AALBORG UNIVERSITET
STUDENTERRAPPORT

MASTER THESIS REPORT

INVESTIGATING THE USE OF BIM IN CONTRACTING COMPANIES IN DENMARK: PRACTICES AND CHALLENGES

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EDUCATION

MSc. Management in the Building Industry

TITLE

Investigating the use of BIM in contracting companies in Denmark: practices and challenges

REPORT TYPE

Master thesis

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PROJECT PERIOD

1st of February 2019 – 7th of June 2019

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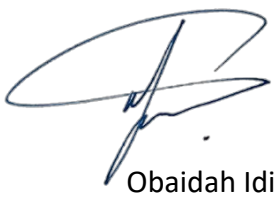
SIZE OF PROJECT

Project report: 54 pages

Appendices : 30 pages

Annex : No annex

SIGNATURES



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SYNOPSIS

As the title implies this research is in relation to BIM use among contracting companies in Denmark and what are the practices of its adoption or what could be the arising challenges for its full potential.

Furthermore, study starts by overviewing BIM application among contracting businesses globally by analysing literature articles, whereas then study is narrowed down to Denmark's leading contracting companies. Thus, respondents of three large contracting companies allows to analyse possible implications once BIM is a part of most of the construction process.

To summarise, thesis report presents an average level of BIM practices among contracting companies in Denmark.

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PREFACE

This Master thesis is conducted as a part of the Management in the Building Industry programme in Civil Engineering department at the faculty of Engineering and Science in Aalborg University. This research aims to investigate use of BIM in Contracting companies across Denmark regarding BIM functions and adaptation of BIM frameworks and standards.

We would like to express their sincere gratitude to everyone who contributed for this project's success. We would like to thank all interviewees from Per Aarsleff A/S, MTHøgaard A/S, and Züblin A/S for agreeing to take part in this study. We would like to devote a special thanks to our supervisors Lene Faber Ussing and Ekaterina Aleksandrova Petrova for their guidance and constant direction throughout the whole project process.

LIST OF ACRONYMS

- BIM – Building Information Modelling
- VDC – Virtual Design and Construction
- BEP – BIM Execution Plan
- IDM – Information Delivery Manual
- ICT – Information and Communication Technology

ABSTRACT

This thesis report is concerning investigation of BIM uses and practices among contracting companies in Denmark, and the implementation challenges they face. The research design starts with a review of relevant literature concerning BIM of contractors and BIM collaboration frameworks, the areas in which contractors use BIM technology are identified as a basis for further investigation. Following that, the hypothesis is identified, questioning the level of BIM use among Danish contractors, the collaboration level, and the challenges contractors face adapting BIM technology to their processes. A series of semi-structured interviews with BIM coordinators and project managers are conducted in collaboration with three of the biggest contracting companies in Denmark, in order to collect sufficient data regarding their use of BIM and developing an overview of the current situation concerning BIM use in Danish contracting companies.

The research gives a general rating of the use of BIM in each area of the construction process among contractors in Denmark. These findings demonstrate that contractors perform their tasks with average or good BIM involvement and use, relying mainly of the ICT declaration agreement for BIM collaboration management. Moreover, the research classifies three principal factors preventing contractors from higher implementation of BIM. Finally, this project methodology aims to assure a high level of validity and reliability, for it to be a basis for future research or as a background to continuous studies of more in-depth analysis.

KEYWORDS: BIM, Contractors, ICT, Collaboration.

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1 INTRODUCTION

The use of BIM has been growing in recent years worldwide, due to increased knowledge of the benefits its functionality could bring to projects, especially considering the augmented level of complexity of construction projects, and the multiple parties and stakeholders involved. However, this escalation in BIM use has been seen mostly in design and conceptual phases of construction projects, usually practiced by architectural firms and engineering consultants. Moreover, the use of BIM in execution phase still seems to be limited in which conventional methods of relying only on 2D drawings and documentations are still dominating in AEC industry regardless of the project size. This slow integration of BIM tools could be a result of many factors which could be poor knowledge of BIM functionality and its advantages among managers and engineers in contracting companies; limited implementation of available BIM supporting software and low quality of 3D models provided by other project parties; as well as, it could be vague and non-binding legislations, declarations and frameworks that Danish authorities have made in order to organize the use of BIM in AEC industry to apply them on an organisational and project level.

Therefore, to investigate these assumptions about BIM use among contracting companies, this project will identify the way Danish contractors incorporate BIM technology into their activities and rate their BIM performance in specific areas compared to relevant literature. The ways and frameworks of BIM collaboration will be researched as well and compared to the actual practice carried out by contractors in Denmark. Furthermore, this research aims to identify the challenges facing Danish contractors in securing good BIM practice in all areas of the construction project, challenges that BIM may bring as a complex and innovative change in a traditional construction industry. All of this will be discussed by analysing the answers of several interviews with BIM coordinators and project managers from multiple big contracting companies in Denmark, correlated with a thorough review of relevant literature and publications.

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2 METHODOLOGY

This chapter aims to define what is the approach to structure this thesis following with research design that directly corresponds to academic methods. Hence these methods are layered in a classified manner according to research guidelines that are described further in this chapter. Thus, methodological framing of the thesis enables to have a core based on which all chapters are interlinked and are easy to follow through.

2.1 RESEARCH DESIGN

Since this thesis research area is within construction industry, researchers conducting it are biased to analysed topics as they are a part of this industry. Thus, researchers are familiar with thesis topics form a perspective where they either have experienced concerning areas first-hand or have been familiar from personal interest or either by having relevant academic courses and knowledge attained throughout their current and previous education.

The thesis is structured according to method given by Saunders, et al. (2009) by using Research Onion to have it as a framework to uncover some layers in a structured way.

Firstly, researchers started study by conducting literature analysis (Chapter 3) to determine the area in which to continue the analysis. Since BIM is a very comprehensive topic, researchers decided to narrow it down by choosing to analyse only contracting companies. In terms of theory building, combination of inductive and deductive approach was laid down as basis for the theory building, to build a hypothesis and then by analysing to come up with a new theory. Thus, hypothesis had an outcome of a problem statement formulation (Chapter 0). Further on to answer the problem statement researchers did a case study analysis (Chapter 6) from the collected qualitative data by conducted interviews so that in a multi-method way it could complement literature analysis and could be used to validate whole project.

2.2 DATA COLLECTION

To collect the data researchers established interview guide (Appendix A). It consists of three main parts of which each correspond to warm-up questions, main questions, and ending question. In the warm-up questions interviewees are given a few general questions to learn about their background and to see how it might affect upcoming questions. Further in the second part interviewees are asked about their organisational and project-based functions that are interrelated to project phases.

Thus, these interviewee perceptions indicate if answers specify whether interviewee use any BIM based tool or process. However, if interviewee does not indicate any, then interviewer elaborates further with sub-questions to learn alternatives. Also, further on questions about different functions are complemented with questions regarding collaboration and coordination that are elaborated further on if they are not BIM-specific to learn about interviewee alternatives. Third part of interview guide is an open question about BIM to justify all interview answers if some of them are not comprehensive enough or interviewees missed something to mention in previous questions.

2.3 VALIDITY AND RELIABILITY

Internal reliability of this research is assured by having an interview guide that allows to result in question-specific answers. Since the same interview guide is used repeatedly, each case has a similar, area-specific answer. Furthermore, interview is designed in a way that has three main groups of questions that enables to have consistency and target direct topics.

Moreover, external reliability is assured that interview questions are designed according to findings in literature analysis and correspond directly with specific research subjects. Also, to assure that company-based interviews are congruent in terms of answers, two interviewees from the same company answers are compared and aligned.

Internal validity is assured by analysis of five interviews in an organised way thus allowing to give them background from literature review to compare specific cases from a global perspective. The number of interviews made in this thesis allows to do assumption that scope of this research is enough to have a locally acceptable internal validity.

External validity is assured in regard to relevancy to study topic as research outcome and analysed areas are in high interest across construction industry and thesis project could be further used for future studies within construction sector among contracting companies

3 LITERATURE REVIEW

This chapter aims to give an overview on functionality that BIM is known for from a perspective of various literature articles regarding BIM use across contracting companies. BIM functionality analysis then is complemented by a review of aspects such as rules and regulations that either mandate BIM benefits or limit them. Moreover, this chapter gives an overview on numerical benefits that BIM results in and description of workforce experiences that are seen from industry's perspective in research case studies.

Since the first introduction of BIM in the construction industry there were many discussions corresponding to understanding what are the improvements that this new concept and technology would bring. According to Dakhil, et al. (2019) BIM is not limited only by its ability to transform industry's overall performance on project delivery process but it is also capable of integrating whole project lifecycle. However, considering that BIM is also a process of information digitalisation through the project lifecycle, it is not exceptional that BIM therefore requires a change in culture as well as new technology integration since in the business that enables requirements for new competencies and specific set of skills (Dakhil, et al., 2019). Therefore, BIM usability is set by various factors. There is variation to what extent BIM is used among various types of companies where some may use BIM software as part of a requirement given by clients in contracts, others may implement BIM in a small scale projects incorporating their employees, as well as some decide to fully immerse into BIM development for most of their projects including establishing and enhancing BIM collaboration into external and internal processes (Chen, et al., 2014).

3.1 BIM FOR CONTRACTING COMPANIES

Considering the variety of ways BIM could be defined, research articles regarding BIM give an overview where definitions of BIM may be classified according to either project parties that are entitled to use it or in most cases BIM has a general definition inspired by the positive change it brings to construction process. Therefore, according to Chen, et al. (2014) differentiation of functions that BIM is known for in one of the ways could be classified by the specialisation where:

- Architects describe it as a process-driven technology to design building so that it meets its characteristics of functionality and physicality.
- Contractors define BIM as "a computer software model to improve decision making and facility delivery process".

- Owners perception on BIM is that it enables collaboration that differs from a traditional process of working on a project.

General definitions of BIM varies in many ways, whereas, one of them is that it is a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" (Succar, et al., 2012). Therefore, it allows to digitally create and collect project data which then could have many uses through all project phases. Other given definition is that BIM is not only a software where it is also an interoperability and process management tool. According to Olatunji, et al. (2010) BIM is a:

> *"representation of the combination of fairly revolutionary ideals for design technology, it portrays the geometry, geographic information spatial relationships, quantities and characteristics of building elements, material inventories, cost estimates and schedule of performance".*

Regarding given definitions, BIM mainly has been used by parties such as Owners and Facility Managers, Architects and Engineers, Subcontractors and Fabricators, as well as Contractors (Eastman, et al., 2018). Therefore, current highlight of this research would be given on Contractors' use of BIM.

Therefore, Eastman, et al. (2018) and McGraw Hill Construction (2014) defines main BIM functions that contractors use BIM for that are:

- Multi-Trade Coordination and Visualisation of Design
- BIM Support for Process Change, including Lean Construction
- Constructability Analysis and Clash Detection
- Quantity Take-off from a Model
- Model Integration with Schedule (4D)
- Model Integration with Costs (5D)
- Construction Analysis and Planning
- Virtual Jobsite Planning and Logistics
- Laser Scanning
- Integration with cost, schedule, quality, and safety control
- Off-site fabrication
- BIM in the field

- Augmented Reality of a Model
- Improved handover of the completed building to the owner

However, functionality of BIM is also predefined by the maturity of an organisation that implements it. According to Chen, et al. (2014) BIM maturity is depicted by the extent to which it is: "explicitly defined, managed, integrated and optimised" and that may vary among different users. However, that depends also on both sides where on the other side is an organisational maturity as BIM maturity highly depends on that as it may increase or decrease levels of BIM implementation effectiveness that results in BIM's benefits brought to an organisation (Ghaffarianhoseini, et al., 2016).

In regard to given BIM functions, Chen, et al. (2014) distinguishes main areas in which BIM directly correlates with are information, process, technology and people. And to see BIM as an improvement tool, these should be the benefits that BIM brings (McGraw Hill Construction, 2014):

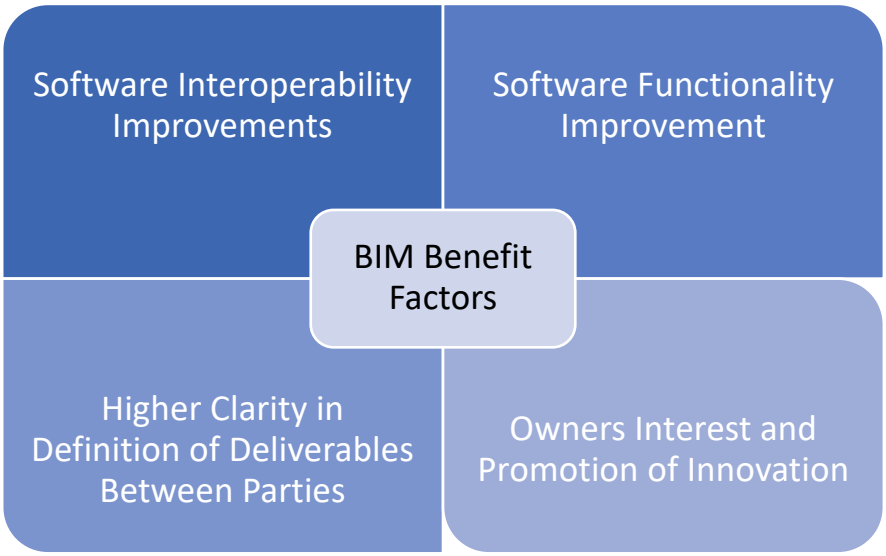

Figure 3.1 - BIM benefit factors (McGraw Hill Construction, 2014)

However, important to mention that these benefit factors by McGraw Hill Construction (2014) are also directly corresponding to BIM maturity that organisation has. As it shows how well an organisation adapts BIM and how well it strives for improvements and further functionality if in all these areas an organisation has a strategy to progress. Nonetheless, clients are those who have the ability to accelerate further innovation and improvements in processes of construction industry as well, whilst additionally stimulating improvements in BIM implementation that are information management, time and cost savings, and facility management (Dakhil, et al., 2019; McGraw Hill Construction, 2014).

In the scope of this research, two phases of a construction project will be investigated in terms of BIM functions used in it. The first is the tender and early construction phase when contractors perform several tasks calculating offers based on quantity take-offs and cost estimations. Following that, the second phase is the construction execution phase, discussing the functions and benefits of BIM in improving the tasks required to effectively complete the project.

1. Tender and early construction phase

The use of BIM for contractors start at the tender phase, usually this phase consists of three main tasks, a **cost estimation** of the bid based on a **quantity take-off.** Aslesen, et al., (2018) emphasized that the use of BIM in the tender phase of a construction project can increase the collaboration level and decrease the uncertainty of that phase:

> "A BIM model can be used for cost estimation and quantity take-offs. The model can also be applied to visualize the timeline for the construction work as well as to detect potential conflicts, interferences and collisions. A BIM model may thus allow us to collaborate more accurately and efficiently in the bidding process"

The use of BIM technology in cost estimation is one of the most desirable BIM functions for contractors, by extracting accurate bill of quantity (BOQ) and linking them to a cost estimating software (Ramaji, et al., 2018). According to Mo, L. (2018), the use of BIM in cost estimation can minimize the time and effort needed by cost estimators to calculate bids, nevertheless BIM based cost estimates can reduce errors and omissions of hand calculations and thus contractors can reach the bidding success. Wei, L., (2017) agreed with this statement describing the BOQ as the most important part of the tender phase and having software technology to generate accurate numbers would be profitable for both the contractor and the client. Eastman, et al, (2018) added to that by encouraging estimators to use BIM technology for BOQ, better visualization of the project and assessment of the conditions which would improve bids for contractors and subcontractors. However, Matejka & Vitasek, (2018) have argued that the use of BIM in cost estimation is still limited, contractors and institutions are struggling to successfully implement is due to lack of standardization, arguing that the process of cost estimation takes more than just accurate BOQ. According to Ramaji, et al. (2018) the value-over-difficulty ratio of using BIM for cost estimation is very low, adding that the use of BIM in this area would not really save any time in the process due to the high detailed formulas estimators have to put into the estimating tools. However, they emphasized that the use of BIM in cost estimation still has some benefits, such as the ability of BIM

technology to reduce errors and omissions by producing accurate BOQ. There are several BIM tools supporting cost estimation such as, iTwo (RIB), Navisworks manage (Autodesk), Vico office and DP manager (Trimble) (Eastman, et al., 2018).

2. Construction execution phase

Throughout this chapter, six areas of BIM use in the construction execution phase were distinguished (Figure 3.2) and will be discussed further on.

