it takes effect throughout the chain of value. Over and above improving productivity and reducing delays the digital technologies, as earlier mentioned, also improves working conditions, safety, environmental protection and contribute to higher-quality buildings. Furthermore, digitalization contributes to the supply of affordable homes and higher-quality infrastructure at a higher pace as well as enhances the quality of life by offering new services that allow for improving communities to the benefit of all citizens and the environment. (FIEC 2018)

For the construction industry, the winds of change are blowing and by adopting new services with a gung-ho spirit, that serve to fulfill clients' demands and are developed in affiliation with the IT industry, the current situation will change in an advantageous direction. Big data, Building Information Modeling with 4, 5, 6+ levels of dimensional design, cloud storage, 3D printing, and pre-fabrication are already changing the way the sector operates in combination with intelligent buildings and smart cities. Digitalization is essential to meet the European Union's policy goals and to cope with the rapid progress strong networks need to be established that supports the demand for rapid transfer of knowledge, expertise, across sectors and geographical borders. (FIEC 2018)

In a press release (268/2020) by the Finnish Government, the Ministry of Economic Affairs and Employment presents an investigation named *"digitization and developed customer functions provide more productive construction projects"*. According to this, municipal and state actors can, by their significance as buyers, influence productivity growth in the construction industry by encouraging innovation activities and introducing digital solutions. In the Finnish construction industry, labor productivity has not seen any significant change during the 2000s. On the other hand, there have been changes in the value chains where productivity has increased as most of the productive tasks have been transferred to other parts of the value chain. Parts of the value chain that previously were manufactured on the construction site as well as related tasks are nowadays made prefab at factories. This means that such work steps are no longer a part of the construction industry statistics. For example, if reinforcement work is moved from site to factory the increase in productivity thanks to automation is accounted for in the metal industry and not in the construction industry. (Finnish Government 2021)

Both municipalities and the state should encourage innovation and a way to improve the ineffective productivity in the construction industry is to start using digitalization such as digital data modeling to a greater extent, in that way both errors and overlapping tasks can be avoided which also opens up for smoother planning, implementation, and coordination. Although the innovation activities play an important role in the development of productivity it is somewhat hindered due to the fact that planning and execution often are done in separate quarters and that the refined methods that are being used in various construction processes are not easily questioned or changed. (Finnish Government 2021)

In the planning process, one or several actors are working together. In the building process it is usually the main contractor with sub-contractors and sub-suppliers, these various actors only cooperate during that particular project and that makes it complicated to analyze and make improvements to the process. A competing offering process can bring alternative and innovative solutions, and even though the required goals should be clarified in the quotation request it is up to the market to deliver and develop valuable solutions. (Finnish Government 2021)

2.4 Lean Construction and BIM

Lean Construction and BIM have been broadly investigated as separate units in the recent past but as a cooperative, there seems to be a smaller range of research (Sacks et al. 2010). This paragraph explores and defines the synergies between Lean Construction and BIM-based on *"The Interaction of Lean and Building Information Modeling in Construction"* by Sacks et al. 2010.

These two processes are not reliant on each other, in other words, can practices by Lean Construction be adopted without BIM, and BIM systems can be applied without traditions of Lean Construction. Still, we contemplate that only an integrated adoption contributes the full potential improvement to any construction project, these types of project deliveries are familiar as Integrated Project Deliveries (IPD). (Sacks et al. 2010)

BIM fortifies the core processes of construction, yet, the construction industry's investments in information and communication technologies to date have been quite inadequate. Two underlying factors to this are 1. Focus mainly on minor issues (for example ERP systems) and 2. the three core domains – people, process, and technology – have not been given sufficient focus and required balance. (Sacks et al. 2010) The balance between people, process, and technology should be of a 40-40-20 proportion (Dave et al. 2013).

2.4.1 Lean Construction – Principles of Relevance

In this sub-section, the relevant principles regarding Lean will be reviewed in general. The criteria's in focus are process, people and partners, and problem-solving – from a prescriptive point of view. The meaning of process regards the concepts flow and value generation. In the following paragraphs, the most significant principles of Lean are emphasized with a bold font and discussed briefly.

Reducing variability is central when it comes to scaling down the alternations in notable product characteristics and temporal variability of production flows. **Reduction of cycle times** can be related to inventory reduction and should in construction be focused on project duration, stage of construction, the flow of materials, and task. The principle of **minimizing batch sizes** is aiming for single piece flow which in turn also contributes to reducing the cycle times. A batch is a particular package with all necessary tasks for a distinct space. This leads us over to streamlined production by **enhancing the flexibility**, to benefit from this in construction multi-skilled teams are of essence considering that their ability to reduce setup or changeover times shortens cycle times. Control systems in production are often mixed push-pull systems; in a pull system, the productive tasks are of a downstream model triggered by customers, while in a push system the tasks are executed into reality through plans and schedules. It is important to select an **appropriate production control approach** that favors all stages of the production line.

To **standardize** work gives advantages in several categories. It emphasizes continuous improvement and reduces variability in product features along with employee self-development. Standardization is linked to **continuous improvement** which allows for a cumulative improvement of technology. **Visual management** connects to standardization and continuous improvement in terms of visualization of production methods and processes. To ensure the capability of the production system it is important to have a **system designed for flow and value**. In addition to the two criteria's the design should as well support production control and continuous improvement suggestions for simplification, parallel processing, and use of reliable technology. **Value generation concept** is necessary to guarantee **comprehensive requirements capture**, this in practice is a particularly tricky stage. Set-based design should lay the groundwork when evaluating different concepts in building design. Designing is divided into concept design and detail design and there is a natural tendency to rush the design stage to detail design, wherefore **concept selection should be of focus.** The next challenging stage in the aspect of value generation is to make sure that each and all necessities flow down to the very bottom of the design and production line. The concept of **verifying and validation** reminds us that all designs and products must be verified against specifications and validated against customer requirements. **Go and see for yourself -** unlike the traditional construction method where the desk-bound principle is a go-to in the name of problem-solving, this concept stresses the weight of personal observation, in other words, to go the Gemba walk. (Sacks et al. 2010)

By widening the circle of decision-makers and increasing the number of options it is possible to gain a broader knowledge base and enlarging the probability of finding the ultimate solution, hence it is important to **decide by consensus and consider all options** – this principle actually distinguishes from Toyota's TPS system. Networking, in the meaning of bonding with business partners, is an important principle that addresses the need of **cultivating an extended network of partners** that should be challenged and improved. (Sacks et al. 2010)

2.4.2 BIM – Principles of Relevance

The idea of BIM is that object behavior's in the model is programmed to respond to any action the way that their ditto would do in real life, this is what makes BIM tools able to model a building's form and function as well as behavior. The following paragraphs express the functionality of BIM (Sacks et al. 2010)

With BIM systems it is possible to render the design with a quite accurate level of realism, these kinds of **visualizations** are of great help for non-technical project participants and stakeholders since the visualizations are more accessible than traditional technical drawings. With the advantage of automated generation and layout of detailed components and also intelligent behaviors and parametric relationships, designers can manipulate design geometry effectively, this is a **rapid generation of multiple design alternatives. Predictive**

analysis of building performance by using model data is value-adding based on three characteristics: 1) Exporting pre-processed data that will be imported to third-party software is a function that most BIM-software's offer, these functions demands some level of human effort to get the exported data interpretable with the recipient software as well as rework when changes have been done in the primary model. Howbeit, those procedures are more efficient than doing analogous work from scratch. 2) The construction and life-cycle cost estimations can be automated, including links to online sources of cost data. 3) The coherence to program-client value and code consent is evaluated automatically. (Sacks et al. 2010)

The integrity between the design model and information maintenance is achieved because BIM tools store each piece of information once as distinct from traditional drawing systems where a design can be stored in multiple drawings, such as plan, section, and detail. This function can also be combined with an automatic clash-checking capability which identifies physical and abstract collisions between objects in the model. (Sacks et al. 2010) The collisions detected by BIM are divided into three categories by Czmoch & Pękala (2014):

- Heavy collisions – Same space occupied by several objects
- Light collisions – Space needed for assembly (clearance or tolerance)
- Technological collisions – Assembly sequence and delivery schedule monitoring; review of workers and time needed to complete the phase

This action is a huge advantage to the BIM system since it saves valuable time and costs both during the design process and during work at the site (Czmoch & Pękala 2014).

BIM software is handy when it comes to the **generation of drawings and documents** since the process is rather automated and requires only a small amount of user input. The integrity between model and report is maintained by an automatic transition of changes. **Collaboration between actors** is possible either internally which means that multiple users editing the same model or externally that is multiple modelers view merged models for coordination. In an internal collaboration, model objects can be locked to avoid inconsistencies when producing duplicates but externally the objects need to be checked separately to exclude collisions and layer upon layer. **The 4D visualization** in BIM is a tool for construction project schedules and the evaluation of construction plan alternatives and it provides functions for a subtle simulation of events which opens up for construction process rehearsals and repetitive pre-incorporations. BIM makes **direct information transfer** possible with business-to-business integration in construction component fabrication when allowing for open access to all product specifications that originate in the building model. (Sacks et al. 2010)

2.5 How BIM and Lean are Affiliated

We have already established the main principles of focus in Lean: waste reduction, increased value to the customer, and continuous improvement. In this paragraph, the focus will lie on the interactions between BIM and Lean. Figure 4 illustrates the four main characteristics that relate BIM and Lean, the interactions will, later on, be exemplified in text based on the guide *Implementing Lean in construction: Lean Construction and BIM* by Dave, Koskela, Kiviniemi, Tzortzopoulos, & Owen (2013).