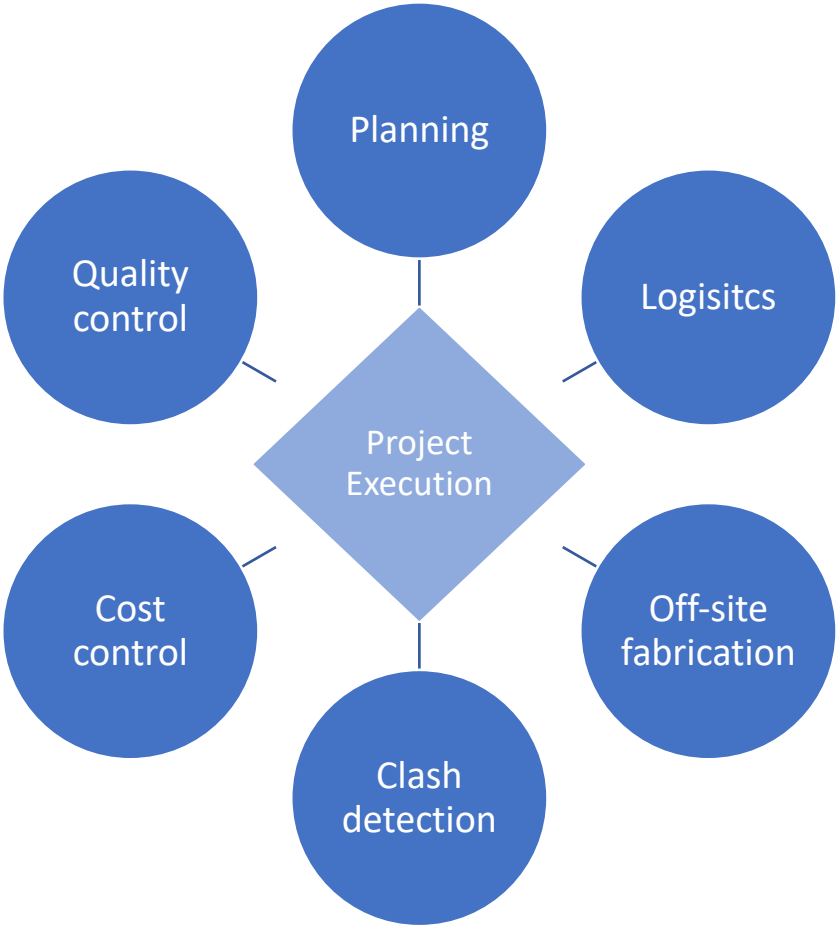

Figure 3.2 – BIM areas in the execution phase

When it comes to **planning and sequencing of the project**, using BIM technology in 4D planning can result in better and more accurate time schedules and coordination, by improving the communication between actors and better visualization of the planned work (Eastman, et al., 2018) (Ghaffarianhoseini, et al., 2016). However, there are several factors determining the quality of the 4D planning used in a project; the level of detail of the 3D model plays a big role, the higher it is the better and more accurate the 4D model would be, the reorganizing and regrouping of components in the model is important for a flexible and accurate 4D model, and the ability to decompose

components and elements so they can follow the as-built planning of the project (Eastman, et al., 2018).

In addition, BIM 4D technology can improve **logistics planning** by performing clash detections and coordinating the temporary logistics installation with the actual construction project model. Project managers can involve all temporary components (the site perimeter hoarding, site access gates and safety rails, loading areas, etc.) resulting in a much more accurate scheduling of the project and foreseeing any problems that may occur in the future (Eastman, et al., 2018) (Whitlock, et al., 2018) (Bortolini, et al., 2019). Multiple software supports BIM 4D planning such as, Navisworks (Autodesk), Synchro Pro (Synchro software), Vico office (Trimble), Visual 4D stimulation (Innovaya), etc. (Eastman, et al., 2018).

Contractors can further use BIM technology in improving the quality of **off-site fabrication.** The use of BIM in off-site fabrication can significantly increase safety, quality and productivity of the work associated with the fabrication of building components (Eastman, et al., 2018). A case study has found that off-site fabrication can account in 13% increase in return of investment of a construction project, significant decrease in work hours needed to complete the job compared to on-site, and reduced safety incidents on-site to zero compared to seven in case the work was to be carried out on-site (Eastman, et al., 2018). According to Maciel and Correa (2016), the production of customized rebars off-site from BIM models would noticeably reduce errors and enhance the consistency of production.

Furthermore, the use of 3D models during construction phase can reduce significant number of reworks as well as cost and time delays, BIM based automated **clash detection** is an excellent tool to identify design errors, clashes between temporary and permanent building components whether it is a soft or hard clash (Eastman, et al., 2018). According to Gledson (2016), clash detection technologies has significant impact on the accuracy of the works during construction, several examples were identified in which clash resolution was carried out prior to installation of main structural steel frame that was clashing with the roofing elements. BIM tools give contractors' staff the ability to visualize the works and detect any clashes before installation, these tools offer variety of uses for users; measuring distance, extracting detail views of specific objects, etc. (Eastman, et al., 2018). Some of the most used tools for clash detection and navigation of 3D models are, Navisworks Manage (Autodesk), Solibri Model Checker, and iTwo (RIB).

Moreover, BIM technology offers contractors the ability to track variances between budget and actual cost, improving the accuracy of **cost control** and minimizing cost overruns on construction projects, allowing project managers to act in accordance with information provided by models to detect the exact location of the overruns (Eastman, et al., 2018). iTwo (RIB) and Vico Cost Planner (Trimble) are examples of tools used to assist project managers in cost control.

According to Chen and Luo (2014), the use of BIM technology in supporting the **quality control** process in a construction project would have numerous advantages to the project, such as:

- Providing a basis of data for all building components and objects from the BIM model, allowing for a better assessment of data nonconformity between the design and the as-built conditions.
- The use of BIM 4D modelling would offer consistency in the quality control process, in which quality checks of objects can be carried out insistently after objects execution.
- The ability of BIM supported quality control process to be linked to other tools such as AR (Augmented reality), and laser scanning linking the models to physical as-built units.

In addition, Luo et al. (2017) emphasized on the importance and benefits of BIM technology in supporting quality control process:

> *"The use of BIM technology provides electronic version of the quality inspection data and documents, not only saving time for inspection and finishing, but also more conduct to the quality of construction control, comparative analysis of quality data, good quality control"*

3.2 DEFINING BENEFITS OF USING BIM

According to Bockstael and Issa's (2016) article there are no industry-accepted methods to dispose if BIM has a positive outcome of return on investment (ROI). Considering this finding, it is important to mention that even though there are no standard ways to analyse BIM's financial return, there are still contractors that according to Giel and Issa (2016) report BIM bringing them positive ROIs. It can be defined through the usefulness of clash detection as that allows to maintain the budget by locating clashes and intersections that usually result in avoidance of schedule delays (Bockstael & Issa, 2016). Thus, benefit of BIM does not have a standardised way to be identified regarding financial means, but it can be seen from a contractor's perspective that by using BIM tools it brings advantages to the construction process.

An analysis done by Lu, et al. (2014) had an outcome that by adoption of BIM technology there was a budget save up of around 7% per square metre. Another study was done by comparison of two projects of which one had an implementation of BIM and another one was done by use of traditional 2D drawings. This this type of study had shown that project in which BIM had an integral part it saved up around 8.61% per square metre as a result of decreased changes of design throughout the execution phase (Tahir, et al., 2018). Study of Sun, et al. (2015) also confirmed previously described benefits of BIM where once collision detection was implemented on a project level, its return on overall cost saving was between 3 to 5%.

A case study done by Ahn, et al. (2016) found out that development of BIM on a project level where specific BIM software and BIM manager needs to be accounted may result from 0.75% to 1.5% of overall project cost, but the given outcome is that:

> *"every $1 invested in BIM implementation at the project eventually brings the company $3 in financial benefits by <…> reducing and eliminating field conflicts and reworks; increasing productivity at the field, minimizing change orders; decreasing construction time; and improving collaboration among all stakeholders"*

Additionally, BIM technology can greatly influence the efficiency of construction projects, by improving the overall control of the entire project's planning and cost by using the various tools BIM offers such as, visibility, coordination and simulation (Mo, 2018).

3.3 BIM COLLABORATION

Definition of BIM in chapter 3.1 gave an overview on what are the main functions of BIM regarding Contractors use. However, not only presence of BIM is the only factor for its application, whereas various rules and regulations play a vital role as well. Thus, this chapter is going to introduce the collaboration formats and contractual agreements used, organizing the use of BIM when implemented in an organisational level or on a project level by a construction company.

In order to take a full advantage of BIM technologies, companies must not rely only on software solutions to get a competitive advantage. Murvold, et al. (2016) suggests that not only a software is what makes BIM process possible, but also tools such as BIM stations are what provides technical solution to production processing. Also, other portable devices such as tablets are what allows to

manage construction process when on the construction site as they immerse engineers and site workers.

However, a high concern is on whether the information given by designers to contractors is comprehensive enough and if it constitutes all of what is needed once on a construction site (Berlo & Nantrop, 2015) as for projects increasing in difficulty and complexness. Given the fact that BIM model carries much more information than traditional drawings it is necessary to identify if this model is going to be implemented on the construction site so that it brings all the advantages (Svalestuen, et al., 2017). Also, Svalestuen, et al. (2017) address that it is also important to acknowledge that regarding complexity of current projects it is vital to have a clear vision towards how BIM tools are implemented as they could create a confusion within the project team. Nonetheless, the link between designer and contractors should be well defined because if there is no partnership or contractual collaboration, then designer's BIM model and given information could not be comprehensive enough to be used by contractor and might require additional work for it to be usable (Smith, 2015). It also has been seen in study case done by Poirier, et al. (2015) that when the information obtained from engineers is lacking constructability, then that requires extra set of skills for it to be enhanced so that it is usable in a construction phases.

However, in certain cases BIM is also what may bring a confusion and decrease productivity to some extent. According to Svalestuen, et al. (2017) Norwegian industry by implementing BIM tools did not oversee that incautious aim to apply it brought a reduction of project team performance. Thus, it is vital to have a right pace when implementing BIM and to elevate concerns such as whether communication between designers and construction specialists is clear enough, what challenges may BIM bring between these parties, and what measures could there be when communication is done through BIM (Svalestuen, et al., 2017). Thus, the challenge many contractors face when applying BIM is the definition of the process as it has many deviations from traditional workflow. Therefore, BIM may significantly change the project delivery process and that may add barriers to BIM's full potential.

According to Ussing, et al. (2016) traditional construction contracts usually are set to be defined in a way that individual entity is taking responsibilities if errors are made in the project, thus, allowing to focus on risk management from a very individual perspective and for the party to shed away avoidable loss. However, BIM changes the way traditional contracts are written and brings

uncertainty into area of responsibility regarding risks, legislations and ownership of digital information (Ussing, et al., 2016).

Another aspect of traditional contractual agreements is that it grounds project team members to share creative solutions only within the organisational boundaries rather than collaborating outside of organisation (Fischer, 2017) defining it to be transaction across project parties (Mejlænder-Larsen, 2018). Whereas (Lahdenperä, 2012) defines opposite approach to transactional relation:

> *"A contract which is based on a relationship of trust between the parties, and where responsibilities and benefits are apportioned fairly and transparently, is called relational as opposed to transactional"*

That brings back to the concept of BIM which reinforces collaboration which distributes areas of responsibility and may bring disputes to the parties regarding shared contractual terms on risk and ownership (Ussing, et al., 2016). On the other hand, not necessarily shared responsibilities may result in possible conflicts between the parties. For example, relational agreement that has a similar concept as BIM does, may also result in beneficial outcome when it binds parties into partnership that enables to minimize transactional costs (Mejlænder-Larsen, 2018). Matthews & Howell (2005) in their case study gave a set of questions of which one was regarding relational collaboration between project parties:

> *"What if all of the design and construction entities on a project could be organized in such a way that they all functioned as if they truly were a single company with a single goal and with no competition amongst themselves for profit or recognition?"*

Therefore, main aim for contractor companies is to achieve project benefits that are low numbers of rework in construction, high-quality design and enhanced production process that is a result of a cross-organisational collaboration that is unfortunately difficult to achieve (Sacks, et al., 2016). Thus, this guides towards a new systematic and directed approaches that are defined by contractors publishing BIM documents that are various protocols followed by guidelines on how to implement them (Sacks, et al., 2016). According to Kassem, et al. (2015) BIM protocols are classification of BIM knowledge, in other words a taxonomy. There are two types of taxonomies of which one is descriptive and other one is prescriptive. Accordingly, guides and protocols are issued by government agencies to promote BIM implementation as part of national standards (Sacks, et al.,

2016). BIM standards define design and construction phases as well as how it is used in collaboration and what information needs to be exchanged followed by other relevant aspects of BIM (Sacks, et al., 2016).

Currently BIM standards describe what possible schemes should be used for data exchange, that include Industry Foundation Classes (IFC) schema and Model View Definition (MVD) that is specified by domain (Sacks, et al., 2016). However, documents that are in project, organisational or national level are defined to be guides which according to Sacks et al. (2016) are:

> *"Guides are <…> documents that establish common ways of working and the contents of BIM exchanges that are appropriate within the relevant contexts and along project timelines"*

However, the outcome of case studies that Sacks, et al. (2016) conducted brought a conclusion that even though implementation of BIM is what governments may be mandating, organisations are the ones that define their own specific needs as they may vary accordingly to different organisations. Thus, different BIM guidelines are set according to specific processes.

Other aspect of BIM guidelines is an insight of what are the details of what is described in documents. Thus, some documents define that there must be regular meetings established for the BIM teams so that each team member could collaborate in an environment that has all necessities such as physical space and digital technologies (Sacks, et al., 2016). Moreover, Alhava, et al. (2015) have researched that many of BIM standards in regard to collaboration requires that there is a "Big Room" which is used for all parties to collaborate in, and builders, designers are allocated to it in a duration of a project.

However, main document that is used to execute a project that is based on BIM tools is BIM Execution Plan (BEP) which is a central part of any BIM project and thus Sacks, et al. (2016) gives a general description on what BEP is:

> *"It defines the desired modes of collaboration and information sharing, covering the roles and responsibilities of all partners involved, the software applications to be used, the scope and level of development of the different aspects of the model required at each stage for each design discipline, the management of the model itself, quality control procedures, object composition and naming conventions"*

Thus, as seen from literature articles BIM changes the traditional collaboration and opens new types of contractual relationships between project parties. Therefore, the change of contractual and collaboration relationship is set to be a vital part of BIM implementation. Moreover, Matthews & Howell (2005) depicts that contractual relationship between parties can be set by a joint venture where parties are binding to collaborate as part of their shared risks and profit. And this is one of possible contractual agreements set to be beneficial and applicable once BIM is an integral part of the project.

Poirier, et al. (2015) distinguishes main factors on an industry level that are vital for the BIM implementation and development:

- BIM is poorly demanded by clients that are owners and general contractors
- Contracting and mechanical engineering is seen to be a market segment that has a low level of maturity in terms of BIM
- Low intensity of industry's development regarding BIM

As investigated by a Poirier, et al. (2015) in a case study, perception of a General Manager regarding BIM:

> *"The biggest challenge I think has pretty much been being "lonely BIM" on all the jobs we have done. We have yet to be on a fully integrated BIM project. Even ones that we were told would be [fully integrated] during tendering, have not proven to be <…> we are basically driving the bus. We are getting very limited support from anybody else"*

Given the analyses in research articles, perception of how complex BIM is in terms of its implementation and use, Sacks, et al. (2016) summarises that:

> *"BIM adoption is a complex endeavour, requiring preparation of a strategy that considers organizational maturity, industry capabilities, regional and national policies and regulations, education, purchase of hardware and of software, changing contract forms and more"*

As given by research articles it is clear that BIM is on a rise of development and there are still a lot of unclarity for contracting companies once they begin implementing it.

3.3.1 BIM Frameworks in Denmark

In Denmark, there has been some initiatives to organize and regulate the use of BIM between parties on aa construction project. In 2007, the ICT-declaration (Information and communication technology in public buildings) was created by the Danish association of construction, information technology, productivity, and collaboration (Bips) to define the use of BIM in the industry (Ussing, et al., 2016). Later in 2012, the association of consulting engineers in collaboration with the Danish Architectural companies (Bips, 2016) (Bips, 2016) (Bips, 2015) (Bips, 2016) (Bips, 2016) (Ingeniører, 2018) (Ingeniører, 2016) published the "Description of services for Building and Landscape" (YB2012) in order to define how the ICT-declaration intersect with the General Conditions for consultancy services (ABR89), in that document they have divided the areas of ICT support into seven areas (2018). The structure used in the YB2012 was later followed in 2013, when the Danish government published the new version of the ICT-declaration (Bips, 2016) making it a requirement for all public funded projects to use the ICT-declaration (Ussing, et al., 2016).

Furthermore, to compliment the ICT-declaration, Bips has issued other supplementing frameworks such as ICT A402-Process manual, the process manual (A402) supports the digital collaboration between parties involved in the project, so that they can agree and organize digital processes and deliveries effectively in accordance with the requirements specified in the ICT-declaration (Bips, 2016). In addition, Bips C402 consistency control offers a clear definition of the concepts and practices that should be used in order to assure the consistency of the project's models (Bips, 2016).

Other associations and organizations have issued some publications to support the ICT-declaration, concerning issues such as digital classifications (Bips, 2016) (DiKon, et al., 2018), or digital design (YB2016 8.4 Digital design), and some efforts from companies in order to produce a level of development (LoD) document (DiKon & BIM7AA, MTHøgaard, etc.). Figure 3.3 shows the relationship between the ICT-declaration (A102) and other publications in Denmark.

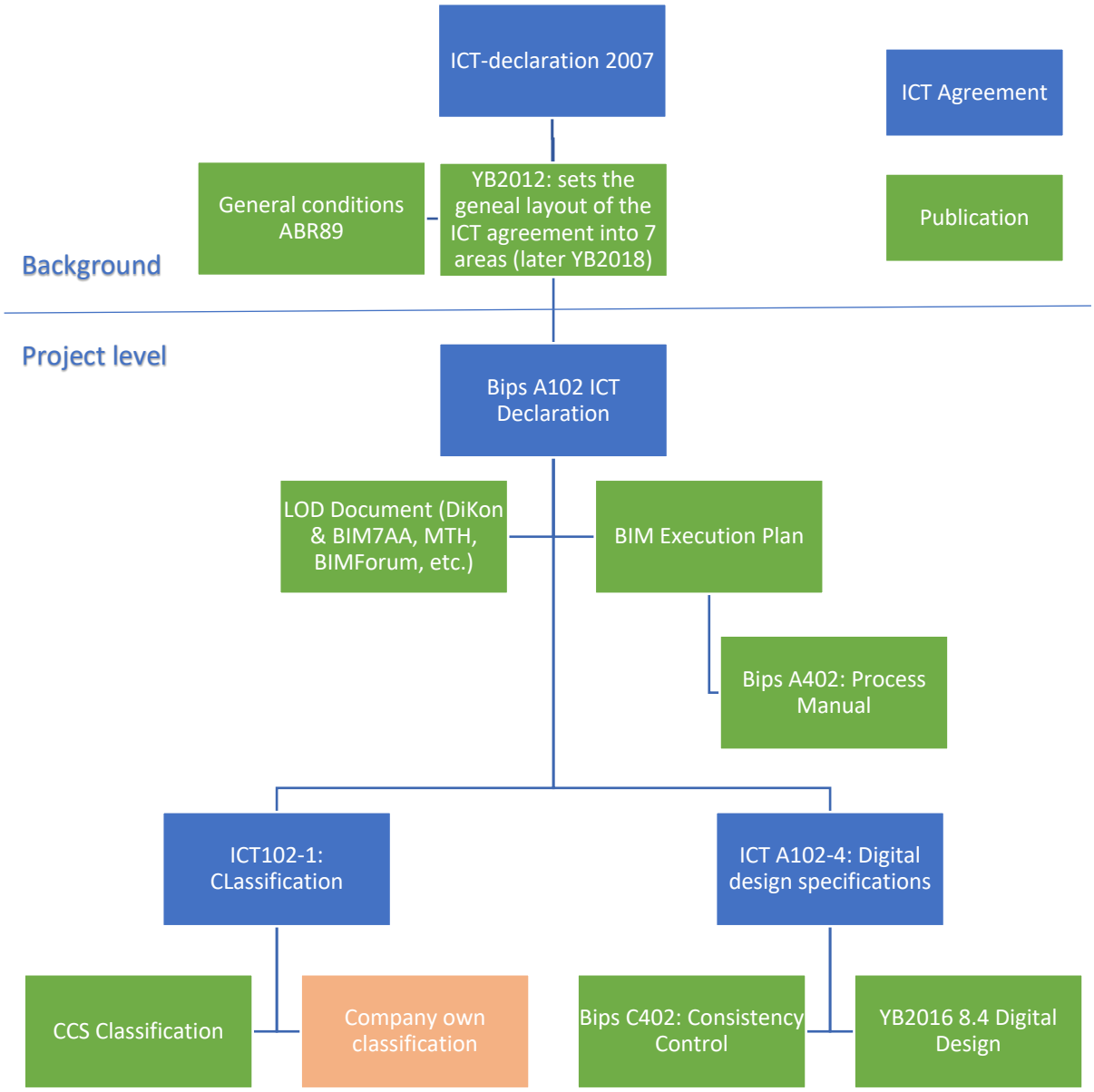

Figure 3.3 - ICT Declaration Hierarchy

3.3.1.1 Structure of the ICT-declaration A102

First introduced in 2007, the ICT declaration in its latest edition "ICT-declaration A102 2016" aims to create a contractual basis of all digital services between different actors, to motivate and organize the use of ICT/BIM in construction projects (Bips, 2016). Moreover, Ussing, et al. (2016) classified three types of requirements in the ICT declaration:

"Requirements which increase the quality and productivity performance for the building owner, requirements which increase the contractor's productivity performance in the construction, and finally requirements which increase the quality and productivity performance in the value chain system, which in this case include advisers, project supervisor, contractors, building material suppliers, IT suppliers etc."

The ICT declaration is categorized in seven chapters, setting the ground rules of the use of ICT/BIM in a construction project as follows:

- **A102-1 Classification:**

  Defining a specific classification and identification system to ensure the consistency in project documentation and models between all actors and during all phases of the project. When drafting the ICT agreement, the project parties have the liberty to choose any classification system they see best. However, some classification and identification systems are advised to be used in all projects in Denmark such as the Cuneco Classification System (CCS) (Bips, 2016), the system created by "Bips" aims to unify the classification methods used in the Danish AEC industry (Bips, 2016):

  "CCS gives the construction industry a common language and methods for establishing unambiguous exchange of information through the entire construction process from idea to operation"

- **A102-2 Digital communication:**

  Identifying a digital communication platform, containing all documentations and models related to the project, which should be available at all times for all parties involved. This document also specifies the common naming system of all documentations as well as the method of managing all data. The use of "Bips A104 Documents handling 2015" is advised to be used on all projects (Bips, 2016) (Bips, 2015).

- **A102-3 Establishing of a communication platform:**

  After specifying a digital communication platform, this clause sets up the general description of what the agree platform should consist of as minimum requirements.

- **A102-4 Digital design:**

  The digital design clause specifies "What must be delivered" (2016). For a better use of ICT/BIM technology on construction projects, all parties must agree on the utilisation of their models and documentation as well as the level of development of these models. The digital design requirements are advised to be peered up with an Information delivery manual (IDM) to specify further information; "How it will be delivered" and "How much exactly is to be delivered by BIM design".

  Furthermore, "Bips" advises to use the consistency control C402 document specifying the requirements for consistency in the models designed (Bips, 2016).

- **A102-5 Digital tenders and offers:**

  This clause specifies the platform on which the tender materials are to be published, as well as all file formats and extensions used in the tender documentations and models (IFC, XML, XLS, PDF, etc.).

- **A102-6 Bill of quantities:**

  This clause states the main source of quantities used on the project, and to what extent models' quantities can be used in cost estimation.

- **A102-7 Digital delivery:**

  The digital delivery clause defines the documentation delivered between different parties throughout the project phases (consultants to contractors, contractors to facility managers, etc.). the type of documentations and models are defined, and the level of development each party must deliver is specified. For contractors this would allow them to know the areas in which they could use the model for during the construction phase, and what kind of as-built documentations and models should they deliver on handover to the facility management company.

In addition to the ICT declaration agreement, "Bips" has issued several other documents to support the implementation of the agreement and give the parties involved better understanding of the requirements they must meet under the ICT declaration.

- **A402 ICT Process Manual:**

  The process manual is a project-oriented collaboration tool that is used to reach the requirements and specifications drafted in the ICT declaration agreement (Bips, 2016)

Moreover, the process manual is a non-contractual agreement, and its sole use is to facilitate and organize the use of BIM between all parties involved. These parties mostly being between the consultants and contractors, whereas the agreement can be seen as some form of an IDM, drafted and organized in accordance with the ICT declaration clauses.

- **LoD publications:**

  There has been a lot of initiatives in Denmark to develop a level of development agreement reflective of the practices performed in the industry. The most recent publication is the DiKon & BIM7AA Building specifications 2018 (2018), published by DiKon, an organization formed by the leading construction companies in Denmark, this document tries to merge many LoD specifications used in Denmark in one appendix. The LoD document is attached as an appendix to the ICT declaration agreement in order for all parties to see the specified information they must meet for their agreed models' level of development.

3.4 COMPETENCES AND PRACTICES NECESSARY FOR BIM USE

By looking forward to the nearest future there is an opportunity for BIM not only to be the innovative software or the new collaborative process definition, but it most certainly is heading towards being a specialisation (Adamu & Thorpe, 2016). However, that is limited by current educational frameworks as BIM in construction management needs to be defined in a correct way and in many ways in education it tends to be taught as stand-alone software and is limited by one discipline whereas it should rather be taught as of a collaborative process (Leite, 2016).

According to Sacks, et al. (2016) BIM lacks to be trained through academic or professional institutions whether for architects or for engineers as well as it is not a requirement to have BIM competences as part of professional certification. Thus, resulting that for now this competence is not a requirement of pre-condition for construction project's competition (Sacks, et al., 2016). It is important to mention that current BIM development within AEC industry is what brings a change to the way this industry is moving towards to creating new possible specialisations as BIM manager, BIM coordinator, BIM engineer, BIM consultant and BIM designer. However, according to Sacks & Pikas (2013); Succar, et al. (2013) there are not yet developed specialised educational programme to supplement AEC training and education.

There are also varying emphasis from people's perspective on what is BIM that result in different education. According to Chen, et al. (2014) two different geographical areas such as USA and non-USA perceive BIM adversely where American professionals tend to understand it as a technology

which then results in emphasis on the training , whereas non-American specialists perceive BIM as a process and that results in prioritisation on structuration and management of teams.

As depicted by Poirier, et al. (2015) BIM implementation is responsibility of two actors that are not only standalone businesses, but also educational institutions that are those that support well established education and training whilst involving professional associations that are to develop frameworks such as Level of Detail (LoD) and specific codes of practice necessary for BIM. To summarise given BIM adoption difficulties Poirier, et al. (2015) depicts common problem:

> *"the difficulty in finding adequate resources to further the BIM adoption and implementation process within the Organisation is seen as stemming from a lack of support and direction from the educational sector"*

Overall, as described in literature, BIM is yet being integrated into education and into organisational development of employees. And it is facing number of difficulties that may impede BIM popularity among contracting companies.

3.5 SUMMARY OF LITERATURE REVIEW

In Table 3.1 there is a given depiction of in the literature analysis used articles that correspond to construction areas in which BIM use was researched in this study.

Table 3.1 - Construction areas according to literature review

Area	Reference
Quantity Take-off	Eastman, et al., 2018; Aslesen, et al., 2018
Cost Estimation	Eastman, et al., 2018; Aslesen, et al., 2018; Ramaji, et al., 2018; Mo, 2018; Wei, 2017; Matejka & Vitasek, 2018
Time Management	Eastman, et al., 2018; Aslesen, et al., 2018; Ghaffarianhoseini, et al., 2016
Cost Control	Eastman, et al., 2018
Logistics Management	Eastman, et al., 2018; Whitlock, et al., 2018
Project Management	Eastman, et al., 2018; Ahn, et al., 2016; Mo, 2018
Collision Detection	Eastman, et al., 2018; Gledson, 2016; Sun, et al., 2015
Quality Control	Eastman, et al., 2018; Chen & Luo, 2014; Luo, et al., 2017

Area	Reference
Knowledge Management	Chen, et al., 2014; Murvold, et al., 2016; Berlo & Nantrop, 2015; Svalestuen, et al., 2017; Smith, 2015; Poirier, et al., 2015
Collaboration Frameworks	Ussing, et al., 2016; Fischer, 2017; Mejlænder-Larsen, 2018; Lahdenperä, 2012; Matthews & Howell, 2005; Sacks, et al., 2016; Kassem, et al., 2015; Poirier, et al., 2015; Bips, 2016; Bips, 2015; Bips, 2016; Bips, 2016; Ingeniører, 2018; Ingeniører, 2016

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4 PROBLEM FORMULATION

Throughout the literature review (chapter 3), the benefits of using BIM for contracting companies were identified through the use of BIM in various areas of the project. It was found as well that a successful implementation of BIM into the construction process requires a set of skills for the contracting companies and collaboration frameworks to organise the use of BIM between all parties involved in the project. However, literature related to the BIM in the Danish AEC industry was found to be minimal, along with researches about the used collaboration frameworks by construction companies in Denmark to organise the use of BIM. Therefore, this master thesis will investigate the use of BIM in contracting companies in Denmark by answering the following questions:

- What is the extent of BIM technology use among contractors in Denmark?
- How do contractors in Denmark collaborate the use of BIM with other parties on the projects?
- What are the challenges that contractors face when using BIM in Denmark?

By answering these questions, the use of BIM technology in contracting companies in Denmark will be rated in relation to the literature study and an average use of BIM among contractors in Denmark will be identified, along with some of the challenges facing contractors in adapting BIM technology on a higher level.

In order to answer these questions, the researchers will conduct a series of semi-structured interviews with several BIM coordinators and project managers from three large contractors in Denmark. The answers obtained from the interviews will be analysed and correlated with the conducted literature review.

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5 CASE DESCRIPTIONS

This chapter elaborates on companies that were chosen as a basis for data analysis in this thesis report. Thus, report analyses large contractors in Denmark that are Per Aarsleff A/S, MT Højgaard A/S, and Züblin A/S. Therefore, Per Aarsleff A/S and MT Højgaard were selected according to their annual turnover (Finans, 2018) that shows them being leaders among contractors in Denmark whereas Züblin A/S was chosen not only because of company being among big players in the industry but also because one of the researches is an employee within the company. Moreover, companies were chosen by researchers according to their given facilitation of VDC and BIM is what this research seeks to analyse and that is within the scope of the project.

Per Aarsleff A/S is a Danish civil engineering business that specialises on large-scale projects in infrastructure. Company was founded in 1947 by Per Aarsleff and employs over 6500 people within the Group inside Denmark and in subsidiary companies abroad (Per Aarsleff A/S, 2019). Today Per Aarsleff A/S facilitates Virtual Design and Construction (VDC) as they describe it:

> *"to visualise the final building, find alternatives, optimise the design, identify risks and find the most buildable solutions as well as plan and optimise the building processes – before the actual building construction starts" (Per Aarsleff A/S, 2019)*

MT Højgaard A/S is a Danish construction company that was established over 100 years ago in 1918 by Sven Schultz and Knud Højgaard. Today MT Højgaard A/S is leading business in construction and civil engineering with projects in Denmark and various places abroad (MT Højgaard, 2019). Thus, according to company's digital strategy their approach towards VDC is as following:

> *"we can not only view the construction virtually, but also predict the financial aspects, operation, maintenance, environment and eventually even the social responsibility of the building" (MT Højgaard, 2019)*

Züblin A/S is a Danish subdivision of German construction company Ed. Züblin AG which was established in 1898 by Eduard Züblin. However, Züblin A/S in Denmark dates to 2002 with a focus on ground engineering and nowadays company expanded into handling variety of construction projects across Denmark (Züblin A/S, 2019). Thus, concerning company's digital processes they solve complexity of today's construction projects by using BIM as it is their integral part of the project:

"We use BIM 5D as an essential tool in both planning and execution to visualise, analyse and coordinate our projects" (Züblin A/S, 2019)

Further on in this study described companies are going to be anonymously referred as letters A, B and C due to confidentiality. Therefore, in company A and company B researchers interviewed a BIM Coordinator (BC) and Project Manager (PM) in each and in company B there was an interview only with BIM Coordinator (BC). Thus, interviewees are going to be referred as BC1, PM1, BC2, PM2, BC3 as follows. Given Table 5.1 shows a summary of all interviewees experience within BIM use.

Table 5.1 - Interviewee experience within the construction industry and BIM

Company	**A**		**B**		**C**
Professional position	BIM Coordinator (BC1)	Project Manager (PM1)	BIM Coordinator (BC2)	Project Manager (PM2)	BIM Coordinator (BC3)
Experience with BIM	4	8	7	7	6
Total years of experience in the industry	22	26	7	11	6

Therefore, as seen from the Table 5.1 interviewee experience with BIM differentiate from 4 to 8 years as that indicates that all interviewees have been familiar with BIM and its use and have gathered particular knowledge about it. Also, professional experience which varies from 6 to 26 years shows a comprehensiveness of industry's knowledge and practice.

6 DATA ANALYSIS

This part of the research consists of data analysis where the answers of companies' interviewees are analysed in order to develop an understanding of the areas in which contracting companies in Denmark use BIM technology and the way they collaborate and organise its use. The chapter will be divided into case studies, each case will analyse the data of one company, the participating companies will be referred to as companies A, B, and C. The answers of both interviewees from the same company (if applies) are presented and compared in order to find the company's way of processing in certain field. A table for each company is given at the end of each individual company's analysis with a summary of the company-specific use of BIM.

Two main areas of analysis are identified in this chapter. The first area is going to analyse the integration of BIM technology in the construction process of the three companies, in both the tender and construction phase. Further on, the second area will discuss the collaboration process and frameworks used by the three companies in order to systematise the use of BIM in their construction projects, as well as the way they manage BIM data in terms of storing and sharing internally and externally. The data analysed in this chapter is based on the interviews' transcription (Appendices B-F).