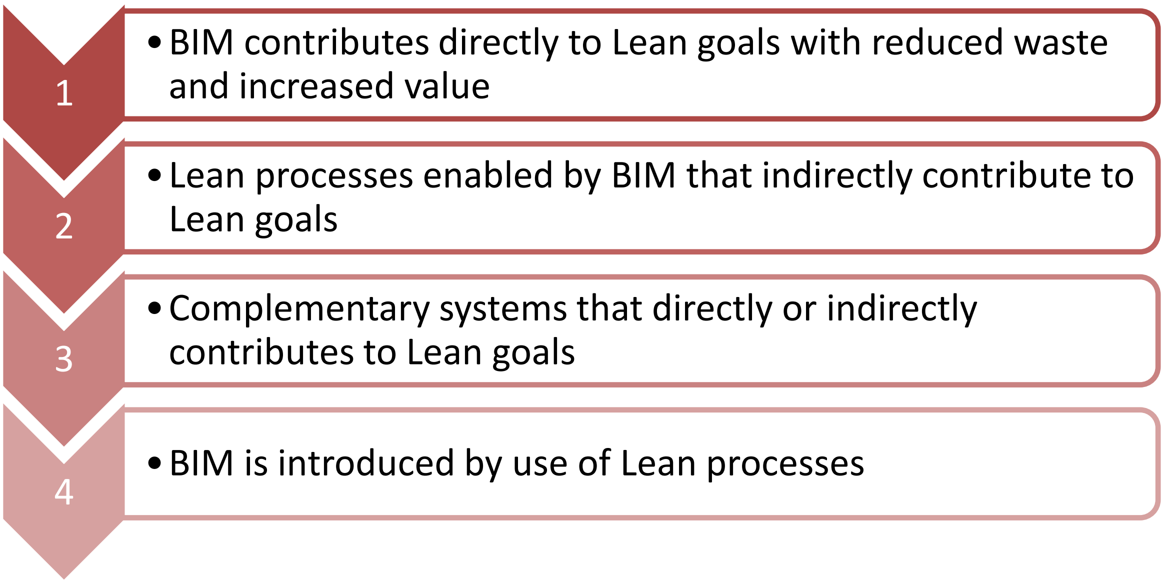

Figure 4. Interaction between BIM and Lean (Dave et al. 2013)

1. **Lean goals directly impacted by BIM:** an example of this is the clash-checking function which was mentioned in the previous chapter. This is a function where models from different actors are aligned against each other to check for any physical or clearance collisions, e.g. between structural beams and ventilation ducts. Doing

this as a virtual activity saves a significant amount of time at the worksite. A 3D model also ensures design flow down through all stages of a project as well as allows clients and end-user to grasp the design and provide their input. These functions cohere with waste reduction and value generation principles from Lean.

2. **Lean processes enabled by BIM with an indirect impact on Lean goals:** by using BIM models in production it is possible to gain a deeper understanding of the planned activities. A 4D BIM model promotes collaborative planning and the simulation of building erection and assembly eliminates delays on the worksite.
3. **Auxiliary information provided by BIM that contributes directly and indirectly to Lean goals:** at this level, the 5D and 6D BIM models can be used as an example. These models carry out valuable information for cost management or carbon footprint calculations.
4. **Introduction of BIM is facilitated by Lean processes:** When looking at the relationship between BIM and Lean it should be emphasized that the environment of Lean Construction will bolster the implementation of BIM-based technologies, by means of predictability, discipline, and collaboration.

The support between BIM activities and Lean functions is a two-way street. Sacks et al. (2010) found in their study, *Interaction of Lean and building information modeling in construction*, 56 unique interactions along with empirical evidence from construction projects that supported interactions. The study pinpoints three fundamental Lean principles that have the most interactions with BIM functions.

1. Waste reduction in the sense of higher quality due to accurate design
2. Reduced production uncertainty and improved flow
3. Increased efficiency resulting in reduced overall construction time

2.5.1 Characteristics in a BIM and Lean Integrated Project

The significant synergies between BIM and Lean have been established. Here on the affinity with characteristics or functions of a construction project will be summarized. Table 3 can be used as a target guide when working on a Lean and BIM integrated project.

Table 3. Features in a Lean and BIM project. (Dave et. al 2013)

Planning and design	**Construction and assembly**	**Operations and facilities management**
Collaborative planning and design	Improvement through constant optimization	BIM model linked with building maintenance system
Gathered design team	Shared models during meetings and planning	The model used for facility management and operations
Early involvement of stakeholders	Models updated throughout the project ensures an accurate as-built model	The model kept as-maintained to ensure reliability
Models detailed for use at site	Relevant information tagged to the model	Access to warranty data for use via smart devices

Besides the typical features in Table 3, other factors are important to appraise when implementing Lean and BIM in a project, particularly if it is a pilot project. The key considerations are listed below: (Dave et al. 2013)

- Focus on long-term benefits
- Visualize project purpose and results
- Adopt appropriate requirements management
- Employ design simulations and verification
- Assess project benefits
- Define governance structures
- Evaluate outcomes and impacts
- Analyze environmental and life cycle impacts

Some factors might interfere with the implementation of BIM and Lean integration, such as (Dave et al. 2013)

- Inadequate involvement of stakeholders
- Using models that are not aligned
- Actors only partially engaged in BIM
- If BIM is only used for design and not through the whole project (e.g. production planning)

- If Lean Construction is only implemented in one project phase (e.g. design or production)
- Models not being shared throughout the supply chain

2.6 Dimensions of BIM

As mentioned in section 2.3.2 the dimensions of BIM goes beyond 3D and, for example, its fourth dimension includes time scheduling in the model and by that the most beneficial alternative for assembly can be chosen already at the design stage and in the aspect of time and value it is attached to Lean Construction. Hereafter, the different dimensions of BIM will be deliberated.

According to Czmoch & Pękala (2014), the BIM dimensions can be construed as follows:

- BIM 3D – A virtual model with 3D parameters that has become a natural extension to the 2D design.
- BIM 4D – Used for time scheduling, another extension to the 3D BIM. This gives opportunities such as phase division and visualization of phases, simulating the schedule, accurate planning for product and material delivery time.
- BIM 5D – Cost estimations; cost of labor and delivery of each item. With this extension to the 4D BIM, the various alternatives of assembly installations can easily be compared and counterbalanced regarding execution time and total costs.
- BIM 6D – A system for sustainability. Analysis of building energy consumption and carbon footprint is possible with by integration of software related to environment protection and energy consumption. Such environments as BIM 6D function as a primary tool to meet requirements defined by LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Methodology).
- BIM 7D – The facility management dimension. A database with comprehensive information about each embedded object and element, i.e. building as a whole, structures, finishing materials, and all equipment. With all this gathered in the same place, it is possible to schedule time for maintenance or replacements and quickly locate items when failures occur.

When talking about BIM beyond the 5th dimension the clarity appears to be rather diffuse and a consensus is missing. Multiple sources have mentioned the 6th dimension of BIM as several different aspects, e.g. project lifecycle, health and safety, procurement, and as-built. For the 7th dimension sustainability and facility management are two strong candidates and some have even included an 8th dimension, accident prevention (Koutamanis 2020).

Chapter 1.2 Problem Formulation, mentioned a questionnaire combined with a systematic review executed by Charef et al. (2018), here follows a brief review of their results. From the systematic review of journals, they could establish that the 4D BIM is linked with time and 5D BIM with cost but for the 6th and 7th dimensions, it got a little blurry. Parallel with the journal reviews the questionnaire survey showed corresponding answers. The awareness of various BIM dimensions is high, likewise is the definition of the 4th and 5th-dimensional functions. As for 6D and 7D BIM, the awareness decreased but was still well-known by three-quarters of the respondents. 86 % of the respondents assigned 6D to sustainability and 7D was assigned to Facility Management by 85 % of the respondents, this is not a consensus but at least confirmation of a general agreement, noteworthy that these numbers are based on answers from "users" of BIM, i.e. practitioners. With academics and "non-users" taken into account the answers conflict even more. The deficiency of familiarity regarding the 6th and 7th dimensions might lead to the loss of benefits brought by these BIM dimensions. There is a broad consensus about what the 4th and 5th dimensions do contribute and that in turn has brought gains to the industry. (Charef et al. 2018)

2.6.1 The 8th dimension – Accident Prevention

Kamardeen (2010) introduces a tool called Accident Prevention-through-Design (PtD) which is a level eight extension to BIM in form of a knowledge base. PtD consists of three stages:

1. Hazard profiling of individual building elements
2. Safe design expertise
3. On-site risk control expertise

In the first step, the PtD system is integrated with a BIM data model. The aim is to perform hazard profiling for BIM building elements using the expertise available in the PtD knowledge base. When the hazard profiling is carried out the elements rated as high hazard are recognized and suggestions for safe design are provided. The third step provides a second set of suggestions for risk control at the site to confront hazards that might be of an undisciplined nature (Kamardeen, 2010).