6.1 BIM INTEGRATION INTO THE CONSTRUCTION PROCESS

The use of BIM functions in the construction process will be divided into two phases in which contractors are usually responsible in a construction project. The tender and early construction phase chapter will identify the BIM functions used by the interviewed companies to support estimators throughout the bidding process and the early planning activities up until the construction works start, the areas of BIM use identified in the literature review in Table 3.1 which will be used as a basis for this analysis. The execution phase chapter will analyse the areas in which the interviewed companies use BIM technology throughout the execution phase.

6.1.1 TENDER AND EARLY CONSTRUCTION PHASE

As identified in chapter 3.1 (BIM for contractors), BIM technology offers several tools to contractors and estimators in three main activities; quantity take-off, cost estimation, and project schedule planning.

According to the interviewees' perceptions on quantity take-offs at the beginning of the project, company A stated that they would always prefer to have any kind of BIM model that is either in IFC

or Revit file when calculating new bids, to extract the BOQ from. However, usually in early stages of the project that is not the case, and what consultancy companies provide contractors with is lacking in comprehensiveness or is a traditional non-BIM approach. In situations where they are provided with only 3D documentations and drawings are in 2D, PM1 distinguishes the method they use:

> *"we have Bluebeam review as a very good tool that we use, it is a very fast tool that we use to check that the quantities supplied to us by the tender materials are correct or not" (PM1, answer 4)*

The challenges facing contractors when only 2D drawings are supplied by the tender material for the quantity take-off were highlighted by BC1, where it was necessary to make a 3D model on *Tekla* to have a better accuracy. More precise quantities were generated out of the new 3D model in addition to the better visualisation of the project the model has provided (BC1, answer 4). However, in some situations just having a BIM model is not enough, where the level of development (LoD) of BIM models play a significant role in determining the degree to which the model can be used in specific tasks especially in quantity take-offs. PM1 stated that this problem often occurs on main contract projects in which consultants and engineers deliver low LoD models limiting their BIM capabilities as then they are unable to facilitate BIM to its full potential (PM1, answer 4)

As indicated by both interviewees their company is moving forward with the use and implementation of iTwo (RIB) software that is known as a BIM 5D tool used for cost estimation and linking cost to quantities and activities. However, they use it only in some cases and from BC1's perspective it should be seen as a working process (BC1, answer 4). As well, PM1 stated that the extent of the use of iTwo as a BIM tool differs depending on the project manager in charge and how well does he/she know how to use the full potential of the software (PM1, answer 5).

Regarding time scheduling in tender phase, if there is no schedule provided, then company A use one of traditional tool that is MS project, where professional planners within the company put down the ideal work schedule (PM1, answer 6). The company A uses other planning tools as well such as Navisworks and Synchro for 4D stimulations and constructability checks of the prepared time schedules, and in few cases, they use VICO Schedule Planner for its location-based planning abilities, and Tilos on railway and highway projects. (PM1, answer 6).

When it comes to company B, quantity take-offs are mostly done based on the 2D documentations and drawings. Using Bluebeam as well, the company's estimators calculate areas and quantities

from the drawings to prepare accurate BoQs (BC2, answer 4). BC2 confirmed company A's reason for not using BIM technology more in the tender phase by stating:

> *"We don't use BIM because we only have pdfs, we only get a model on 10-20% of new projects of which only 25% would have reliable LoD (Level of Detail) where we can extract an accurate BoQ" (BC2, answer 4)*

Concerning cost estimation on new projects, both interviewees stated that their company use Sigma estimates, and the use of this tool in BIM is dependant of the project manager own experience with using it (BC2, answer 5; PM2, answer 5). However, PM2's perception on cost estimation in tender phase is as follows:

> *"I think its important part for us that we need to use different software and it's a combination of a different software that give us the best result when we need to take our quantities and put some prices on it" (PM2, answer 4)*

Regarding early time scheduling and planning on the projects BC2 distinguished that it depends on the type of contract. In case of a design-bid-build (main contract), the main schedule is usually provided by the consultant. On the other hand, if it is a turnkey contract then the initiative is to establish a well-defined location-based schedule using Vico office in which 4D model is established to assure the constructability and the quality of the schedule (BC2, answer 6). PM2 confirmed the use of Vico office as a main tool for planning their construction projects in order to plan the project in a location-based manner. However, he expressed the challenge they face in using the heavy full Vico office software, instead they use Vico control, a much lighter and faster tool to use (PM2, answer 6).

Moreover, BC2 stated that the use of any BIM technology such as 4D modelling depends on the need of it at each project:

> *"We look up into whether this will give us any value; is the project complex; do we have a model; is it worth to make a model" (BC2, answer 6)*

Adding that the Company develops 4D models in early stage only in around 5% of their projects (BC2, answer 6), other tools are used in addition to Vico office on a smaller scale such as, MS Office and Primavera (PM2, answer 6).

In company C, the quantity take-off process usually depends on the particular project and the nature of the tender documents they have received, where in most cases the tender material provides 2D documentations and drawings only (BC3, answer 4). Nevertheless, if they receive IFC files of BIM models, then various tools are used such as Solibri, Navisworks and Revit that company has implemented (BC3, answer 4). Hence BC3 distinguishes that:

"in Denmark it is still not always that BIM models and IFC files are contractually overtaking the drawings and documentations" (BC3, answer 4)

Which underlines another challenge facing company C in relying on BIM models for quantity take-off instead of the 2D documentation and drawings.

For cost estimation, company C uses Sigma estimates regardless whether BIM is used in the process or not. In case BIM was used, then they use Sigma's 5D functionality linking the cost estimates to the 3D model (BC3, answer 5). Describing his own perception on BIM implementation at the company, BC3 said:

"We are moving to a more digitalised way of working and we are moving in the right direction but that is not something you can do in one day"

In terms of time scheduling in tender stages of the projects company C uses VICO office and Synchro as a basis for 4D planning, however, in some cases they have projects on which they use traditional MS Project (BC3, answer 6).

6.1.2 EXECUTION PHASE

As discussed in chapter 3.1 (BIM for contractors), BIM technology can support contractors with various tools and functions throughout the project execution phase, making it easier for project managers to handover their projects in accordance with the conditions provided in the contract.

Starting with cost control of the construction project, PM1 stated that company A use iTwo software for cost control and defines a perception on its use:

"the work is divided into months with the quantities and the works performed throughout the projects and as you fill in the bills and budgets it shows how the project finances is doing and it gives you a forecast for project completion and we have a discussion based on the results shown on iTwo" (PM1, answer 8)

However, PM1 identified that the accuracy and anticipated result of the software's outcome depends on two main constituents; the level of detail in which the model is defined in iTwo, and the project manager's initiatives for full facilitation of the software (PM1, answer 8).

Regarding site logistics planning, BC1 distinguished that they are not using BIM since that in most cases logistics planning is done by foremen, who are experienced in this. Adding that it is easier use conventional methods in planning logistics on site especially that the blue-collar employees are more familiar with the traditional way of doing it and it will require time and effort to adapt new approaches (BC1, answer 7).However, BC1 stated that drone scans are captured for the construction site and its surroundings on some projects to link it to the 3D model in order to get a clear view of the areas around the project and their potential uses for logistics purposes. When asked about more complex construction sites with various parties involved and limited areas, PM1 gave an example of a current project of the company in which the clients overall project manager gathers logistics data from all contractors and subcontractors involved in the mega project and plans the logistics for a specific period of time without the use of BIM technology, adding that he is convinced that BIM wouldn't have added value to the process if used:

> *"client's project manager had the duty of gathering all logistics planning of the different companies and putting them into a master logistics plan for the upcoming period of time with a drawing showing the areas reserved and used by the different companies" (PM1, answer 7)*

For collision detection both interviewees indicated that they use Tekla model to detect for any clashes in the design (BC1, answer 8; PM1, answer 8). PM1 depicted that it is their best BIM practice as the information received from consultants have many design discrepancies (PM1, answer 8). However, according to BC1 if a project is not complex, then 2D drawings may be enough to see possible clashes (BC1, answer 8). Both interviewees pointed out to the use of Tekla to design the reinforcement for concrete, avoiding design errors on site and any clashes with other elements (BC1, answer 1; PM1, answer 1).

In quality control both interviewees indicated that the process is done in a traditional way by using paper-based plans and checklists:

"It really differs from a project to another, but it is still a very manual process, so it is still a red pen on a printed paper added to the As-built binders" (PM1, answer 12)

Even though company A proceeds to use traditional quality control methods, both interviewees expressed the company's plans to implement BIM supported quality assurance and control apps in the future (BC1, answer 11; PM1, answer 12).

Moving to company B, the BIM coordinator (BC2) was not really sure of the process used for cost control at the company, a clear indication that BIM technology is not used in that area. However, BC2 did mention that project managers use Aspect4 software (an ERP tool with no BIM functionality), stating that the duty of BIM coordinators is limited to supplying the project managers with the accurate quantities to be used in Aspect4 (BC2, answer 8). Nevertheless, PM2 identified another use of BIM in cost control process where an up to date 4D capture of the model is attached to the cost bills sent to the client each month (PM2, answer 8).

For planning and site logistics BC2 was clear that the use of BIM in logistics planning depends on the nature of the project and its surroundings:

"it all depends on the project how much space do we have how much time do we have" (BC2, answer 7)

Therefore, according to BC2 there were many cases in which company B had to implement different techniques in order to achieve the best results concerning logistics planning. In one of the projects they have used drone scanning to assure logistics in small area, and on another one they have used Revit model to add additional information such as trucks and their arrival time as well as objects' unloading areas and other important details (BC2, answer 7). Thus again, as perceived by BC2 it always depends on precondition if logistics on each project is complex enough to use BIM (BC2, answer 7). However, PM2 considers the use of traditional methods by using 2D drawings is enough in most of the projects:

"We can manage that in 2D and that for me is just an easy way to do that <…> (BIM) is still too flashy, and it does not generate the same value as I have to put in more resources of a project" (PM2, answer 7)

In terms of quality control, both interviewees identified Dalux software (a BIM supporting tool and database) as the main tool used in the company for quality checks (BC2, answer 12; PM2, answer

12). The quality control process is carried out by quality managers using Dalux on their tablet devices on construction site, the 3D model can be visualised on the tablet screen and managers can select the exact location in which they are carrying out the quality checks, and they can see the list of checks they have to do as well as further detailed drawings of that object/area. Following that, managers can then approve the quality of the works done or send the issue to the responsible person through Dalux for resolving (BC2, answer 12).

According to both interviewees, Company B uses both Solibri checker and Navisworks for collision detection. Moreover, BC2 specified that sometimes they even use BIM Collab as a communication tool for the collisions (BC2, answer 9; PM2, answer 9).

According to BC3, the use of BIM in company C is voluntary but highly encouraged, where each project manager has the freedom to choose the way he/she wants to carry out the assigned project. From that prospective, BC3 emphasised that the extent of BIM use in the company varies from a project to another, ranging from low BIM involvement to fully integrated BIM projects in joint venture projects.

The cost control process in company C is performed mostly by conventional non-BIM tools but BC3 stated that they have really good examples of the use of BIM in cost control in some projects using Vico office, but using BIM supported cost control is still not dominant in the company due to project managers' preferences (BC3, answer 8).

For site logistics and planning BC3 identified many tools that company C uses. However, the degree of BIM involvement in the process is dictated by the complexity of the project (BC3, answer 7). Yet according to BC3, a construction site 3D model is developed for the majority of company C's construction project allowing for a better logistics planning:

> *"We try to do a 3D construction site model for all our projects, that means the whole surroundings on site and not just the building itself" (BC3, answer 7)*

The construction site 3D models are developed on Revit, whereas Synchro is used for its functionality in site management and logistics (BC3, answer 7). When needed, BIM coordinators uses drones to laser scan the construction site for better understanding and more accurate logistics planning.

Clash detections are performed regularly by BIM coordinators on construction sites using Solibri and Navisworks tools (BC3, answer 9). Moreover, digital design of rebars is developed on Tekla

structures at all projects by company C, increasing the accuracy of the reinforcement manufacturing and reducing the amount of work on site (BC3, answer 3).

Quality control by the company C is done via Dalux and Trimble connect almost in all projects. In addition, interior laser scanning is used on some projects to assure the quality of elements (BC3, answer 12).

6.2 BIM COLLABORATION AND FRAMEWORKS

As found in chapter 3.3, in order for a construction company to successfully and efficiently incorporate BIM technology into its process, a clear set of collaboration standard should be set and agreed by a construction project's parties in order to predefine each party's responsibilities and their use of the model. In addition to important information for a smoother process. The interviewees were asked about the process of which they follow when starting a new project, in terms of agreements and frameworks organising the use of BIM and setting clear goals and means to effectively use BIM technology. Additionally, the interviewees were asked about the process they follow in gathering, storing and sharing BIM models and data, both internally and externally.

6.2.1 BIM KNOWLEDGE MANAGEMENT

For data storage Company A's employees save their models and documents on an internal server that can be accessed by all project members in the company (BC1, answer 14). Therefore, according to both interviewees data exchange internally between the project actors is done via traditional methods by sending PDF files or simply by sending screenshots via e-mail, and saving models on the accessible server (BC1, answer 14; PM1, answer 14).

In terms of data on site, company A's BC1 stated that the use of tablets is now dominant in the company. Managers and foremen have access to Trimble connect, a 3D viewer allowing the managers on site to visualise the project on portable tablets, and access latest updates of drawings and models. The experience that workers on site had using digital tools varied. Some of them got optimistic about its use and saw the value it brought to their activities, whereas other workers did not have a positive feedback of their experience and they still prefer the conventional way. However, seen from BC1 perspective, it is still a process and overall workers will get used to the use of tablets once they get better insights on its capabilities (BC1, answer 14). Company A also had tried using computers on site where they would be placed in a room for every project member to

use, however, that had some challenges and the use of tablet was seen as a better alternative (BC1, answer 14).

Regarding external sharing of data, as indicated by BC1 a specific online database for storing and sharing is always required by the client (mostly Byggeweb an online database), BC1 also indicated to the use of Trimble connect as a data sharing platform on some projects. Moreover, PM1 mentioned that on some larger projects they use Synchro data base, a BIM supporting database enabling better view of models shared (PM1, answer 14). Both interviewees named that IFC is most preferable format for project model sharing among external parties (BC1, answer 14; PM1, answer 14). Also, according to PM1 Company A has been looking into implementing BIM 360 (Autodesk), a cloud-based database for team collaboration, but it still in concern whether it is going to be used in the future (PM1, answer 14).

The use of Byggeweb as a database for data sharing was also stated by company B's interviewees, identifying it as the preferred database in Denmark by most of the clients. However, company B have started experimenting the use of Dalux, the platform they use for quality assurance and model visualisation to be used as the main collaboration database for its BIM support (BC2, answer 14).

Internally company B uses SharePoint (Microsoft, cloud-based) and Dalux. They also at times use A360 (Autodesk) that as stated by BC2 has difficulties in its functionality (BC2, answer 14). BC2 gives a perception on why sometimes one software is not enough to reach the best practice:

> *"it is hard to rely on one software because they promise these things will stay in the newer version and then they change them, or they promise they will put some wanted functions in the next version but we want it now not after one year" (BC2, answer 14)*

For external collaboration, company C uses Byggeweb as well following the requirement of most clients (BC3, answer 14). As for internal collaboration platform, they use Dalux and Trimble connect as given by BC3 on how these software platforms allow to view models and to select access to it. Also, company C's investigation of BIM 360 (Autodesk) was perceived by BC3 as follows:

> *"it is a very interesting tool, but it is still not a complete tool, because of the legal aspect of using it where Autodesk did not issue the complete service in Europe like they have in the US" (BC3, answer 14)*

Adding that the BIM development department at company C always try to investigate the newest digital tools and trends in order to make the work better for project managers to efficiently complete their projects.

6.2.2 COLLABORATION FRAMEWORKS

When it comes to collaboration frameworks and the way interviewed contractors organise their BIM implementations on construction projects. Both interviewees from company A have stated that the core framework used on their projects is the ICT declaration agreement (A102), the agreement defines the scope of BIM use on their projects regardless of the contract nature. However, PM1 stated that the full template of the ICT agreement is only used in fully or partly public funded project, whereas a customised agreement is drafted for private clients depending on the needs of the project (PM1, answer 13; BC1, answer 13). The extent to which ICT collaboration framework is used by Company A PM1 describes:

> *"we use the ICT agreement on all public funded and PPP projects and on 95% of private funded projects. The level of detail in the agreement can vary as needed but we always have it. We always follow the national guidelines in drafting the agreement and take it from there and change few things if needed" (PM1, answer 13)*

Moreover, BC1 indicated to the challenges they face to know what the details about their BIM responsibilities and what can they expect to receive from other parties through the ICT agreement specifically in main contracts in which the ICT agreement is already drafted when they start working on the project (BC1, answer 13). To overcome this, the BIM department at company A prepared detailed guidelines describing the processes BIM coordinators have to follow when working under the ICT agreement. However, BC1 also stated that in most cases the company adapts BIM technology in its projects even in the case where no ICT or BIM agreement was made with the client or consultants, for the sole purpose of bringing more value into the project process (BC1, answer 13). When the use of BIM technology becomes optional for a main contractor, and with the absence of any BIM models handed over to the contractor from the consultants or the engineers, it becomes very challenging to incorporate BIM into the execution process, BC1 emphasised. Consequently, there is no enough time for the main contractor to develop BIM models in the short period between the late tender and the start of the project, limiting their ability to benefit from BIM.

A similar situation might occur even with the presence of a BIM model developed by the consultant company, where the limited knowledge of the clients can affect their ability to assure the compliance of all parties with the ICT agreement. Resulting in inconsistent, low quality BIM models that contractors cannot rely on (BC1, answer 13). Both interviewees from company A speculated that the low quality BIM models developed by consultants are often a result of a low price bid in a very competitive market, where consultants often do not have the resources to assure the consistency of their BIM models and perform necessary changes (BC1, answer 1; PM1, answer 13).

At company B, the process of using BIM has more structure to it than company A. According to BC2, a BIM strategy plan is prepared when the company takes over a new project, specifically a turnkey contract. The BIM strategy plan consists of detailed information of the areas in which BIM will be used, a description of the way BIM will be used in these areas, and the responsible BIM coordinators and designers of the project (BC2, answer 13). The BIM strategy plan is designed to assure the compliance with the ICT agreement's demands, as well as what the project manager and BIM coordinator agree will create value for the construction process. BC2 stated that the ICT agreement is more responsible for defining other technicalities of the use of BIM such as; the database platform, documents naming, digital design requirements of all parties, etc. the ICT agreement is developed through a workshop between all parties involved at the beginning of the project in order to agree on the process used to deal with the specific situations (BC2, answer 13). Furthermore, the BIM department attaches a Level of Development (LoD) specifications and a Model Progression Specification (MPS) documents to the agreements prepared, to supply more detail resources to the managers working on the project (BC2, answer 13).

Moving to company C, the process carried out is similar to that in company B. At the beginning of the project the project manager and the BIM coordinator meet to take a look at the project's detail in order to decide the where would BIM create value for the process, the decisions made are then transcribed in a prepared template defining the areas of BIM used, the process, and the responsible employees (BC3, answer 13). Nevertheless, BC3 identified the ICT agreement as the only document organising the use of BIM on a project in company C, where all the parties involved in the project organise a workshop to draft the agreement and specify the minimum requirement for each party. BC3 added that in company C they tend to go beyond the requirements of the ICT agreement in order to create more value for their process, for instance; digital design or rebars in always developed by the company on all of their projects to avoid any design errors and increase the efficiency of the products using BIM supported off-site fabrication (BC3).

BC3 summarised the challenges facing a bigger implementation of BIM technology in construction projects and specifically for contractors by the fact that clients do not think BIM would create great value for the process, saying:

> *"I think it is a waste of effort and great potential when the engineers spend a lot of time working on the models and when they pass them in a main contract the models cannot be relied on, but we have to refer to the drawings" (BC3, answer 14)*

Adding that in most cases the clients carry out the facility management duties themselves upon project handover, which would limit their interest in having BIM models because it does not create value for them. Therefore, BC3 argues that all parties of the AEC industry should find a new way of collaboration in which they would create value not only for their own activities but for all actors on a project, saying:

> *"(We need to collaborate better) Because all of our works as different parties on a project is connected and we all effect the way others do their job" (BC3, answer 14)*

BC3 discussed a new collaboration format that company C is working on in collaboration with an architectural company and an engineering firm. The details of the newly designed framework remain classified for time being due to the highly competitive market company C operates in. However, BC3 described the new framework as shift in collaborating the use of BIM in the industry, enabling a fully integrated BIM process throughout the lifecycle of the construction project (BC3, answer 15).

Table 6.1 summarises the practices of all interviewed companies during the construction phase of the project using BIM technology:

Table 6.1 - Summary of BIM applications in companies A, B, and C

General Area	Area	Company A	Company B	Company C
Tender phase	Quantity take-off	From BIM model only if a reliable model is provided by the tender documents	Only from 2D documents	From BIM model only if a reliable model is provided by the tender documents.
	Cost estimation	iTwo RIB, a 5D tool not used to full potential in most of the projects	Sigma estimates, a 5D tool not used to full potential in any	Sigma estimates, a 5D tool not used to

General Area	Area	Company A	Company B	Company C
			of the projects (presumably)	full potential in most of the projects
	Schedule planning	MS Project planning, 4D model is used to review the schedule prepared using Navisworks and Synchro	Vico office, location-based planning linked to BIM model in many of the projects. No use of 4D BIM in early stages.	Vico office, location-based planning linked to BIM model in many of the projects. Synchro for 4D planning
Construction phase	Cost control	iTwo RIB, a 5D tool not used to full potential in most of the projects	No BIM uses	Non-BIM tools in most projects, Vico office on some projects
	Logistics planning	BIM use is limited to drone scanning linked to the 3D model to create a realistic construction site model	Drone scans to develop a construction site model, Revit for logistics planning of trucks and loading areas scheduling	A construction site 3D model is developed for each project, drone scans when needed, Synchro for logistics planning
	Project management	Digital design of reinforcement on all projects, tablets on site using Trimble connect to visualise the model and access drawings	Tablets on site using Dalux to visualise the model and access drawings	Digital design of reinforcement on all projects, tablets on site using Dalux and Trimble connect to visualise the model and access drawings
	Collision detection	BIM based collision detection using Tekla and Navisworks	Solibri and Navisworks for collision detection	Solibri and Navisworks for collision detection
	Quality control	No BIM uses	Use of Dalux, a BIM supporting tool for quality control	Use of Dalux and Trimble connect for quality control, laser scanning on some projects
Knowledge management	BIM knowledge management	Trimble connect platform for models and documentations, internal server for all data sharing	SharePoint (cloud-based) for storing and sharing of documentations, Dalux platform for models sharing	Dalux and Trimble connect platforms
Collaboration frameworks	Internal collaboration	Internal guidelines of the process followed in each ICT agreement clause	BIM strategy plan; setting the areas in which BIM will be used in the project, the process, and the responsible	A prepared template describing what the project manager and BIM coordinator decided to use BIM at in the project
	External collaboration	ICT declaration agreement	ICT declaration agreement	ICT declaration agreement

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7 DISCUSSION

The discussion chapter of this report will be divided into two chapters. The first chapter will be a comparison of the data analysed in chapter 6 (Data analysis) from the interviewed contracting companies regarding the use of BIM technology, and the theories of BIM uses for contractors and the collaboration frameworks in Denmark discussed in chapter 3 (Literature review), based on that, the researchers will rate the companies' use of BIM in each category and an average practice of BIM for contractors will be identified based on the data summarised in Table 6.1. Following that, chapter 7.2 will classify different reasons for the poor or average performance in using BIM technology for contractors in construction projects.

7.1 THE USE OF BIM IN CONTRACTING COMPANIES IN DENMARK

The aim of this chapter is to discuss and rate the application of BIM technology in the three researched contracting companies in order to come up with an average practice of BIM for contractors in Denmark regarding each of the areas identified in Table 3.1 and further investigated in Table 6.1. The rating scale used in this chapter is inspired by three-points Likert scale, a rating of good, average, or bad will be given to the practice of a company in a specific field compared with literature review in chapter 3 and the researchers' perception. An average practice in each specific area will be identified further on and will be rated based on the average rating of the three companies. An illustration of the rating system is shown in Table 7.1:

Table 7.1 - Company rating system

Area	Company A	Company B	Company C	Denmark Avg.
BIM function	Good BIM practice	Average BIM Practice	Bad BIM practice	Average practice of the three companies

A good practice will be given the value of 1, an average practice the value of 0, and a bad practice the value of -1. The average of Denmark will be taken based on the average score of all three companies as follows:

- Good BIM practice: for average values of +0,5 to +1.
- Average BIM practice: for average values of -0,5 to +0,5.
- Bad BIM practice: for average values of -1 to -0,5.

The chapter will be divided into two topics, following the path of this report. The first topic will discuss BIM practices in the construction phase, whereas the second topic will discuss BIM collaboration and frameworks.

7.1.1 BIM functions in the construction process

Starting with tender phase activities, there has been a distinguish between main and turnkey contracts when it comes to activities such as, quantity take-offs from BIM models and cost estimation. Contractors often use traditional methods in calculating bids when it is a late bidding main contract, especially when no reliable BIM models are submitted with the tender materials. Therefore, contractors in Denmark have very low implementation of BIM technology when it comes to tender phase, regardless of the BIM supported tools they use that makes them ready to use BIM in tender phase if the circumstances allow. When it comes to Turnkey contracts, contractors tend to use more BIM support in bidding activities depending on the knowledge of the managers handling the specific bidding process. The researchers noticed the limited role of BIM coordinators in tender phase, in which they only contribute in retrieving accurate BoQs from models, and participate in planning the use of BIM in further stages of the project (i.e. execution phase), this lack of contribution results in a more basic use of the estimation tools contractors use (Sigma estimates, iTwo RIB, etc.). This might correlate with Ramaji, et al. (2018), arguing that the value-over-difficult ratio of BIM use for cost estimation is very low, and the use of BIM would not save time of the process. Wei, L. (2017) also indicated that the key BIM use in tender phase is obtaining accurate and detailed BoQ from the models, a result of poor standardisation in the estimation tools that would allow estimators to use them in a fast and effective way (Matejka & Vitasek, 2018).

The use of BIM was more present in schedule planning, all companies found it very beneficial to use 4D models to review their time plans. However, the use of BIM technology in schedule planning was mostly limited to 4D visualisation and did not go further to be updated by time to end up with an as-built 4D model by the end of the project. The reason behind that was what Eastman, et al. (2018) pointed out, stating that the reorganising and regrouping of components in the 4D model would result in a higher quality and accuracy 4D model that reflects the as-built process. Nevertheless, some of the BIM coordinators interviewed reflected on that issue saying that reorganising the elements and dividing them based on the time schedule is a time-consuming process that contractors do not think will bring value to their work. There are many initiatives to use BIM

supporting time scheduling tools (ex. Vico planner) which would set the ground for a bigger implementation of BIM technology in the process in the future.

The use of BIM technology is cost control is not so different than cost estimation, BIM involvement in cost control process is very limited. Some contractors tend to use the same tools for both cost estimation and control, and others use other tools with no BIM support. Just like cost estimation, the use of BIM in cost control is very limited to the project managers' preferences and experience in using the software, as well as the quality of the BIM model and the BoQ.

When it comes to logistics planning, the majority of the companies interviewed agreed with literature arguing that BIM supported logistics planning would help foreseeing any potential conflicts in the schedules between temporary and permanent components of the project, and organising site logistics (Eastman, et al., 2018; Whitlock, et al., 2018; Bortolini, et al., 2019). Many contractors in Denmark use different logistics management tools, starting with the development of a 3D construction site model developed by correlating the project's 3D model and drone scans of the project's surroundings to get an accurate site model. Multiple tools are used by contractors for logistics management such as Synchro software and Revit. Nevertheless, many contracting companies in Denmark still use traditional methods for logistics management.

Different other BIM functions are used by contractors in Denmark during project execution. Most contractors tend to model digital reinforcement using Tekla structures in order to reduce omissions and errors that might occur on site in cutting and bending of bars process, a point emphasised by Maciel and Correa (2016). Digital collision detection checks is an activity performed by all interviewed, increasing the accuracy of the models and foreseeing any clashes that they might face in the process, benefits discussed in the literature review by Gledson (2016), and Eastman et al. (2018). Moreover, contractors in Denmark are relying more on tablets on site for model visualisation and accessing all detail drawings using BIM supporting platforms, an activity that all interviewees agreed to be reducing errors and reworks on site.

Furthermore, the use of BIM in quality control and assurance could be the most growing use of BIM among contractors in Denmark, the majority of contractors in Denmark are either using BIM for quality control or have serious plans to embed it in the near future. The use of BIM in quality management creates value for the project by providing detailed data of building components, increasing the quality in the checks, as well as the potential it offers by having all as-built documentations stored in the quality control platform (Chen & Luo, 2014).

Finally, Table 7.2 illustrates a summary of the use of BIM in each area of the construction process for the interviewed companies, the rating of BIM performance based on the rating scale presented in Table 7.1, and the average use of BIM technology in Denmark for contracting companies:

Table 7.2 - Company rating according to BIM functions performance

BIM function	Company A	Company B	Company C	Denmark Avg.
Quantity take-off	From BIM model only if a reliable model is provided by the tender documents	Only from 2D documents	From BIM model only if a reliable model is provided by the tender documents.	BIM models are used for QTO if a reliable model is available. Or if it's a turnkey contract
Cost estimation	iTwo RIB, a 5D tool not used to full potential in most of the projects	Sigma estimates, a 5D tool not used to full potential in any of the projects (presumably)	Sigma estimates, a 5D tool not used to full potential in most of the projects	BIM supported cost estimation tools are used, but the use of BIM depends on experience and the presence of a model
Schedule planning	MS Project planning, 4D model is used to review the schedule prepared using Navisworks and Synchro	Vico office, location-based planning linked to BIM model in many of the projects. No use of 4D BIM in early stages.	Vico office, location-based planning linked to BIM model in many of the projects. Synchro for 4D planning	BIM supported schedule planning tools are used, 4D modelling is used to assure the constructability of schedule
Cost control	iTwo RIB, a 5D tool not used to full potential in most of the projects	No BIM uses	Non-BIM tools in most of the projects, BIM for cost control using Vico office on some projects	The use of traditional cost control tools is more dominant, some examples of efficient use of BIM 5D for cost control
Logistics planning	BIM use is limited to drone scanning linked to the 3D model to create a realistic construction site model	Drone scans to develop a construction site model, Revit for logistics planning of trucks and loading areas scheduling	A construction site 3D model is developed for each project, drone scans when needed, Synchro for logistics planning	Logistics planning tools are used for digital management of construction sites, drone scans are used for more accurate site models

BIM function	Company A	Company B	Company C	Denmark Avg.
Project management	Digital design of reinforcement on all projects, tablets on site using Trimble connect to visualise the model and access drawings	Tablets on site using Dalux to visualise the model and access drawings	Digital design of reinforcement on all projects, tablets on site using Dalux and Trimble connect to visualise the model and access drawings	Off-site digital fabrication for reinforcement is used, tablets are used on site to access models and drawings easily
Collision detection	BIM based collision detection using Tekla and Navisworks	Solibri and Navisworks for collision detection	Solibri and Navisworks for collision detection	Collision detection BIM tools are used
Quality control	No BIM uses	Use of Dalux, a BIM supporting tool for quality control	Use of Dalux and Trimble connect for quality control, interior laser scanning on some projects	Many contractors perform quality control through BIM supported platforms using tablets on site.

7.1.2 BIM collaboration

When it comes to BIM collaboration, contractors in Denmark are performing well in terms of internal collaboration using BIM supporting database platforms, allowing all project members to access the models and drawings for visualisation, and retrieving needed data in a fast and effective way. However, the internal collaboration concerning the use of BIM is in most cases is not drafted in a clear framework in order to allow employees to get a clear view of their duties and the general scope of BIM use in each area of the project, even though the majority of companies have internal general guidelines for the use of BIM in each area of the ICT declaration agreement (ex. Classification, digital design, digital communication, etc.).

On the other hand, the external collaboration of BIM use in the construction industry is unified in Denmark. With the ICT declaration agreement as the sole framework organizing BIM collaboration between parties. Most companies reflected their unsatisfaction of the agreement, implying that it is a first step into wider BIM implementation in the industry, but it should be more detailed. The researchers found that contractors in Denmark do not use other non-binding frameworks offered by Bips, such as, the process manual A402, and the Consistency control C402. These standard agreements have the potential to support the use of the ICT agreement. However, further researches in the use of these standards are advised to be carried out to determine the value they add to the project collaboration. Furthermore, upon analysing the various standards and

frameworks organising the use of BIM in Denmark, the researchers have the impression that adapting the hierarchy presented in Figure 3.3 (chapter 3) would bring the same results of collaboration offered by other international frameworks such as the BuildingSmart's building execution plan (BEP), information delivery manual (IDM), and model view definition (MVD), given the fact that they contain nearly the same processes and structure.