2.6.2 The Complexity of Capacity and Information in BIM

Koutamanis (2020) questions the complex hierarchies of domain information in BIM. With most publications regarding BIM dimensions mainly focusing on applications and results rather than the representation and how the relevant data is contained Koutamanis (2020) addresses the nature and structure of such information. 5D BIM taken as an example, the 5^{th} dimension is described as the generation of cost budgets but unlike width or length that are linked to symbols, the cost is linked to construction work packages, for instance ‘drywall on the second floor’. Perpetually these kinds of packages involve a breakdown of BIM symbols by their kind into clusters of products such as productivity and scheduling. As for 6D sustainability analyses which Lean on properties and relations of BIM symbols to estimate building performance, inclusive of comparisons between various design options. New information added is attached to the symbols of the origin model. The conclusion of this is that dimensions higher than 4D are based on information in the basic 3D or 4D model but further processed to fit and describe features of building performance or behavior.

BIM symbol properties are what the different dimensions in BIM are presented by. Each symbol has several properties comparable to its real-world equivalents, geometric dimensions, material, characteristics just to name a few. The properties are a potpourri of data including both primary data like length and height and derivative data like the area and volume of the object. This is also applicable to other characteristics as thermal, acoustic, and fire safety performance. Even though the required performance of an object is known does not mean that the data is primary, but it is the first step of problem-solving and sorting out which primary data would meet the requirements. In a design process progress the designer’s work is to add missing primary data to the symbols and in that way refine the existing ones. Conflicts with normalization principles in database theory occur when both primary and derivative data are present in a symbol. A normalized database stores primary data (e.g. length, width, and height) combined with a function to calculate derivative data (e.g. area and volume). Simplification: the stored properties for a specific object are length, width, and height, and also both are and volume, the latter are repetitious because they can be calculated based on length, width, and height properties. An excessive amount of properties stored increases storage space needed and uncertainty because area and volume can be answered through different sources which may even conflict with each other, hence is the elimination of dependencies important in symbol properties and storage. (Koutamanis, 2020)

BIM models do however not follow the principles of normalization and problems with storage due to size and inefficient queries are not unusual. These problems are commonly known and acknowledged in the literature. It has also been proposed that, as a way to improve the integrity of the model, inconsistencies can be reduced if data are only entered once in a model, and that should be by the most authoritative source. (Koutamanis, 2020)

As earlier mentioned, derivative data are not and cannot refer to true dimensions; in contrast to length, width, and height, area and volume do not qualify as dimensions and the same goes for performance characteristics. In BIM both resources and objects are represented by distinct symbols, for example, if a crane is used to erect a wall the crane is not a property of the wall but the two are connected by links within the frames of a particular work package. These are separate symbols, and neither is a dimension of the other. This is consistent with the database theory’s description of different entities, that different tables contain different entities, and these are connected when required. (Koutamanis, 2020)

If all derivative properties are removed from a symbol, does the rest qualify as primary data, i.e. in this case dimensions, is for example color a dimension? To answer this Koutamanis (2020) uses a database example: to identify a person their birthdate is of the essence, if we abstract that the whole description of the person immediately becomes uncertain, e.g. “John Smith born on June 19, 2020” versus “John Smith born in the 2020s”. By considering what is fundamental to the identity of a symbol in BIM and what is significant to define something at a high level of abstraction the correct label of the property can be determined. In the early stages of design work, there might be fuzziness regarding e.g. precise dimensions or exact geometry of an object, and properties like materials can be totally absent at the time but there is rarely uncertainty about the position and approximate dimension. Scilicet, just like with real-world objects all materials do not need to be familiar to recognize the type of the element, e.g. a wall. BIM dimension can be defined with the following three principles:

1. All attributes in BIM must be accounted for as a dimension of a symbol.
2. Properties must qualify as dimensions of a symbol, i.e. properties dependent on others should be excluded, that is derivative properties.
3. Primary properties do not always qualify as dimensions, the ones that can be abstracted without loss of identity to the symbol should be excluded.

The three first dimensions of BIM can be defined on the basis of the three fundamental geometric dimensions: length, width, and height. Even the fourth dimension in BIM, generally known as time, can be accepted as a dimension of BIM through the aspect of the history of an object, furthermore, it incorporates as-built and as-is information. Even though the information may be fuzzy it is essential, and any object belongs to a certain phase or stage. (Koutamanis, 2020)

Cost is the fifth dimension to BIM but there are some levels of abstraction that complicate the definition of cost as a dimension. Pricing for components (e.g. plasterboard) and deliveries are definitely primary data. However, costs for assembly of building components such as plasterboards use derivative information and are expressed, for example, as cost per square or cubic meter. BIM symbols should include unit prices as they function as primary data, these are on the other hand not significant for the identity of an object and cannot be considered a dimension in BIM. 6D BIM and beyond are dimensions that represent building performance, for example, thermal values. These do not qualify as dimensions because they are derivative and dependent on primary data calculated based on geometric and material properties. (Koutamanis, 2020)

To sum up the above, it can be stated that BIM should be limited to 4D with time as the fourth dimension. The following ‘dimensions’ are properties that can be calculated based on symbols already present in 4D BIM. (Koutamanis, 2020)

2.7 A Lean and BIM Project – What to Ponder

Here follows a concise review of what is important to consider for clients, contractors, and designers in a Lean and BIM project.

Clients should evaluate the contractors based on their Lean and BIM capability instead of the lowest price; the overall lifecycle costs exceed the projects' construction costs by far. Furthermore, are lifecycle costs far exceeded by the organization's operating costs and in that aspect, the main users should be identified and involved in the design stage as early as possible to harness the as-built modeling effectively. To fully grasp business opportunities and their costs, risks, and contributions, and ensure deployment of the BIM strategy through the organization a BIM advisor should be appointed. (Dave et al. 2013)

The potential for construction companies to improve productivity is huge through digital value creation (Hossain et al. 2019). Although BIM was believed to be a tool for designers, the use of BIM during production management gives support for on-schedule and within-budget project deliveries. For this scenario to be successful the requirements from the contractor need to be communicated to the designer at an early stage of the project. Some of the main functions demanded from contractors are *collaborative planning, clash detection,* and *quantity take-off.* (Dave et al. 2013)

From a designer's perspective, various benefits can be gained from a Lean and BIM implementation. For example, reduced costs and better value creation for clients leading to increased competitiveness. (Dave et al. 2013)

Further is the incorporation of a BIM manager or coordinator a vital aspect in a Lean and BIM project integration process. According to Dave et al. (2013) has Skanska in Finland a policy to assign a BIM coordinator for all major projects in the region. Some of the main functions for a coordinator identified by Skanska: coordination with designers during the design phase, perform model auditing, start-up and attend design and modeling meetings, and share assessed knowledge across the project team.

3 Methodology

In this chapter, the methodology of the survey is explained with a focus on the questionnaire method. It brings up convenient benefits as well as identifies difficulties such as low response rates.

This is a quantitative study and the empirical part of this thesis will be based on survey methodology with an online questionnaire of 14 questions as a point of departure, these questions will be presented and discussed later in this chapter. The participants are chosen from organizations operating in construction, real estate, and the public sector and that are based in Ostrobothnia, Finland.

As a clarification to why a questionnaire is needed Ian Brace (2018) says - *"so that all respondents are asked the questions that are appropriate to them, and so that, when those questions are asked, they are always asked in exactly the same way"*.