Table 7.3 presents the summary of BIM collaboration processes in interviewed companies, the rating of the processes according to the rating scale in Table 7.1, and the average for Denmark:

Table 7.3 - Company summary based on BIM collaboration processes

Collab. area	Company A	Company B	Company C	Denmark Avg.
BIM knowledge management	Trimble connect platform for models and documentations, internal server for data sharing	SharePoint (cloud-based) for storing and sharing of documentations, Dalux platform for models sharing	Dalux and Trimble connect platforms	BIM models' viewers database platforms are used to facilitate the exchange of models and data
Internal collaboration	Internal guidelines of the process followed in each ICT agreement clause	BIM strategy plan; setting the areas in which BIM will be used in the project, the process, and the responsible	A sample template describing what the project manager and BIM coordinator decided to use BIM at in the project	No clear BIM collaboration frameworks for contractors to effectively perform BIM activities
External collaboration	ICT declaration agreement, LoD specifications	ICT declaration agreement, LoD specifications	ICT declaration agreement, LoD specifications	ICT declaration agreement, LoD specifications

7.2 CHALLENGES OF BIM IMPLEMENTATION FOR CONTRACTORS

This chapter will discuss the potential challenges that contractors face when implementing BIM technology into the construction process. Through the literature review conducted in this report and the primary analysis, the researchers classified three main areas in which contractors face challenges when implementing BIM:

1. **Lack of knowledge:**

The knowledge and competencies of employees in using BIM tools and the knowledge of the software's full potential is a key factor in a successful and efficient BIM use. BIM functions wise,

contracting companies are struggling with adaptation of BIM in cost estimation and control areas, in which they did not seem to reach the perfect formula of using the tools they already have for more BIM involvement in the process. On the other hand, the lack of knowledge of staff in using other frameworks to increase the collaboration of BIM use such as (Bips's Process manual and Consistency control; and Building smart's BEP, IDM, and MVD) can decrease the value created by BIM technology to the construction project, with the lack of clear definitions of the objectives, process, and resource allocation for each BIM use and function. Furthermore, the low level of knowledge of the clients for the benefits of BIM can influence their initiative to enhance collaboration between parties by obliging them to follow the ICT agreement and other collaborative frameworks. Table 7.4 illustrates the challenges contractors face in BIM collaboration:

Table 7.4 - BIM collaboration challenges

Collaboration Area	Lack of knowledge	Poor collaboration	Lack of interest
BIM Knowledge management			
Internal collaboration	The lack of knowledge of contractors' staff to deal with other frameworks (Bips; A402, C402, BuildingSmart; BEP, IDM, etc.)		
External collaboration	Lack of Knowledge for clients of other supporting frameworks to efficiently collaborate BIM use	Focus of companies in the industry on self-interest only and not the interest of the project	

2. **Poor collaboration:**

The performance of other parties involved in the project when it comes to BIM technology can heavily influence contractors' BIM performance. This bad influence is clear in main contracts specifically, in which the lack of a reliable BIM model developed by the clients' consultants or the engineers can limit the contractors' ability to use BIM in extracting accurate quantity take-offs which would reflect on both the cost estimation and cost control processes. Moreover, as expressed by many of the interviewees and literature (Mejlænder-Larsen, 2018), all actors on a construction project focus solely on what is in their own interest and not the interest of the project, and goals are set party wise and not project wise. This attitude in the AEC industry can negatively affect any attempts to enhance collaboration in general and not only digital collaboration of BIM.

3. **Lack of interest:**

Just like all technologies and methods, some contracting companies find some of BIM functions unnecessary and believe that current methods bring equal value to the project. This can be attributed to the not-yet competitive technology offered by BIM tools (Cost estimation), or because companies are poorly informed of the benefits of these technologies.

Finally, Table 7.5 summarises the challenges contractors face implementing BIM in each of the distinguished BIM functions based on the three challenges areas:

Table 7.5 - BIM functions implementation challenges

BIM function	Lack of knowledge	Poor collaboration	Lack of interest
Quantity Take-off		No reliable BIM models are handed over in tender phase that are minimum 300 LoD	
Cost Estimation	Most of project managers cannot use the full potential of BIM in the cost tools	No reliable BIM models are handed over in tender phase	The technology offered by BIM tools is not proven worthy yet
Schedule planning			Companies rely more on their experienced planners to develop the time schedules
Cost control	Most of project managers cannot use the full potential of BIM in the cost tools	BIM models' low LoD	
Logistics Planning			Some contractors are not convinced that BIM-based logistics planning would create value for the project
Project management			
Collision Detection			
Quality control	Lack of knowledge for some contractors to the benefits of BIM-based quality control		

Finally, it is found that contractors in Denmark use a variety of BIM functions in their processes. However, just like the other actors in the AEC industry, contractors are facing collaboration problems that is limiting their ability to carry on their BIM practices in many of areas of the project.

It is therefore recommended for contractors to inform and educate their project managers of the other frameworks supporting the use of the ICT agreement and oblige other parties in their projects to use them. Nevertheless, this recommendation has the limitation of contractors not being part of the ICT agreement drafting process when they are hired as main contractors. It is therefore the client's duty to be more aware of other frameworks, and contractors have the ability to inform their connections of clients and consultants to the importance of such frameworks in future projects.

7.3 RESEARCH PROCESS DISCUSSION

This section objective is to evaluate how did the research process was followed through, how well did it followed research design and how was validity and reliability assured. Also, it includes future studies that could be followed to either improve this thesis report or to continue with future studies.

7.3.1 Research reliability and validity

In chapter 0 there was a presentation of methods on how to assure internal and external project validity and reliability. Thus, internal reliability was achieved in a high level because interview guide allowed to distinguish investigated areas in a way that interviewee were able to answer comprehensive enough for the researchers to fully have all necessary answers to finalise summary of BIM applications (Table 6.1) without missing answers in all BIM areas. Also, high internal reliability correspond to high external reliability since following was a design of interview questions based on literature study which then enabled to have a complete discussion based on interviewee perceptions and compared with literature findings. Whereas for internal validity, goal was to have a number of interviews to represent large contracting companies in Denmark. Thus, since corresponding companies are large contracting companies, that allowed to represent great portion of industry's practices concerning this research's scope. However, to have a better overview number of corresponding companies could have been higher, but currently that is due to the limitation of time in which this project was carried through. As for external validity, it is clear that it is in high level since the research area is universal and can be transferred to further study in regard to contracting companies' practices using BIM in Denmark.

7.3.2 Future studies

This research presented an outcome of what is the average use of BIM in contracting companies in Denmark, since three large contracting companies were analysed in this study. Therefore,

considering that data was collected by series interviews, respondents from these companies were BIM coordinators and Project managers. Their perceptions on BIM subject were the ones that laid a background for what researchers were aiming for. However, to have a more in-depth analysis there could have been also other representatives from these companies that could have been included to have a broader study concerning other actors that are included in BIM process within the organisations. That would have enabled to have a wider perspective, to expand the research for future studies.

This research was very inclusive study of all aspects of BIM use for contractors, further studies can focus on one aspect or area to go more into depth regarding contractors' performance in BIM use.

Further researches can investigate the effect on collaboration that implementing all frameworks in Figure 3.3 (ICT frameworks hierarchy), by conducting a case study on a construction project to identify the potential change and improvement in collaboration between parties.

Other perspective on what could be done in the future studies would be to include wider range of contracting companies that are variating in their expertise to see how their use and practices vary according to differentiating projects. That could complement this study by adding a scale of expertise and to see how BIM implementation deviates according to it.

Since collaboration among contracting and consulting companies is another comprehensive area to analyse, this study can be elaborated on general contract level to have even more in-depth perspective on links between these project level entities. Broader continuous case study analysing knowledge management and collaboration between project parties could enable better understanding of data handovers that were discussed in this study.

8 CONCLUSION

BIM is a fast-growing technology, that aims to integrate and facilitate the construction process throughout its phases in a digitalised way to cope with the complexity of modern-day projects, and the multiple stockholders and actors they consist of. Contractors are important actors in the construction process, responsible for the execution of the project. This research aimed to investigate further the use of BIM technology in contracting companies.

Following the research design. The study started with a comprehensive literature review of BIM functions and practices for contractors, and the collaboration frameworks that exist both in Denmark and internationally. It was found that contractors can benefit from BIM in several areas, creating value of the construction process, and that several collaboration frameworks exist in Denmark mostly published by Bips (the Construction information technology, productivity, and cooperation organisation) forming a network of frameworks to organise the use of BIM in the Danish AEC industry.

Following that, the researchers were able to develop a problem statement questioning the extent of BIM use in contracting companies in Denmark, regarding both functions and collaboration methods, and the challenges contractors are facing in implementing BIM into their processes. To answer the problem statement, a series of semi-structured interviews with BIM coordinators and project managers from three big contracting companies were conducted. The data collected from the interviews was then analysed, and several variations in the implementation and use of BIM was then distinguished between the three companies.

By analysing the data collected from interviews and correlating it with literature review, the research came up with several findings concerning the use of BIM in contracting companies in Denmark. It was found that on average, contractors in Denmark have average to good BIM use in all areas in which BIM can support the construction process. Cost estimation and control were found to be the least developed areas of BIM use among contractors in Denmark, whereas BIM collaboration was found to be average among parties of the construction project, mainly because other frameworks are not being used to support the ICT agreement, the main and only agreement organising the use of BIM. Moreover, three main factors were distinguished for poor or average use of BIM technology among contractors; lack of knowledge, poor collaboration, and lack of interest. Finally, it was recommended for further studies to investigate consequences on collaboration

between AEC industry actors if all frameworks by Bips are implemented on a project, to determine effectiveness of these frameworks in enhancing BIM collaboration on construction projects.

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10 APPENDIX

Appendix	Description
A	Interview guide
B	Interview 1 with BC1
C	Interview 2 with PM1
D	Interview 3 with BC2
E	Interview 4 with PM2
F	Interview 5 with BC3

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APPENDIX A – INTERVIEW GUIDE

INTERVIEW QUESTIONS	QUESTION OUTCOME	FOLLOW-UP QUESTIONS	REFLECTIONS [WHAT WE EXPECT]
[Warmup questions]			
1. Can you tell us a little about your tasks and duties?			**The different tasks concerning BIM coordinators or PMs in different contracting companies in Denmark**
2. How long have you been using BIM for?			**To know the experience period of the interviewee**
3. Are there any internal guidelines deciding when do you use BIM on a new project?			**To know on what kind of projects do they use BIM (PPP – Public – Private)**
[Main questions] BIM Functions for Contractors			**These questions are only concerning projects where they use BIM**
4. How do you do your quantity take-offs on new projects?	They use BIM in this area	[No follow up question. Write down method and software used]	**To know whether they use BIM functions in extracting quantity take-off from a BIM model**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
5. How do you do your cost estimation on new projects?	They use BIM in this area	[No follow up question. Write down method and software used]	**To find out if they are linking 3D BIM model by use of software (e.g. iTow RIB, Primavera, etc...) to develop a 5D model for cost estimation.**

	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
6. How do you plan and prepare time schedules for your new projects?	They use BIM in this area	[No follow up question. Write down method and software used]	**To know if they use 4D modelling, linking time schedule software (MS project, VICO schedule planner, etc..) to the 3D model to assure the constructability of the project.**
	They don't use BIM	How do you assure the constructability of your plans?	**To verify that they don't use BIM 4D in planning.**
	If the answer still doesn't concern BIM use.	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
7. How do you plan and organize site logistics?	They use BIM in this area	[No follow up question. Write down method and software used]	**What BIM methods and software do they use for logistics planning (3D model with high LOD, Laser scanning using drones, specific logistics planning software, etc...)**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**

8. What is the process you use for cost control on projects?	They use BIM in this area	[No follow up question. Write down method and software used]	**To find out if they are updating BIM 5D model to control the cost in comparison to estimate.**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
9. How do you detect any collisions between designs? Or work clashes?	They use BIM in this area	[No follow up question. Write down method and software used]	**To know whether they use Collision detection software (Navisworks, Solibri, etc...)**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
10. How do you plan the weekly tasks and activities on construction site?	They use BIM in this area	[No follow up question. Write down method and software used]	**To know if they use 4D models and BIM logistics plan for the weekly plans on site, by discussing them in weekly meetings.**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**

11. How do your site engineers and workers perform their work on site and how is information exchanged with them?	They use BIM in this area	[No follow up question. Write down method and software used]	**To know whether they use any BIM technology (iPads on site, Stationary computers with 3D models, etc...) in order to exchange more information with the workers and reduce reworks concerning different activities (reinforcement, concrete casting, formwork, visualisation, etc...).**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
12. How do you assure and control the quality of your on-site production?	They use BIM in this area	[No follow up question. Write down method and software used]	**To find out if they use BIM-based platforms and checklists to link quality errors to existing BIM models.**
	They don't use BIM	Why do you do it this way and not through BIM functions?	**To know if the reason for not using BIM function in that area is because of:** **1. Lack of know-how workforce.** **2. Limited by regulations.** **3. Not convinced with the need of it.**
[additional questions] concerning BIM frameworks **if BIM is used in regard to most of the previous answers**			**To know if they establish BEP, how they manage interoperability, coordination, distribute responsibility areas, and solve legal aspects**

13. Can you take us through the process of using BIM on projects? How do you implement BIM in a construction project (steps?)	They mention a framework similar or is BEP	What is included in your framework?	**To know more about BIM maturity in the company and whether they use any frameworks (BEP-IDM-MVD)**
	They don't mention any frameworks	What documents do you use to define interoperability and coordination between involved parties?	**To know if they don't use BEP then maybe they use other frameworks**
14. How do you exchange project data/models with external parties?	They mention using cloud-based software.	Do you also use it for internal communication?	**To know if they use cloud-based technology (BIM 360 or A360)**
[Close-up question]			
15. Is it anything else you would like to add about BIM?			**To find out if there is something more that company does by using BIM that we haven't asked in previous questions.**

APPENDIX B – INTERVIEW 1

1.1. Can you tell us about your tasks and duties on this project?

<…> I'm in a waiting position <…> we are going to do the reinforcement; we are going to model it and then extract barbells from that <…> we use Tekla for that. But we've already done some BIM things which not I did but some other persons did> The project is not actually that… <…> on one hand it is not that simple, but on the other hand it is complicated because we have metro station and we have this tunnel <…> so at the beginning they did a model so that the client could walk in the model and see how complicated it actually is we have to put sheet piles and <…> it was nice for the clients to use Virtual Reality (VR) and see. We also used point clouds to see, because we are so close to the existing building <…> we didn't have a model of existing building, we had a point cloud. We did a lot of thing and we also want to do the 3D printing <…> also to when we talk with the clients to make it clear. We also have a 4D time schedule of the project. There is one guy in the office that is doing it and he is doing it in {indecipherable software name}. We don't have 5D.

- **What software do you work on personally?**

I work mostly in Tekla, but also on Revit and a little bit on Navisworks.

1.2. How long have you been using BIM for? How long have you been a BIM technician?

It depends on how you look at it. 4 years.

- **What previous experiences do you have before you became a BIM technician?**

I am a CAD technician. So, I have worked with CAD in years, I made drawings and stuff like that and then I <…> we had this education called CAD technic and then I took another one where I learned a little bit more about BIM. And I am a constructing architect.

- **And how long have you been working as a CAD technician before there 4 years?**

I've started in 1997.

1.3. Are there any internal guidelines deciding when do you use BIM on a new project?

No. I think a goal is to use it on any new project. But it is of course a question how much and what for are we using it on a project. We are doing reinforcement and I think we have done it so far in Tekla. And we use 4D a lot. I'm not sure but I think there is some sort of guideline, but I think when you look at any project you decide what makes sense now to use

- **Does it have to do with budget of that project if it is over something over 50 M DKK or something like that? Or does it have to do with what kind of client you have? Is it public or is it private or is it a shared?**

Of course, if client wants it, we have to do it but I still thing we often choose to it anyways because our experience. We are talking about ground engineering and that's a little bit different from buildings. Because buildings they have used BIM for many years. And it's kind of like client knows what it is about. They all want to use it. But for ground engineering is still like they are a little bit <…> so in ground engineering you will meet people that still doesn't really know what it is bout and what is the benefit and stuff like that but also you have to be aware that it also cost money and of course you have to use it in a right way to see the benefits. Actually, I'm sure that we have some kind of guidelines but it something they talk about when they start a project. I'm not a part of that decision what to use.

- **But it also involves if you have to use ICT declaration.**

But again, it is very common in buildings and in ground engineering it is not that.

1.4. How do you do your quantity take-offs on new projects? When you start a new project?

Normally, we use an IFC or a Revit file. And I think they are doing a schedule. I'm not doing it normally. So, I think they are doing a schedule.

- **But normally, in a BIM department they don't come for your help for the quantity take-off?**

It's often my colleague in the office that do that. We had a project where we wanted to do a tender and I made a model in Tekla cause we wanted to make it clear on what we are offering and from that one I've extracted quantities and sent report.

- **Do they mostly do the quantity take-off using as you said by Tekla or Revit model or IFC models? Or do they do it just by calculating based on drawings and documentation from the client?**

I would say that they do both. If we have a model, we use it. But I think that sometimes it's about generation in question. Older people they are used to look at the drawings. I know that they have tried to implement ITwo and I think we should look at it as a process and we are still working on it.

1.5. You have talked about ITwo and then it is same with the cost estimation.

I know that people on the tender department they have of course an ITwo and also a colleague which had it, so he knew what it is all about it.

- **So, you are saying that this colleague which is no longer in company. So, people in company they no longer use it for cost estimation?**

What I am talking about people in ground engineering because I know that people in building, they are using much more than we do. If we are talking company in general, then we use it.

1.6. How do you plan and prepare time schedules for new projects?

Often, we have a time schedule from tender documents. I think that this which we are using as a basic. I know that my colleague who is using synchro, he often gets a time schedule which are made in MS project and then he uses that one implemented in Synchro, and I think we use the same one for Navisworks.

- **But then how do you assure the constructability of the plans that are made before they come to you?**

Well, that the other guy. He should look at it we are also talk about it with health and safety because they have to also look at it (4D plan) because it is also important that they agree that it's constructible.

- **But you said that you also use Synchro 4D for the modelling normally that you play it and decide if the sequence is fine for the construction.**

But often the main time schedule is made in MS project.