Survey methodology means that a number of respondents answer a set of questions in a questionnaire (Blomkvist, Hallin 2014). The questionnaire is the backbone of any survey and works well for collecting quantitative primary data as it allows for a standardized gathering of data. The purpose of a questionnaire should be definite and have a clear relation to the research (Roopa, Rani 2012). The questions are based on the research questions of the work and the theoretical frame of reference. The questions can be multi-option questions with pre-set answers or free form questions, as well as a combination of the two. The survey method is appropriate in quantitative research, and where you want to find an answer to a general question. With a survey, it is possible to collect a large amount of data about a specific topic and what's important is to reserve an adequate amount of time to compile and analyze the data. (Blomkvist et al. 2014)

The form of a questionnaire is either structured or unstructured. In a structured questionnaire, the questions are presented with consistent wording and with a majority of "yes" and "no" - option questions. A questionnaire without such characteristics is unstructured and formulation lays in the hands of the interviewer (Roopa et al. 2012). The two most important things to keep in mind when designing a survey are the formulation of the survey questions and the overall design of the form. The survey serves to analyze the concepts of the hypothesis and the relationship between these, as formulated in the questionnaire. Translation of concepts into questions is called operationalization and this step requires great reflection of the concepts in focus because of the variety in theories different terms and concept can have a slightly dissent emphasis. The most suitable theory for the own study should be chosen and motivated for. Terms and concepts should be defined depending on the theory of choice. (Blomkvist et al. 2014)

From operationalization indicators of the studied terms and concepts are obtained. These indicators or measurements are called variables and can be categorized as three types: *nominal* – when the answers to questions are two or more and they cannot be ranked by size, *ordinal* – two or more answers that can be ranked by size but the intensity between them vary and *interval* – two or more questions that can be ranked by size with a continuous intensity. (Blomkvist et al. 2014)

The questions should have a clear and fluent arrangement to lower the instance of misinterpretation of individual questions (Roopa et al. 2012). The survey questions should be formulated in a way so that they do not come on as charged or negative; questions with negations have a tendency to be misunderstood. Furthermore, is transparency significant, respondents should not be able to choose an answer alternative based on the formulation of the question. The introductory questions should put focus on the respondent, i.e. age or gender, this can be used for comparison between or analysis of groups (Blomkvist et al. 2014). Questions related to personal character or wealth or that puts great strain on the memory should be ruled out as opening questions (Roopa et al. 2012).

A well-planned design and presentation are essential for the credibility of the survey. It should contain relevant questions with simple wording and logical order, an appropriate amount of questions preferably numbered, a short but informative introduction of the purpose and how answers are handled, clear alternatives with a cLean visual layout. (Blomkvist et al. 2014)

To ensure that the questions are properly formulated, in desirable order, with adequate instructions, and to check the need for specifying questions a pilot survey can be conducted prior to the complete survey. This method enables reframing of poor questions and assures overall understanding of the questionnaire (Roopa et al. 2012). The survey should beneficially be sent out to as many respondents as possible to ensure an adequate number of responses even if everyone does not answer; do not send the survey to 10 respondents if 10 responses are required. If the response rate is below 100 percent, which often is the case, a non-response analysis should be carried out. A non-response analysis tries to answer questions such as *"why did not everyone answer?"* and *"what has been done to ensure as many responses as possible?"*. The attrition can be analyzed if the introductory, or any question is connected to specific information about a respondent. The response rate is measured as surveys conducted through surveys sent. A reminder to the respondents that have not yet answered can be sent out when a certain amount of time has passed since the survey was sent out or with a certain time remaining to the deadline. In the result chapter, the response rate will be presented as well as a non-response analysis. In the concluding chapter, the response rate will be compared to conclusions made and their general level of accuracy. (Blomkvist et al. 2014)

The survey can be validated on the basis of the connection to the research questions. These connections should be explained in detail in the method chapter. Well-drafted and deliberated arguments about the response rate and attrition also increase the validity of the survey since it affects the relevance of the knowledge. (Blomkvist et al. 2014)

The following keywords are essential to this thesis:

3D, 4D, 5D, 6D, 7D, 8D, Building, BIM, Building Information Model, Building Information Modeling, Construction 4.0, Construction, Construction Industry, Construction Management, Project Management, Visualization, Lean, Lean Construction, Industry 4.0, Integration, Integrated Project Delivery

The keywords used are based on a list by Boton, Rivest, Ghnaya, & Chouchen, (2020). In their research paper *"What is the root of Construction 4.0"* they present a listing of keywords and their relevance to Construction 4.0.

3.1 Survey

This subsection covers the survey procedure and the structure of the questions. The survey was designed and collected through Google Forms. Google Forms is an online survey tool with which the design, distribution, collection, and analysis of questionnaire data is possible. The survey took place between the 19th March 2021 and the 9th April 2021. The survey consisted of 14 questions and was distributed via e-mail to the respondents including a direct link to the questionnaire.

To ensure a sufficient amount of responses a group of 17 people was chosen based on position working either in construction, real estate, or the public sector. The participants are people with high-level positions such as CEO, manager, technical director, etc. Phone calls were made to all 17 respondents in advance to discuss the subject briefly and ask for participation. Unfortunately, two could not be reached and in those cases, more detailed e-mails were sent with the distribution.

Of 17 respondents are seven construction companies, five real estate organizations, and five public sectors. The sizes of the companies are small and mid-sized because larger companies and organizations tend to have larger projects hence, they are more likely further developed in digitization. The size of the company will not be considered in the analysis. The public sectors are technical departments in a municipality within the size range from 5 500 to 19 000 inhabitants. Among the real estate owners, there are respondents from both private and public organizations, this category is not graded by size due to its diversity.

3.1.1 Questionnaire

The survey opens with a few lines about the education and the ambition of the questionnaire. The ambition is to establish common ground and possible directions for the future development of Construction 4.0. Here on follows a short introduction to two of the main trends in Construction 4.0 – BIM and Lean Construction.

This paragraph talks through the questions and explains them briefly. The questions are held at a general level which helps to foster a better understanding and to increase the response rate by lowering the threshold. That being said, the questions do require some level of basic knowledge in construction, design, and project management. The questionnaire as a whole is found in Appendix 1. Here on follows the questions:

1. Area of business (e.g. real estate, construction, design, public sector)

This question is simply for follow-up purposes and analysis between the different organizations. This was the only mandatory question of the questionnaire.

2. Is your organization familiar with the concept of Construction 4.0? How would you describe it?

The second question investigates the respondent’s perception of the concept Construction 4.0. The European construction industry (FIEC) mentioned that for a digital transformation to become genuinely absorbed and business as usual it is important that it takes effect throughout the chain of value. Just as important is the existence of the fundamental knowledge about the process that is being implemented partially or entirely.

3. Do you have software that supports the use of BIM in your organization?

The third question explores the availability of BIM software in these organizations. This can help to establish future development such as integration of BIM tools in daily work tasks.

4. If you use BIM, what is the most common use of it?

This question is an extension of the third question. The aim is to explore the prevalence of BIM tools and the use of such.

5. Are you familiar with dimensions beyond 3D BIM? Please also tick the box if you are interested in a specific dimension.

Number 5 is a multiple-option question, as presented in Figure 5. The purpose of this question is to delve into the common understanding of the dimensions beyond 3D BIM. With an additional box to tick if the respondent would find any particular dimension more interesting to their own area of expertise, which also suggests future development.

	Yes	No	Interested (as in would be beneficial to own operations)
4D – time (visualization and planning of project assembly in a 3D model)	☐	☐	☐
5D – cost (cost calculation for labor and deliveries - connects to objects in the 3D model)	☐	☐	☐
6D – sustainability (energy consumption, meet environmental classification requirements e.g. BREEAM)	☐	☐	☐
7D – facility management (for maintenance of building elements in detail and building as a whole)	☐	☐	☐

Figure 5. Question no. 5 from the questionnaire

6. If you ticked "interested" for any of the above dimensions, please specify how it would be useful for your own business.

Question number six is tied to number five and the aim here is that the respondents explain in a freely formulated text how the particular dimension or dimensions of interest from question 5 would be useful for their own business.

7. What aspects of Lean Construction are familiar to you?

	Yes	No
Waste reduction	☐	☐
Increased to value to customer	☐	☐
Continious improvement	☐	☐

Figure 6. Question no. 7 from the questionnaire

As presented in Figure 8, question number 7 has multiple options exploring the general awareness of the three principles of Lean Construction – *waste reduction, increased value to the customer,* and *continuous improvement.*

8. How is Lean Construction implemented in your organization?

Even if the three principles in question 7 would not be known some aspects of Lean thinking might anyhow be implemented in an organization. Question 8 intends to find out in which way Lean Construction is implemented, regardless of known or unknown principles.

9. How do you think that Construction 4.0 and the digitization in construction benefits your operational and managerial processes?

This question examines respondents' own points of view regarding Construction 4.0 and the implementation of digitization through the supply chain.

10. Have you lost contracts/assignments/projects due to a lack of digitalized technologies?

In the interviews conducted by Ahonen et al. (2020) a consultant organization raised an issue that had been discussed with the Finnish Transport Infrastructure Agency (FTIA). FTIA claimed that data modeling requirements cannot be enforced on designers and constructors due to the uneven distribution of digitalization among organizations creating unfair situations (Ahonen et al. 2020). Well, at what stage is Ostrobothnia when it comes to competitive offering? Has digitalization already adversely affected less digitized companies? Question number 10 tries to dig into that matter.

11. Are there any tasks or processes that run smoother with the traditional way of working, compared to using BIM models? Which tasks or processes?

Is it possible that traditional construction and design to date are more efficient in many aspects? For example, in renovation projects, there might be unforeseen beams and hidden details that affect both timelines and budgets, even with detailed preliminary investigations carried out. This question also pokes around in the matter of resistance to the use of BIM models from different directions.

12. For what purposes do you think BIM models are/would be useful?

- ☐ Building lifecycle monitoring
- ☐ Cost planning
- ☐ Collaboration between actors
- ☐ Time scheduling
- ☐ Visualization building elements
- ☐ Elimination of collisions between objects and materials

Figure 7. Question no. 12 from the questionnaire

Based on NBS (2020) and Dave et al (2013) the most advantageous benefits of BIM were listed as a multi-option question, see Figure 7. The aim is to obtain the respondents' thoughts of BIM and possible benefits.

13. What benefits would BIM models of your properties provide?

What are the real estate owners' expectations or perhaps knowledge? Is it a potential opportunity for private and public property owners?

14. When you contract a new project is the availability of a BIM model significant?

How important is the availability of a BIM model when a new project is contracted? Is there a need for more detailed models that can be used for lifecycle maintenance purposes?

At the end of the questionnaire was also a free-form question for the respondent's own comments.

4 Result

This chapter summarizes the received answers followed by a more thorough analysis of individual responses. A total of seven respondents answered the questionnaire which leads to a response rate of 41.2 %, in construction management, this is an acceptable ratio and in line with similar research in the area (Hadzaman, Takim, & Nawawi 2015; Charef et. al 2018). And fortunately, the respondents are evenly represented by each of the examined areas: construction, real estate, and public sector.

To summarize the first question regarding the respondent's area of business - two respondents represented a construction company, two from the public sector, two from real estate, and one combination of real estate and construction, statistics are presented in Table 4. This provides the opportunity for a fair and coequal analysis of the subject.

Table 4. Participants from the various organizations and the response rate

Respondents (type of ogranization)	Questionnaires distributed	Responses returned	Percentage of responses (%)
Construction	7	2	29 %
Real Estate (& construction*)	5	3	60 %
Public sector	5	2	40 %
TOTAL	17	7	41 %
*One respondent represented both and RE and construction			

The second question asked about familiarity with the concept of Construction 4.0 and how the respondent would describe it. Out of seven answers, only three had heard about it, one answer was left blank which is assumed as "not familiar". This suggests that Construction 4.0 is a rather unfamiliar concept, at least in Ostrobothnia.

Question number three in the questionnaire examined the use and support of BIM software in and among participant organizations. As in this case, the outcome was quite clear being only on respondent acknowledged use of BIM software.

In the fourth question "If you use BIM, what is the most common use of it?", an answer from a respondent that in the previous question did not have software supporting BIM said that they use a web-based application that supports viewing BIM models. Another respondent said that if they used it, it would be for visualization of premises. The participant that actually has software for BIM uses it for layout and modeling for offering purposes.

The fifth question investigated the awareness of dimensions beyond 3D BIM with an additional box for the interest of any specific dimension. The answers were the following:

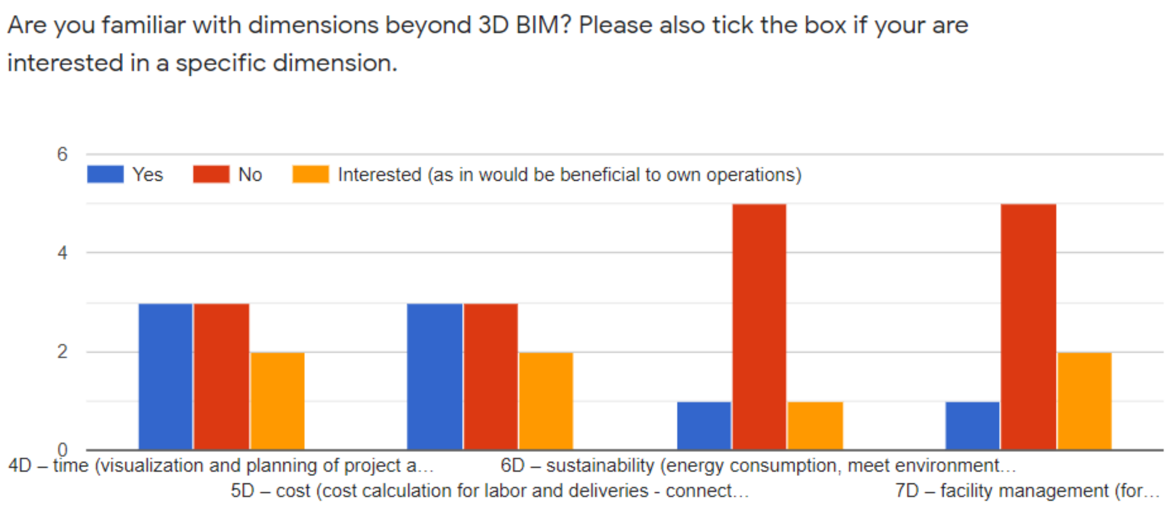

Figure 8. Visualization of BIM dimension awareness and interest

For 4D and 5D BIM, the awareness was evenly distributed, as presented in Figure 8. The orange columns indicate interest in the dimensions which is enlightening. In the case of 6D and 7D BIM, there was a greater lack of familiarity, however, indications for interest can be construed here as well.

As an extension to the fifth question is number six aiming to find out how the interesting dimensions would be useful to the participant organization. Among the four describing answers provided is lifecycle analysis mentioned but also cost and time scheduling.

In the seventh question, the focus lies on Lean Construction and the familiarity of the three main aspects: waste reduction, increased value to the customer, and continuous improvement. As presented in Figure 9 the awareness is rather high, and the aspects of waste reduction and continuous improvement tend to be more familiar than the aspect increased value to the customer.

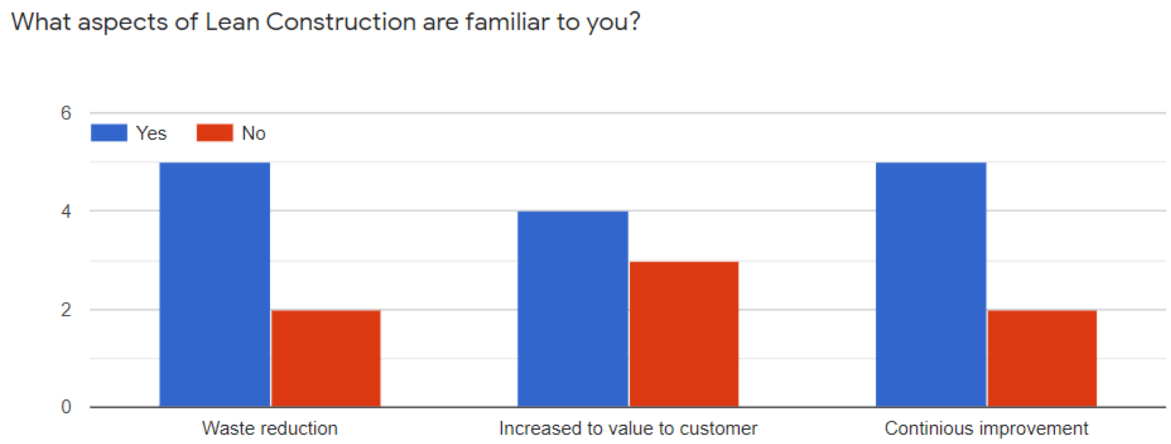

Figure 9. Familiarity to Lean Construction aspects

In the following question, eight, are the respondents asked to describe how Lean Construction is implemented in their organization. The answers that define the question here are low costs, reduced waste, and higher quality. Three participants have no Lean thinking implemented within their organization.

"In everyday work, important in all aspects. Visible in everything we do. Awareness could of course always be increased among workers and employees." A respondent from real estate and construction about how Lean Construction is implemented.

The ninth question of the questionnaire intends to sort out the expected benefits of Construction 4.0 and digitization to the participant organizations' own operational and managerial processes. As four respondents were not that familiar with Construction 4.0 and had no clear expectations, three mentioned improved customer satisfaction, reduced conflicts, and reduced managerial requirements.

"Sounds like Star Trek, we just build." Response from a construction company about expected benefits of Construction 4.0 and digitization.

Question 10 wants to know if any contract, assignment, or project losses have occurred due to lack of digitalized technologies and is stated as "have you lost contracts/assignments/projects due to lack of digitalized technologies?". Five out of seven answers said clearly "no" to this question and two were left blank which also is assumed as a "no" in this case.

Question 11 compares the traditional way of working with the use of BIM models by questioning if there are any tasks that run smoother the conventional way of working. The majority agreed that in smaller projects, e.g. renovations where many surprises can occur or if BIM is not familiar to all contractors it can lose its benefits.

"BIM is better as long as all the contractors have experience from it. When one part is not familiar with BIM it can quickly lose its benefits as a whole." Respondent from public sector about traditional working versus using BIM models.

In question 12 the respondents are asked to tick boxes for what purposes they think BIM would be useful, see Figure 10.