1.7. How do you plan your logistics and organise them?

When it is detailed then we are actually not using BIM <…> it's usually the foremen, he sees when truck is coming, and drilling is on this particular project.

- **But if you have a BIM model, why don't you use more BIM for logistics planning?**

I think one thing is we have a model, but the other thing is using it active on the site. I think most of the guys here, they know how to look in the model, but by going on the site they have to do decisions and they are not used to it. So, I think they are still in process. When we are busy, we are using what we are used to.

1.8. How do you perform collision detection?

Well, again <…> we have received 2D drawings <…> we saw it in the model, but we didn't do any clash detection, because the clash is very visible. But in Tekla I can do a clash detection with reinforcement, I will run it in Tekla.

- **And how about other surrounding when you are drilling, with the pipes or with the cables?**

In this project we don't have it in 3D, cables or stuff like that, but I know on other sites we have done it before we've started drilling. <…>

1.9. How do you plan weekly tasks and activities?

It's not my work, but we have like three weeks schedule and I guess it is made in excel so it's not like BIM at all.

- **Why don't they use BIM for the planning? Maybe the project manager is not very experienced with BIM?**

I would say that guy doing the schedule I think he could do it if he wanted to. Maybe it's also a question again how it is faster for him. And sometimes you have to do a lot of things to do BIM so is it worth it.

1.10. How do your site engineers and workers perform their work on site and how is the information exchanged with them?

We are doing it in Synchro, and it is more to illustrate to client which task is depending on each, what is possible what is not.

1.11. What about quality assurance and control?

It is also the old way. On paper, schedule, checklists.

- **And why don't they use any BIM software?**

Right now, only done the sheet piles and very few things.

- **Is there anyone that goes to check it and compare it to Tekla model or something like that?**

I know that they have talked about to have an app. Because we receive a paper and we have to type it in afterwards. Well, it's not implemented on site.

- **Might it be implemented in the future?**

We hope so. So, there is a plan to use it.

1.12. When you as a technician when you start working on a project is there any protocol or guidelines or any kind of framework or how you will do your business. How will you submit your work to whom? Who are the people involved?

When we have ICT then we follow that one. And now again, primarily I do the reinforcement, so it's like often it's not a requirement from the client and we do model the reinforcement and it's

something that we do because we think that it's a good thing to do. It's a good thing to have it like that. So, we do it as normal depending on requirements from the client.

- **Have you worked on any construction project that there was some kind of a framework or something that who is responsible, what kind of a software you would have to use, what kind of version of software?**

I would say I haven't been on a project that was very clear. I've experienced some but I haven't had that much. Maybe it's not that clear on what they really want and stuff like that. I see it as an impression that hey actually don't know what they need and what they want to use it for. My group leader he had made some process guidelines on what to do <…> of course we have some guidelines but again depending on what they decide on what we are going to do on each project. I've been in company for 2,5 years <…> and it's still like convincing people that it's a good idea to use it so it's like even though we have a lot of good thoughts on what we can do on each project and how we could benefit of it and stuff like that. <…> There's also not for every project but for many projects it's like you have to start like this, and you have to finalise on that date, and you have a very short time to start and also where is your period where you have to construct. So, you don't have that much time and sometimes you actually need a little time to plan to see where it would be good to use it. <…> At BIM you have too looks at as a process.

- **On this project, is the any other BIM technicians or coordinators from other parties not from company? But from a consultant of a client?**

No, on this project consultant only made a 2D drawings. He hadn't made a 3D drawing. And we see that he should have done it because we see how many mistakes they have done, but a client <…> is now learning about BIM. On this project we are still the ones that are trying to convince that they should use it.

- **And what about on other projects you've worked on as a BIM technician? Were there any parties that use BIM?**

I've been on a project where we received a Revit model and IFC and <…> if we had any question, they said look at the model. And we did so, but there wasn't in the model. Because they made a model in LOD 3 or something like that. It's not that detailed. And the ones that made the model think that the answer is in the model, but it isn't.

- **Now, coming to this point. For this particular case. Was there anything to define LOD that consultant had to submit its model as?**

I think so, because it was an ICT agreement on this project.

- **But when he told you that that information is in the model and you checked the model and it wasn't there, he had to do some works on the model and then issue a new version of the model, right?**

Yeah, but they didn't detail it much more so then we had to ask again but we didn't receive the answer. And also, they made a lot of mistakes in the model too, so it was also: have you checked a model before you sent it. And I think like they didn't have any more money on the project and that cost us a lot of money because we had to model and to ask a lot because we didn't have many information. And that was a very expensive learning for us.

- **But don't you think that that situation would have been prevented if you had some kind of framework that organises the relationship between you and the consultant on how do you ask for information and how the reply should be guided?**

I'm not sure if that had helped because on this project, they have done the design and we should just build after that design. But design wasn't good enough so that we could build after it. And again, we shouldn't use time on asking, it's very time consuming.

- **I don't know if you are familiar with BIM execution plan and the IDM and all of these things?**

Again, the client, he wanted them to use BIM but didn't knew how to set up this BEP. It's lack of experience from the client and consultant.

1.13. How do you exchange project data and model with other parties, external parties or internal?

On this project I would prefer IFC. But on this project again, they don't know so much about BIM so they don't have a software where they can see IFC, so we use 3D pdf or something like that if we want to show or it is just some screenshots on the mail. But on the other project we tried to send an IFC or make some screenshots again, but we used a platform where we could exchange.

- **Why don't you use some cloud-based platforms like BIM 360 or A360?**

When we did reinforcement on this project, we used Trimble connect which is also for free. So that is what we use with the guys on site. When they look at the model, they have an iPad and they can see model. But we weren't sure if they will know how to see it. All the foremen have received an iPad and we made some training on how to use it how they can see the reinforcement model on Trimble connect. And they can also see of course other models and we also put drawings barbell schedule and stuff like that. Information is there on site. And some had been very happy about it,

and for it is still a process. Some are using it, and some are not. But again, it's coming slowly, and they kind of see that its ok. But they also see a problem because, ok, they have an iPad people who are doing the work they don't have it. But should they also have an iPad? I know on a project they had a room where they had computer and they could go and have a look at it. We have tried this, and we see that there are some challenges about it.

- **But, using these iPads and for the foremen. Do you think they have reduced reworks on site, or it made it easier for them to visualise?**

Out thought at the beginning was that we could reduce drawings. And I was working on a project where we didn't do any drawings. But then the reinforcement was also simple. So, depending on degree how complex it is. But if we still do the drawings they like to see from different angles.

- **So even if you send some information to or a model to the BIM department, you only use the server, you don't use any kind of?**

Normally we work on a server. So normally I'm not sending. But if I'm using Trimble connect everyone on the project has access to the model. <…> But I know that on the larger projects they use Synchro. But it's still the experience <…> But the client wanted to use Byggeweb and it had to be placed on two different places <…>.

1.14. Is there anything else you would like to add about BIM?

For me it is very important that I can see that other people can also benefit from the model. That's when they use it on site because I think with the people that are in office and are on site. They feel like there is a lot of distance between us. But when you see this 3D and they understand I think this is even get bigger. So, I think it challenges to make it simpler. So, they can also what's benefit for me for using it. Otherwise, it's just a thing we have in office.

APPENDIX C – INTERVIEW 2

2.1. Can you tell us a little about your tasks and duties?

I am the director of civil and ground projects in Zealand area, specifically in reinforced concrete. I manage around 40 white collar employees and around 70 blue collars. I have started as a production project manager. I have worked on big projects on shore and offshore, mostly big civil projects.

2.2. How long have you been using BIM for?

I have started working on BIM involved projects around the year 2010-11.

2.3. Are there any internal guidelines deciding when do you use BIM on a new project?

We use BIM on all projects. I want BIM to be used on all of our projects, if we have reinforcement then I want Tekla model to be designed and used which is the bare minimum to use BIM on our projects, we design the rebars on Tekla and we order them from there.

2.4. How do you do your quantity take-offs on new projects?

I would like first to point out that the answers I will be giving are only related to my department of civil and ground engineering projects and it doesn't represent the full use of BIM in company because the building construction department is much more advanced in this. We seriously prefer models that we can use for quantities take-off and then we have Bluebeam review as a very good tool that we use, it is a very fast tool that we use to check that the quantities supplied to us by the tender materials are correct or not. We always prefer and like to have a BIM model of 300 LoD in main contract bids but sometimes we get a 100 LoD model and that would limit our ability to use full potential of the model.

2.5. How do you do your cost estimation on new projects?

We put what we think is the most accurate quantity take-off into iTwo RIB preferably generated by the BIM model but not always.

2.6. How do you plan and prepare time schedules for your new projects?

If the client has provided a time schedule in the tender phase, we go through it and validate it, and if it doesn't make sense for us, we don't bid. If the time schedule or we do our own schedule where we have really skilled planners, we do a brain storming meeting to see what is the best way to plan

the project and we start creating activities one by one using MS Project, we also used Thylos over the years but usually for highway projects where it is much better than MS Project. We have also used Vico schedule planner but the use of it is still limited to building projects. In order to check the constructability, we use Navisworks and we keep playing it to find the best time schedule to shorten the lead time of the project. Navisworks is now being taken out of our company and we are replacing it with Synchro a better tool for 4D planning and we have started using it on new projects.

2.7. How do you plan and organize site logistics?

We have a very complex project at Carlsberg Byen in Copenhagen where there are many parties and contractors involved in the project so the client's project manager had the duty of gathering all logistics planning of the different companies and putting them into a master logistics plan for the upcoming period of time with a drawing showing the areas reserved and used by the different companies. If it is our own project, then it is communicated internally so we don't have any work clashes and that is part of the phase planning on projects.

2.8. What is the process you use for cost control on projects?

We use iTwo for cost control on our projects, the work is divided into months with the quantities and the works performed throughout the projects and as you fill in the bills and budgets it shows how the project finances is doing and it gives you a forecast for project completion and we always have a discussion based on the results shown on iTwo. But the results you get from iTwo depends on the level of detail you put into the software, because the cost on iTwo is linked to the activities and quantities and it can easily show you the place of the overruns, but again if the manager working with it doesn't use the full potential of it then it gives less detailed outcomes.

2.9. How do you detect any collisions between designs? Or work clashes?

Clash detection is the most BIM area we use on our projects using the Tekla model we design, and we perform it a lot because the models we get from the consultants often have a lot of design problems and we have to resolve.

2.10. How do you plan the weekly tasks and activities on construction site?

Phase planning varies from project to another, it can be very simple as simple 2D drawings coloured on Bluebeam showing the works scheduled for that week. Or it could be with more detailing if its more complex. But I can say that all phase plans are 2D drawings updated weekly and once in a

while we use 3D viewers to detect detail works if they are complex. I think phase plans should be really simple transforming time schedule into a simple coloured drawing, because if it is not simple it will not be looked at and if it doesn't then it won't be made so we always try to make it simple. I don't know if we will implement more BIM into this area, it depends if it makes sense, we have a BIM department always looking for new things and technologies to make life easier for us and we are always interested in using BIM more.

2.11. How do your site engineers and workers perform their work on site and how is information exchanged with them?

Typically, it's flat 2D drawings and sometimes some 3D prints from the model if the work if complicated, because they are used to look into the 2D drawings. Then we have tablets on site for the foremen and site engineers on site to view the model and drawings. The errors on site have now changed in reason behind them, earlier we used to have a lot of errors because the design was wrong but now the errors are due to human errors in following the models so now it's about educating the staff on site to use the models correctly.

2.12. How do you assure and control the quality of your on-site production?

It really differs from a project to another, but it is still a very manual process, so it is still a red pen on a printed paper added to the As-built binders. So, models are a big help in seeing how the elements should look like, but it is still a 2D process. But the new apps for quality assurance and control are fantastic and I think they are the future.

2.13. Can you take us through the process of using BIM on projects? How do you implement BIM in a construction project (steps?)

There is the ICT agreement, we either take over something or we make them ourselves. So, we use the ICT agreement on all public funded and PPP projects and on 95% of private funded projects. The level of detail in the agreement can vary as needed but we always have it. We always follow the national guidelines in drafting the agreement and take it from there and change few things if needed.

2.14. How do you exchange project data/models with external parties?

I have no clue, I know IFC I know that we always ask for IFC in addition to the software version in case we have the same software. Internally we just take snapshots of the model as pdf so people

who don't have the software can see and make comments. I know that they are starting in the BIM department to investigate the use of BIM 360 platform, but I don't know if we are going to use that in the future.

2.15. Is it anything else you would like to add about BIM?

I like the idea that "you get what you see" which means you don't need to read all documentation to know what you have to deliver and for clients to know what they will receive instead now we just look at the model and we see what we should build and deliver. Also I think that engineers and architects should be better work in designing 3D models, because they never design the complex difficult part they just sketch detail drawing of it and they leave it vague on the model so they don't spend resources designing it and they just show the client the model and say ok here is the model we delivered it as we promised.

APPENDIX D – INTERVIEW 3

3.1 Can you tell us a little about your tasks and duties?

I am a BIM coordinator in our projects, and an ICT leader on projects where we have design when the project in governed by ICT declaration. My duties depends on the project and the phase of the project; to look in the model, did anything change in the scope?, to help set up the quantities in the structure that refers to the schedule and to follow up whether there are more quantities that we have to look into. Just helping all the people on site to use the model and the information contained in it. quality control, setting up schedules, Dalux, Capture, and the different applications, so to set up the structure so they can perform the quality control. I also do clash detections I also help with schedules 4D or attaching IDs for the elements. My duties vary but mostly it is about laying down the structure for people i am working with, that could be in the office or the subcontractors, I helped the carpenter to set up the model for his work so he uses iPad to follow his orders. As built design.

3.2 How long have you been using BIM for?

I have been working as a BIM coordinator for 7 years, I have been one of the first to use BIM in here. Before that I was working as a researcher in AAU Building informatics and selling applications.

3.3 Are there any internal guidelines deciding when do you use BIM on a new project?

Yes, there is. In the tender phase the tender material is sent to the VDC/BIM department to go through them and decide if value will be added to the project if we use BIM, then we write a statement report with our recommendations in how we will be using BIM and what personnel will be responsible and the period of his duties.

3.4 How do you do your quantity take-offs on new projects?

We normally don’t have any models in the tender phase, so we do the quantity take-off in 2D. Using Bluebeam by tender department they calculate areas and coloraturas them up. It is accurate because of the experience of the employees and having several people working on a project. We don’t use BIM because we only have pdfs, we only get a model on 10-20% of new projects of which only 25% would have reliable LoD where we can extract an accurate BoQ.

3.5 How do you do your cost estimation on new projects?

From the BoQ to Aspect4 but we are changing it now. We use Aspect4 to follow up on cost in the construction phase (Cost control) whereas in the tender phase we use Sigma.

3.6 How do you plan and prepare time schedules for your new projects?

It depends on the scale of the project and what do we get. If it is a Bid-Build (Main) then we don't have much time to look into the schedule and the main schedule is already defined. Whereas when we have a design-build contract (turnkey), we use more time to carefully look into the schedule. We start up with a location based and then when we get closer to the design of the building, we would get closer to an actual working schedule, so we look into it several times. (Assuring constructability), Well it is always hard in the design phase because you don't always know the building until the last period of time but we ask to make the structures in 3D then you know if you have the right structure in your plan. So, if you start planning something for example a bearing walls is different than what you thought it won't be possible. Again, we look up into whether doing this will give us any value. Is the project complex, do we have a model, is it worth it to make a model. We only use 4D planning in an early stage on 5% of our projects, for example the Aalborg hospital project we prepared a 4D planning in tender phase because it is a very large and complex project. We had a really good model in the tender phase (by consultant.

3.7 How do you plan and organize site logistics?

In some projects such as the hospital in Esbjerg, it is a very small site so we had to scan the area using drones once a month to see how close we are to the surrounding streets and walls to know how much area do we have to place or materials and equipment. Because what we experienced is that the engineers when they gave us the site drawings the road was a meter smaller from our construction pit, so we had to have actual data, to deal with the small area and its logistics. In other projects like Nordea in Copenhagen we used Revit to put in the model with the trucks coming and unloading materials, so we would put the dates of the trucks arriving and all the daily details of the site. So, it all depends on the project how much space do we have how much time do we have. and again, this is decided in the beginning in our meeting of how we will use BIM in this project and whether the logistics is complex or not. I is actually really hard to rely on a software for a long period because at the beginning we used Vico then it was always breaking down when you update the model and you have to put back all the data so we stopped using it and now it became better.

3.8 What is the process you use for cost control on projects?

As a BIM coordinator we only deliver the quantities to the Cost control responsible who uses Aspect4, the quantities are as built from Revit or Solibri and from drawings in areas where level of detail is higher.

3.9 How do you detect any collisions between designs? Or work clashes?

In Solibri, sometimes we use BIM Collab as a communication tool for the collisions. We perform the detection once a week. In the beginning of the project it takes 5 people 4 weeks to investigate the model and make sure it is reliable and it is good to use in collision detection and for other uses. (To what extent can we use the model)

3.10 How do you plan the weekly tasks and activities on construction site?

We do not get into the weekly and phase planning; it is the Forman and project manager duties using blue-beam and 2D drawings. Sometimes they go to the model and look at it to get a better understanding of the tasks ahead before the works are done, maybe take some pictures of the 3D model if the work is more complex. So, the use of BIM is only for visualisation for them.