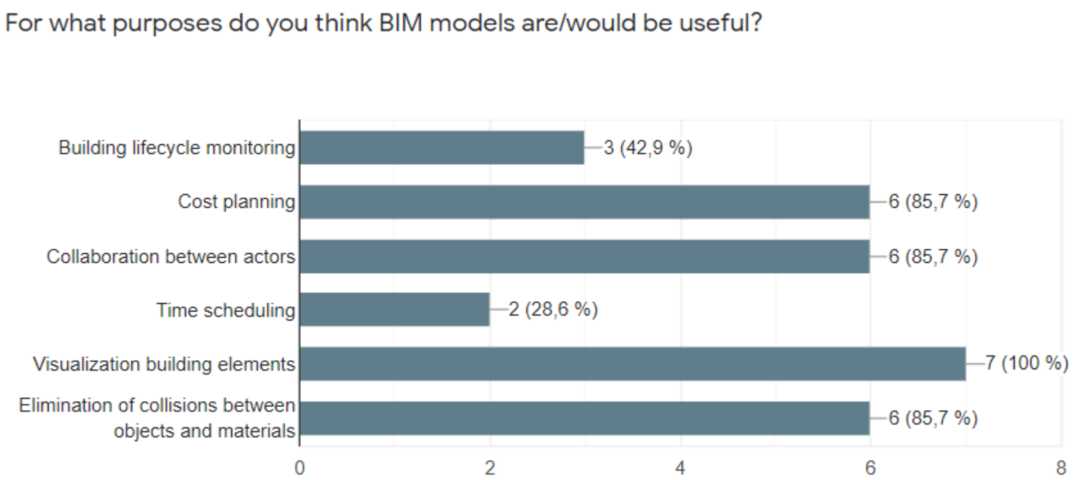

Figure 10. Foreseen beneficial purposes of BIM

The expected benefits of BIM models for properties examined in question 13 were, among others, lifecycle monitoring, marketing, and predictability.

Question 14 is mainly addressed to real estate organizations, both public and private sectors. With the question formulation, if the availability of a BIM model is significant when contracting a new project. As it turns out this is not significant to the vast majority of the participants, one respondent from the public sector actually pointed out that it would reduce the number of contractors willing to offer. Only one respondent provided a clear and distinct "yes" to this question.

The questionnaire had at the end a free form for other comments. One respondent said that tools like BIM and Lean Construction might solve problems to some extent for general issues in the construction industry. However, alone they will not remedy headaches such as high costs, unclear responsibilities, poor quality, attitude problems, and so on. A solution to these problems would require a deeper, more profound analysis.

4.1 Analysis of the Result

In this sub-section, the answers will be evaluated and discussed in relation to the theoretical framework.

Contemplating the awareness of the Construction 4.0 concept in Ostrobothnia based on received answers the knowledge is possessed by the real estate organizations. Neither one from the construction or public organizations admitted any insight into the subject. This fact in combination with the familiarity of dimensions beyond 3D BIM that did show a higher awareness of the 4^{th} and 5^{th} dimensions compared to the 5^{th} and 6^{th} is aligned with the survey conducted by Charef et al. (2018), where BIM awareness was studied among both users and non-user within borders of the European Union. Results in that survey showed that the 4^{th} and 5^{th} dimensions were familiar to 96 % of the respondents and the 6^{th} and 7^{th} dimensions were known by 78 % respectively 72 % of the respondents.

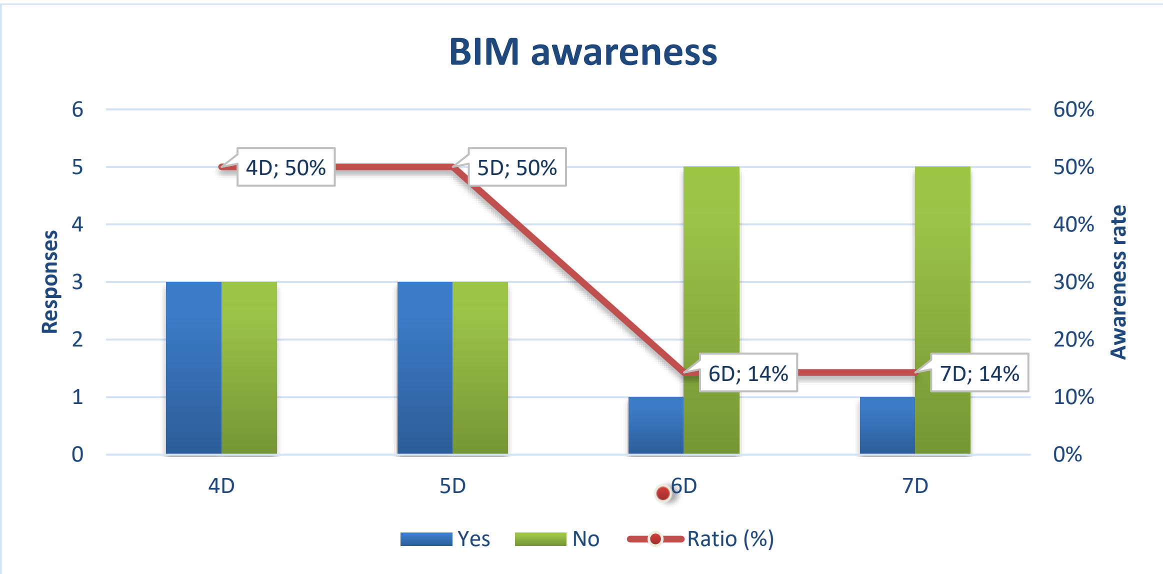

Figure 11. BIM awareness rate

The large gap in familiarity between 4D and 5D BIM (50 %) respectively 6D and 7D BIM (14 %) shown in Figure 11 and the overall lower awareness rate can be connected to fewer responses and participants. As well as the fact that in this case, the respondents are mainly non-users and not actual practitioners such as architects or structural engineers – when compared to the survey by Charef et al. (2018).

Only one out of seven participating organizations had software that supported the use of BIM and an additional one used a web-based client for viewing BIM-models, that is 2 out of 7 or about 28.5 % using BIM in their processes. From question 5 interest for the different BIM dimensions can be construed (see Figure 10) which can be connected to the answers in question 12 – *for what purposes do you think BIM models are/would be useful?* The alternatives in question 12 relate to the different BIM dimensions as presented in Table 5. The respondents' answers according to dimension based on Table 5 in combination with the interest for own operations in question 5 are presented in Figure 12.

Table 5. Options related to BIM dimension in question 12

Option	Relation to BIM dimension
Building lifecylce monitoring	6D & 7D
Cost planning	5D
Collaboration between actors	3D
Time scheduling	4D
Visualization of building elements	3D
Elimination of collisions between objects and materials	3D

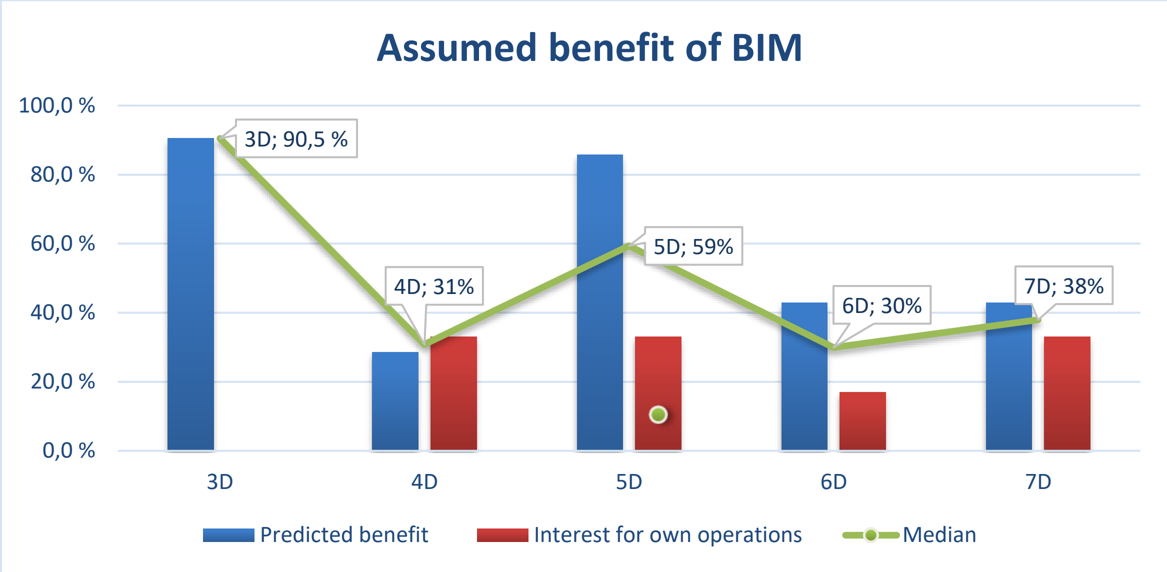

Figure 12. The assumed benefit of investigated BIM dimensions

As shown in Figure 12 the expectations for the traditional 3D modeling are high but a fair amount of anticipation also appears for 5D BIM, that is cost planning. Considering that only two respondents used some kind of BIM software the expectations overall seem to be high. The inference drawn from this is that the general interest for BIM implementation exists, but the progress is still at an early stage. Lines can well be drawn to the report that NBS (2020) compiled where 58 % of those organizations that have not yet implemented felt that implementation is crucial to stay in the game but, negligence due to barriers such as lacking demand from clients', low in-house expertise, too small projects, and the cost is holding back the process.

Aspects from Lean Construction were familiar to a majority of the respondents' as seen from the statistics presented in Table 6. From the answers to how Lean Construction is implemented within participating organizations' the main principle of Lean thinking is waste reduction, cost efficiency, and high quality. Regular discussions with staff are also mentioned as a way to find appropriate solutions for customers which is directly connected to the principle decide by consensus and consider all options (Sacks et al. 2010).

Table 6. Respondents' familiarity with aspects of Lean Construction

Lean Construction aspect	Yes	No	Familiarity
Waste reduction	5	2	71 %
Increased value to the customer	4	3	57 %
Continious improvement	5	2	71 %

In question 7 the respondents were asked if they had lost any contracts or assignments due to a lack of digitalized technologies. The reaction is quite clear when every answer had a distinct "no". The lacking demand from clients (NBS 2020; Vass et al. 2017) functions as the main reason for the conclusion that can be made out of this. This can be validated by the question if a BIM model is significant when contracting a new project where only one out of five (public or real estate organizations) said that the availability of a BIM model is important in a new project. One actually pointed out that such demand would reduce the level of interest from contractors. To patronize a common issue the Finnish Government said in their investigation that municipal and state actors can, by their significance as buyers, influence productivity growth in the construction industry by encouraging innovation activities and introducing digital solutions (Finnish Government 2021).

4.2 Non-Response Analysis

In line with Blomkvist et al. (2014), a non-response analysis will here be presented as a short evaluation of the approach and procedure with comments on what might have affected the response rate and what could have been done differently.

Similar research has shown equivalent results, for example in Charef et al (2018) the response rate was 46,4 % in a survey about the awareness of BIM, another research is Hadzaman et al. (2015).

In this case, the starting grid was not too big, to begin with, which automatically affects the possibility to reach the diversity wanted. Personal phone calls were made to each respondent before launch and the responses were mainly positive. Of course, some mentioned low familiarity with the subject, but such answers are also of value in research. Two of the participants could not be reached through phone despite several tries, in their e-mails the presentation that otherwise was done by phone was included.

The time given to answer the questionnaire was between the 19th March 2021 and the 9th April 2021, which is three weeks. At the beginning of the last week, a reminder was sent out to all respondents as a personal e-mail, including those who had already answered since it was anonymous and impossible to tell who had already answered. No further reminders were sent out, the plan was to do another round with phone calls but due to lack of time, this had to be ruled out which otherwise probably could have had a positive impact. Those calls could also have investigated the factors that made respondents' leave the questionnaire unanswered. As possible as it might be the formulation of the questions it might also be related to benighted respondents or a combination of both.

5 Conclusion and Answer to Research Questions

The main purpose of this thesis was to examine the overall stage of digitization in Ostrobothnia associated with construction companies, real estate organizations, and public sectors with the goal to establish some common ground for the local use of Construction 4.0 channels and find valuable add-ons, from a project management perspective.

The two dominant themes in focus were Building Information Modeling and Lean Construction. A BIM and Lean Construction project could yield opportunities that enable innovation and development in an organization. By seizing knowledge from previous and ongoing projects the aspect of continuous improvement is maintained. Continually reviewing what does and does not work reinforces the process approach and efficiency and enhances the knowledge communicated through the supply chain partners. (Dave et al. 2013)

To enable accessibility and possibility for all stakeholders' pilot projects should be utilized. A pilot project is a rather low-risk on-the-job learning strategy, the company needs to address the business value and cooperate with outside qualified experts of the field to stimulate digital innovation. Lessons learned are a valuable part of a pilot project that needs to be assimilated for further development of strategies and new technologies. (Hossain et al. 2019) From a project management point of view, a valuable add-on would be to offer the capability and knowledge to consult such pilot projects to ensure that all participants get the required support - and benefits from the process. The availability of pilot projects is perhaps not that generous because the understanding of their importance is limited. As project management consultants there is a possibility to emphasize and advocate the pilot-project strategy already at the pre-design stage of a project. In a continuously evolving field, the own knowledge needs to be maintained and kept up to date. From Kerosuo et al. (2015) can be interpreted that implementation of BIM is reliant on project managers to serve as early adopters.

The Finnish Government (2021) said that public sectors could encourage innovation in the construction industry to a greater extent and that a competing offering process can bring alternative and innovative solutions to the market. This on the other hand requires certain demands from the client, such as a request for Building Information Models in the contract. The requirements set by the client should be carefully considered, wherefore too wide demands lead to the outcomes not meeting expectations while too narrow might decrease the interest from contractors (Dave et al. 2013). The introduction chapters mention the construction industry's impact on a country's economic development. Considering that, small and mid-sized enterprises in construction are one of the main contributors to the country's GDP it would be a necessary opportunity for the government to provide the support needed to SMEs with limited capabilities to do investments in new technologies (Hossain et al. 2019)

By conducting a survey based on a questionnaire, the aim was to answer the following research questions: *How far adapted is digitization in Ostrobothnia today; Is there a general knowledge in the subject? What are the experienced or expected benefits and opportunities*?

From the above analysis of the results, it can be summarized as - Ostrobothnia is at the first steps on the stairway to digitization. The general knowledge is existing but far from adequate in order to achieve requisite progress. To balance the flat curve in digitization the expected benefits act as a counterweight. The foreseen usability related to 3D was high and the dimensions beyond were also given attention. Lifecycle cost calculations were mentioned by several respondents. Another thing mentioned is a speeded-up process that would enable better offers for customers, which is directly connected to the Lean principle *increased value to the customer*. The respondents also predicted that benefits such as collaboration between actors, elimination of collisions between objects, cost planning, and visualization of building elements would be useful tasks to their operations. According to Dave et al. (2013), the most popular tasks for which BIM is used are *visualization, clash detection, building design, and as-built modeling.*

6 Discussion and Future Research

The general observation from the result is that the awareness of Construction 4.0 as a concept is not that widely known. In contrast, is the familiarity and use of BIM per se existing and a sound basis for development can be noted. The perception of Lean Construction was highly related to waste reduction, but the results revealed that a lot of Lean thinking might be done in ignorance arising from limited knowledge.

The year 2020 will probably go down in history as the year of COVID-19. During that period and even at the time of writing a lot of employees were forced to do teleworking due to governmental restrictions and company policies as a way to slow down the virus pandemic and keep the troops fit for work. A lot of remote-working systems have been deployed that enable efficient meetings, collaborations, and file-sharing. There is a strong possibility that teleworking will be a common combination to the regular office hours from now on, even after going back to a more normal world scene.

Boton et al. (2020) say that BIM is the tree that hides a forest of emerging technologies and that the development is continuous in several directions serving various practitioners. My own experience from using BIM in projects is mainly positive. In a current project, it is used for cross-checking models to rule out collisions of objects between designers with online meetings scheduled at appropriate intervals. These are held by a BIM manager that coordinates and prepares a report from the latest BIM model, which is then reviewed at the meeting where the responsible designer per collision is appointed to make the necessary changes. In other assignments, it has been used for quantity take-offs for cost calculating and follow-ups which is a very smooth way to work as long as the model is correct and harmonious with the CAD drawings.

Building Research Establishment Environmental Assessment Methodology, or BREEAM, has been given a lot of attention in an ongoing project. BREEAM is a system for environmental classifications for buildings based on European standards. The requirements are many and rather demanding and the purpose of 6D BIM, sustainability, would become a distinct advantage in terms of time consumed for gathering various information needed.

Construction 4.0 with BIM and Lean Construction leading the way will probably have a huge impact on the construction industry’s carbon footprint as well as reduce overall waste.

With utilization from early design to assembly and facility maintenance, the possibilities are infinite. Repetitive and time-consuming tasks can be avoided while the human errors decrease which leaves room for added value to the actual process. New ways of working call for training and learning, not only within the own organization but also for subcontractors and other actors in the entire supply chain. The goal should be to enable the use of building information models throughout a building's lifecycle. Charef et al. (2018) mentioned a tool called End of Life to facilitate the deconstruction or demolition process of a building that could be an extension to BIM. This would have been beneficial with today's aging building stock, especially for public buildings such as schools that have encountered a lot of problems and are now at the end of their time as faithful servants. These buildings tend to contain a lot of subjects that today are forbidden in building materials, such as asbestos and lead. To calculate volumes and levels of hazardous waste without expensive mapping and comprehensive analyzes would facilitate the work that many municipalities today face. But, as the life span of buildings increases, and a lot of lessons have been learned along the way this might not be fully exploited in the future. With that said, the claim is not that today's solutions are bulletproof, of course, unexpected problems later can occur right in the middle of a building's planned life span.

From a long-term perspective BIM will function as a tool for exact assessments of investments as well as a system to compare solutions for planning and maintenance by monitoring energy, environmental and lifecycle analyzes. Today's clamor for a circular economy and the calculation of companies' carbon footprint could well benefit from including Construction 4.0 processes in their progress. Hopefully, the future will allow a continuous and correct mapping of the environmental impact of a building's entire life cycle.

Financial aids can be applied for many reasons and maybe would it be a justifiable proposal that an opportunity for those who want to develop their digital transformation would be offered, with a low threshold. With a vision to support digitalization in the construction industry, particularly for the smaller actors.

Although the response rate was fairly high in the survey, the number of responses was not that many. This is probably due to the narrow scope of participants and the limitation being set only to Ostrobothnia. The result indicates the current stage of digitization and can only be used as a starting point for further studies.

As future regional research could the actual interest of digital transformation or at least inclusion of such tools be investigated. Here it probably will not be enough to just ask will or will not but also simultaneously present the advantages digitization contributes, the scope could be expanded to include designers and other practitioners as well as economical aspects. The word of Lean thinking could be further developed and well spread with concrete examples on how to utilize it.

References

Ahonen, A., Ali-Yrkkö, J., Avela, A., Junnonen, J-M., Kulvik, M., Kuusi, T., Mäkäräinen, K., & Puhto, J. (2020). *Rakennusalan kilpailukyky ja rakentamisen laatu Suomessa.* Valtioneuvoston kansila.

Blomkvist, P., Hallin, A. (2014). *Metod för teknologer: examensarbete enligt 4-fasmodellen.* Studentlitteratur AB, Lund

Boton, C., Rivest, L., Ghnaya, O., & Chouchen, M. (2020). *What is at the Root of Construction 4.0: A systematic review of the recent research effort*. Archives of Computational Methods in Engineering, 1-20.

Brace, I. (2018). *Questionnaire design: How to plan, structure and write survey material for effective market research*. Kogan Page Publishers.

Charef, R., Alaka, H., & Emmitt, S. (2018). *Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views.* Journal of Building Engineering, 19, 242-257.

Czmoch, I., & Pękala, A. (2014). *Traditional design versus BIM based design. Procedia Engineering*, 91, 210-215.

Dave, B., Koskela, L., Kiviniemi, A., Tzortzopoulos, P., & Owen, R. (2013). *Implementing Lean in construction: Lean Construction and BIM* [CIRIA Guide C725].

Eastman, C. M., Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors.* John Wiley & Sons.

FIEC. (2018). *FIEC Manifesto for digitalisation.* [Online] https://www.fiec.eu/application/files/3515/7830/0780/2018-06-12_The_European_Construction_Industry_Manifesto_on_Digitalisation_A4_1.pdf (retrieved: 6.2.2021)

FIEC. (2017). *FIEC Manifesto on BIM - Making BIM a global success*. [Online] https://www.fiec.eu/application/files/1415/7830/0093/FIEC_BIM-Manifesto.pdf (retrieved: 6.2.2021)

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). *Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges.* Renewable and Sustainable Energy Reviews, 75, 1046–1053.

Finnish Government (2021). *Utredning: Digitalisering och utvecklade beställarfunktioner ger mer produktiva byggprojekt.* [Online] https://valtioneuvosto.fi/sv/-/10616/selvitys-rakentamiseen-lisaa-tuottavuutta-digitalisoinnilla-ja-tilaajatoimintoja-kehittamalla (retrieved: 17.2.2021)

Hadzaman, N. A. H., Takim, R., & Nawawi, A. H. (2015). *Building Information Modelling (BIM): the impact of project attributes towards clients' demand in BIM-based project.* Building Information Modelling (BIM) in Design, Construction and Operations, 149, 59.

Hossain, A., & Nadeem, A. (2019). *Towards digitizing the construction industry: State of the art of Construction 4.0*. Structural Engineering and Construction Management, 1-6.

Kamardeen, I. (2010, September). *8D BIM modelling tool for accident prevention through design.* In 26th annual ARCOM conference (Vol. 1, pp. 281-289). Leeds: Association of Researchers in Construction Management.

Kerosuo, H., Miettinen, R., Paavola, S., Mäki, T., & Korpela, J. (2015). *Challenges of the expansive use of Building Information Modeling (BIM) in construction projects.* Production, 25(2), 289-297.

Klinc, R., & Turk, Ž. (2019). *Construction 4.0-digital transformation of one of the oldest industries. Economic and Business Review for Central and South-Eastern Europe, 21*(3), 393-496.

Koutamanis, A. (2020). Dimensionality in BIM: *Why BIM cannot have more than four dimensions?* Automation in Construction, 114, 103153.

Ministry of the Environment 2021. *Digital byggd miljö.* [Online] https://ym.fi/sv/digital-byggd-miljo (retrieved: 16.2.2021)

Munoz-La Rivera, F., Mora-Serrano, J., Valero, I., & Oñate, E. (2021). *Methodological-technological framework for Construction 4.0*. Archives of Computational Methods in Engineering, 28(2), 689-711.

NBS (2020). *10th annual BIM Report*. NBS Enterprises Ltd 2020

Official Statistics of Finland. (2021). *Regional statistics on entrepreneurial activity.* [Online] https://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__yri__alyr/ (retrieved: 20.4.2021)

Osunsanmi, T. O., Aigbavboa, C. O., Oke, A. E., & Liphadzi, M. (2020). *Appraisal of stakeholders' willingness to adopt Construction 4.0 technologies for construction projects.* Built Environment Project and Asset Management.

Roopa, S., & Rani, M. S. (2012). *Questionnaire designing for a survey.* Journal of Indian Orthodontic Society, 46(4_suppl1), 273-277.

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). *Interaction of Lean and building information modeling in construction*. Journal of construction engineering and management, 136(9), 968-980.

Schönbeck, P., Löfsjögård, M., & Ansell, A. (2020). *Quantitative Review of Construction 4.0 Technology Presence in Construction Project Research*. Buildings, 10(10), 173.

Tezel, A., Taggart, M., Koskela, L., Tzortzopoulos, P., Hanahoe, J., & Kelly, M. (2020). *Lean Construction and BIM in small and medium-sized enterprises (SMEs) in* *construction: a systematic literature review.* Canadian Journal of Civil Engineering, 47(2), 186-201.

Vass, S., & Gustavsson, T. K. (2017). *Challenges when implementing BIM for industry change.* Construction management and economics, 35(10), 597-610.

Appendix 1

Construction 4.0 in Ostrobothnia

This survey is a part of my Master's Thesis, Construction 4.0 in Ostrobothnia, in Industrial Management and Engineering at Novia University of Applied Sciences. The aim of this survey is to investigate the stage of digitization among construction companies, real estate organizations and public sectors in Ostrobothnia. The ambition is to establish common ground and possible directions for future development of Construction 4.0. The answers will be held anonymous.

The fourth industrial revolution, or Industry 4.0, is transforming many industries at a high pace. Construction 4.0 is about adopting digitalization in operational and managerial processes in construction.

Two of the main trends in Construction 4.0 is Building Information Modeling (BIM) and Lean Construction (LC). BIM is a digital solution for 3D design, that enhances collaboration throughout the whole design process and eliminates collisions and unnecessary work in the assembly process. Lean Construction is more of a visionary approach focusing on waste reduction, increased value to the customer, and continuous improvement. BIM and LC are connected by many principles, for example the principle of waste reduction, a precise 3D-design contributes to reduction of waste in the construction progress.

As the digitization in construction evolve, more dimensions have been enabled to BIM, such as time scheduling, cost calculations and so on.

*Required

1. Area of business (e.g. real estate, construction, design, public sector) *

2. Are your organization familiar with the concept Construction 4.0? How would you describe it?

3. Do you have software that support the use of BIM in your organization?

4. If you use BIM, what is the most common use of it?

5. Are you familiar with dimensions beyond 3D BIM? Please also tick the box if your are interested in a specific dimension.

Tick all that apply.

	Yes	No	Interested (as in would be beneficial to own operations)
4D – time (visualization and planning of project assembly in a 3D model)	☐	☐	☐
5D – cost (cost calculation for labor and deliveries - connects to objects in the 3D model)	☐	☐	☐
6D – sustainability (energy consumption, meet environmental classification requirements e.g. BREEAM)	☐	☐	☐
7D – facility management (for maintenance of building elements in detail and building as a whole)	☐	☐	☐

6. If you ticked interested for any of the above dimensions, please specify how it would be useful for your own business

7. What aspects of Lean Construction are familiar to you?

Tick all that apply.

	Yes	No
Waste reduction	☐	☐
Increased to value to customer	☐	☐
Continious improvement	☐	☐

8. How is Lean Construction implemented in your organization?

9. How do you think that Construction 4.0 and the digitization in construction benefits your operational and managerial processes?

10. Have you lost contracts/assignments/projects due to lack of digitalized technologies?

11. Are there any tasks or processes that run smoother with the traditional way of working, compared to using BIM models? Which tasks or processes?

12. For what purposes do you think BIM models are/would be useful?

Tick all that apply.

- [ ] Building lifecycle monitoring
- [ ] Cost planning
- [ ] Collaboration between actors
- [ ] Time scheduling
- [ ] Visualization building elements
- [ ] Elimination of collisions between objects and materials

13. What benefits would BIM models of your properties provide?

14. When you contract a new project is the availability of a BIM model significant?

15. Other comments