What do you use BIM 4D for?

We use it to see if the schedule is good (constructability), Is the safety as it should be?, but I have never experienced doing a follow up on 4D model during the project, it is just a tool used in the early stages to see if the schedule is good and it is built in the right way. Because no matter how experienced schedulers are, they will have comments on the schedule they approved after seeing the 4D model, so it is just a visualisation tool.

We do not use it during the project, because software related to it are very heavy and time consuming so often objects will go into two spaces and dividing it will take time and when you split components according to the way you will build them and you give them ID then you have to do the same again when a newer version of the model is out and the ID of that element will be lost, so there is still a lot of manual work to be put into. It is not worth investing in on the projects I have worked on, but I can imagine some projects where it will be worth the effort.

3.11 How do your site engineers and workers perform their work on site and how is information exchanged with them?

What I send the workers and managers on site from the model is quantities divided into only the areas they are currently working on, also prefabricated elements I give them numbers of the element and ID to know what element to use in that location, also we help them know what exact type of plaster wall is used in this area by sending detailed drawings specifying colours for different plasters and reinforcements so we simplify the drawings by colouring the drawings and we send it to their iPads where they view them in Blue-beam so they can zoom in to details and measure distances and areas compared to pdf sometimes it is hard for the workers to know the location of the element. Also, when distances on a drawing are shown from mid wall to mid wall but there are different thicknesses and plasters on the wall and measuring exact distances on iPads is much more accurate for the works. So definitely the use of iPads reduced the reworks on site and increased

the accuracy of the works done. On the plan drawing it shows you if there is a detail drawing of this area and you can click to see the detailed drawing and so on (all drawings are linked together in the software).

3.12 How do you assure and control the quality of your on-site production?

We have used Capture for quite some years in company but 3 months ago we purchased Dalux (previously we have used Dalux on some projects when the client asked for it). But now we bought it for the whole company, and we use more BIM for quality control because it is linked to the model now. So the quality manager goes into a room with the iPad he selects on the model the room he is in and it shows in 3D he points to the exact location he is in and a predetermined schema of what he should check for comes out and he takes a picture and check if everything is according to the model and if not he sends it directly to the responsible person for repair.

3.13 Can you take us through the process of using BIM on projects? How do you implement BIM in a construction project?

I will speak only about turnkey contract. We make a BIM strategy plan internally after hearing the clients BIM demands, the strategy plan has a lot of subjects so it decides in what areas of the project we will use BIM (Surveying, Automation, quantity take-off, 3D, 4D, etc.) how will we use it and how should it be used and who is the responsible and what time do we start up with it. Then we have the ICT agreement with other parties (architects, engineers, client, subcontractors, etc.) it defines how to name documents and where to publish them (platform) and the format and the responsible for different documents, also demands that cost something for the architect and engineer. Then we prepare an MPS and a defining LoD of models. And further you use these documents through. Out the project. Often, we have a workshop with other parties to add to the ICT agreement and to go more into details in what to do in specific situations because the ICT agreement is more general. What we do is close to BEP by BuildingSmart but not the same, I have worked on projects with American and English clients where we used BEP and IDM is very close to our MPS, but the IDM is much more technical especially the ones by BuildingSmart. But what I think is there are not many companies that have staff who can go and check the IDM and BEP for details, you have to be quite the specialist to know what to look for and where. So normally we solve conflicts higher in the company and we effect the decisions in the MPS. So, the BEP is designed differently than how the industry in Denmark carries out the work so it will take money to introduce new framework when people don't know that that information is in chapter 3 or 4 to see the amount they have to design.

3.14 How do you exchange project data/models with external parties?

We have a demand normally to use Byggeweb platform in Denmark but now that we have bought Dalux maybe we will go to another platform, but I don't know about that yet. Internally we use SharePoint by

Microsoft (one drive) we have recently switched to it and previously we used to use a local server drive to store and exchange data. Sometimes we use A360 from Autodesk, but we still have difficulties with it especially when you use Field function for quality control it flips the names. So currently we prefer using Dalux, and we use Solibri to view models from SharePoint where I upload the newest version every Monday after receiving it from designers every Friday. We are testing now A360 and the extra functions of Dalux, but again it is hard to rely on one software because they promise these things will stay in the newer version and then they change them or they promise they will put some wanted functions in the next version but we want it now not after one year. And when you start a project you have to finish the project using the same software you can't switch halfway through. We always consider what is the best for our department and what is working and what is not working at this moment and not what they promise for the future.

3.15 Is it anything else you would like to add about BIM?

Just that it is that construction is old and BIM is still very new, and I think it is not about BIM because BIM isn't more than a more structured way to do what people has always done, so I think that BIM is just a tool for project managers to do things smarter. BIM shouldn't be done just to do BIM it should be done to do things smarter and sometimes this is forgotten.

Additional question: in current industry in Denmark, who do you think is the weakest link in adapting a holistic BIM process throughout the project phases?

I don't think a lot of the advisors (consultants) have the right strategy for BIM and I think deciding and agreeing on a unified classifications and method of naming of projects and models will make the use of BIM much faster and easier and it would allow us to be smarter in dealing with the way we divide elements and knowing the costs when we can learn from past experiences and see how we did in other projects. And ideally, we can achieve automatization as big goal for this industry but that only can happen when we get so organised and unified in methods.

APPENDIX E – INTERVIEW 4

4.1. Can you tell us a little about your tasks and duties?

I am a project manager in the company. I've been here 11 years. My title is senior project director and that means that my focus is mainly on very large projects, very complex projects. That is my main focus. And I have responsibilities for one project at a time because they are so large.

4.2. How long have you been using BIM for?

Yeah. The last six or seven years I have used BIM tools. I thinks it's around 2012 when Denmark will build these major hospitals and I started at a hospital project in Aarhus where BIM was quite new and afterwards, I did hospital in Aalborg and after that it is {indecipherable word} major clients from abroad. So, in all these projects we have worked with BIM and of course the 3D models.

4.3. Are there any internal guidelines deciding when do you use BIM on a new project?

Basically, we use BIM in all of our projects. That's our main goal. We want to be first movers about BIM and VDC in the construction industry. So, we use it basically, I'm saying, maybe some small project for private clients that we don't use it. But for all, we use it in most of our projects. We use it in different scales also depending on what the client wants, and which contract form we have together with the client.

4.4. How do you do your quantity take-offs on new projects?

Normally, I don't actually do the BIM works. Projects are quite huge. In my organisation I have BIM managers, BIM coordinators, and ICT responsible persons as well. So, they do together with production team do the actual work. But normally I would say the quantity take-off would be something we would do with Solibri. It would be the most normal tool.

4.5. How do you do your cost estimation on new projects?

In the early start when we started using BIM, we had the BIM coordinators that took out the quantities from a mode. But they were, let's call them specialist maybe in using computer and software. And the we had a production guy who actually do the construction on site. And what we did to price elements what was to compare the two organisations and say ok, you know something about the computer and other guys know something about pricing and how to build stuff and realise. And we combine these to get the right price. And what we use for it is actually we use. OK relation software is called Sigma but that is more like a database. And we use. Normally it would be

of course Revit when we are having with the model, Navisworks, Solibri and ITwo. We also had done tests with VICO office, but I think that didn't do the job well. So, I think its important part for us that we need to use different software and it's a combination of a different software that give us the best result when we need to take our quantities and put some prices on it.

4.6. How do you plan and prepare time schedules for your new projects?

We like to use location-based planning. So that would be VICO office. Normally it would be VICO control because it's lighter and faster to handle than VICO office. On some project we still use MS project. But I prefer VICO control or Primavera as main tools.

4.7. How do you plan and organize site logistics?

If you ask company on a higher level, they would say that we normally do 3D logistics. I don't like that. And that's because it's very flashy but in real life is just, I don't know what it's called, smart BIM or flashy BIM because the construction people on site they don't care about it, they just want to see if they can have their trucks or car in the right place and we can easily handle that in 2D drawings. So, we don't need another guy in our team to just have a computer and to put in some weird objects as a crane or a car. We can manage that in 2D and that's for me is just an easy way to do that the other part is still too flashy, and it doesn't generate the same value as I have to put in more resources of a project. So that part I still like to do the old-fashioned way.

4.8. What is the process you use for cost control on projects?

For cost control I like to use BIM. Once a month I need to send an application for payment to the client and what I do is I take the model and delete all objects that I haven't built yet. So, I actually have a model that look like what I have done on the construction site and I take out the quantities for that and out from there quantities. I can measure what size of the bill I need to send to the client.

4.9. How do you detect any collisions between designs? Or work clashes?

It can also be a Solibri or Navisworks as well.

4.10. How do you plan the weekly tasks and activities on construction site?

Yeah, that would be VICO control and Primavera.

4.11. How do your site engineers and workers perform their work on site and how is information exchanged with them?

All of the engineers have the iPads and of course we have our meeting rooms with big screens when we come out to the constructions sites all our workers in own production have iPads so they always have the newest drawings they cannot build after old drawings because they are updated automatically so you always have the newest drawings. And we have taken a container and put in a big screen in a bottom and stand-up table. So, let's say we have a concrete shaft they can go in there and take the iPads, put up the model on a screen and collaborate around the model so they can plan a job even better and take the container and with the crane move it up through the building as the construction progress in working.

4.12. How do you assure and control the quality of your on-site production?

That would be something like Capture or Dalux that would be most common tools. Personally, I like Dalux best because I think it's most intuitive and it works not only in 2D but also in 3D. So, it has the model in the program.

4.13. Can you take us through the process of using BIM on projects? How do you implement BIM in a construction project (steps?)

Yeah. For each project when we start tendering a new project, we need to develop a BEP. And out of BEP we pick which items could support and help the project. And we look if we have resources to handle these items on project do we need support from somewhere else in the organisation. And also, out from the BEP and the items that we pick we generate the IKT documents that we work out from.

4.14. How do you exchange project data/models with external parties?

Not that I know of. I think, but I'm not a BIM guy, I'm not into the details. It's more like I know that I could take quantities take-off, but I cannot do that myself. So, I think there's some file format they use to switch between the programs but I'm not into that part of.

4.15. Is it anything else you would like to add about BIM?

In the most ways I think BIM is very good for the construction industry if we have a good manner about it. It can also give us some new challenges. For example, some call it evil BIM but now it's very easy to see if the designers have done their job correctly or if there is something missing it the drawings it is very easy now to see that. Also, it's very easy to see if they've changed something and for example, they forgot to draw their clouds in the drawings. Now it's actually very easy to see if they tried to cheat about changing. So, it can be used on a very evil way if you want it. And another

problem is that it's very easy for a designer to change the project. If we just look 10 years back, the designer was very good to finalise their drawings in the first step because everything was on paper and with pen. So, if they needed to do new drawings, that would have taken a lot of time. Today, if they only do the drawings 50% it's very easy just to say: hey can you fix that? And they only do that small part and that generated the new drawings for the contractor. Do, before, the designers were interested to develop a very good project fist time and now they tried to do as poor project as they can get away with and then get the questions afterwards. So, what we see is that before we haven't had that many changes in the project and now we have a tons of changes and that's very hard for a contractors organisation on site to handle all these changes. So that's not good about BIM. So now we can see that organisation in the construction needs to be even larger because of all these changes and so easily they can do small changes just putting out a new drawing on an email. They can change hundreds of drawings each day actually. And it actually drowns the contractor because they can't measure it and they don't have time to look at all these changes. And now contracts and ICT documents need to be even better on their part of a project.

APPENDIX F – INTERVIEW 5

5.1. Can you tell us a little about your tasks and duties?

I am a VDC group manager and that only make sense if you know the company, we have a small centralise VDC/BIM group in charge of digitalisation and digital development. My duties consist of the overall digital development and strategy specifically targeting building construction. This small department oversees the VDC coordinators located in our construction projects across Denmark where they work closer to the actual work on construction site.

5.2. How long have you been using BIM for?

I have worked with BIM for close to 6 years.

5.3. Are there any internal guidelines deciding when do you use BIM on a new project?

In company it is completely up to the project manager responsible for a specific project to decide how he wants to use BIM and if he wants to use the models more or less, the company does not dictate a minimum use of BIM in projects. At the tender phase the VDC coordinator and the project manager of the project take a look and see what make sense to use BIM in and how can they improve the work by using BIM and min what area of the project.

5.4. How do you do your quantity take-offs on new projects?

It depends on the project and it varies from a project to another. We don't have a specific tool or method that we dictate for the whole company to use. Some projects we still use very old-fashioned methods of 2D drawings and documentations. But nowadays nearly all building construction projects have a BIM model that we can use Solibri, Revit or Navisworks to extract quantities from. If it is a main contract then it will depend on what we receive with the tender materials, in Denmark it is still not always that BIM models and IFC files are contractually overtaking the drawings and documentations. Where the final say is always for the drawings if there was any inconsistency between the two sources. So, we take a look on the model, but we can't rely 100% on the model.

5.5. How do you do your cost estimation on new projects?

In general, in company we use Sigma, whether there is a model or not we use Sigma. We use the 5D functions of Sigma a little bit on some projects, but we think it is an interesting tool and we will see how we can use it more in the future. But it all still depends on what kind of materials do we receive in the tender phase. We are moving to a more digitalised way of working and we are moving in the

right direction but that is not something you can do in one day and you tell everyone in the company ok this is how we do things from now on so it is a long journey and we have a lot of areas we are focusing on and this is certainly one of them.

5.6. How do you plan and prepare time schedules for your new projects?

We have projects still using old fashioned MS Project, but we are moving into using LBS with Vico schedule planner on all our projects and Synchro as a tool of 4D planning. I always advise my colleagues to use Vico schedule planner whether it is linked to the BIM model or not. In the company the VDC development department is not really working on companies' projects but more on development issues. Whereas the VDC coordinators are the personnel in charge of Digital assistance on projects, the way we do it in the company is different than other companies such as MTH where I used to work where they have a big central BIM department overseeing all digital matters on all projects. We try to have the VDC coordinators closer to the projects and focus only on their projects. We assure the constructability by having a meeting between all the parties involved in the project where they discuss the main time schedule until it is ready and on some project we use Vico office for 4D stimulation if they are using the whole Vico office and if not then we use Synchro.

5.7. How do you plan and organize site logistics?

We try to do a 3D construction site models for all our projects that means the whole surroundings on site and not just the building itself. The priority of having this model varies from a project to another depending on the complexity of the project, if the project is in downtown with very limited areas then it is very important to have the model and it has proven it is advantages and how it helps all parties on site to plan their daily tasks. We use Revit to model the construction site and we use Synchro because of its construction site functionalities and site management and logistics. And we use drone scans for the site, and we use some scanning of the inside of the building to see what is going on. It is safe to say that all building construction projects in the company have BIM models designed on Revit or Tekla but the thing that stops us from using it more is that as I said until today most of the contracts we are obliged to follow the data in the drawings and documentations as first priority before the model. I think it is a waste of effort and great potential when the engineers spend a lot of time working on the models and when they pass them in a main contract the models cannot be relied on, but we have to refer to the drawings. But at least the ICT declaration offers more use of these models on public funded projects. But when it comes to private owners only few of them

are interested in making a good ICT agreement, so BIM is used throughout the project phases but a lot of them are still not interested. In general in the industry we have all the tools we need we have all the staff that can use these tools and we do have projects that have been a great collaboration example and where BIM models have been used from design phase till hand-over and facility management phase but I think one of the challenges is that private owners don't have a lot of needs in the facility management phase when they are in charge of the building and as a result they don't set any requirements for models but that's fine as long as we as an AEC parties can find a way to use these tools in optimising the way we collaborate and optimise the way we design then it should be a benefit for everyone, but that is where the problem is "when we want to use all these technologies to optimise our work and design we have to change the way we collaborate and the way we communicate with each other and that is the big challenge in our industry we still write contracts the way we used to do decades ago". These contracts in my opinion makes us collaborate less because it is very focused on what we have to do for the client so we do only that and if they want us to do any more effort in collaborating, they will have to pay a lot more. The ICT agreements is the only good thing we can do to increase the level of collaboration by having work shops to decide what is in the interest of all parties and the project to draft an ICT agreement. Because all of our works as different parties on a project are connected and we all effect the way others do their job. I think the AB18 is a good step towards that than the AB92 but we still have a long journey to achieve that, because it is a difficult job to manage the change on industry level because we have to understand each others needs better and know what is the interest of all parties better. It is very important when digitalising the processes of the company that we answer to the core values of the company and that is why we have a decentralised VDC management where each project choose the way they want to use BIM in. Even if this move into digitalising the company is slow the main focus of a contracting company should be the execution of the project and using the digital tools to achieve that and help with that

5.8. What is the process you use for cost control on projects?

We have projects where we can rely on the model especially when it is a turnkey contract then it only makes sense to use the model for cost control. We have very good examples where we used vice office for cost control. I can't answer this question fully because I am not involved in this process and I wouldn't want to reveal confidential information. It is not yet a very BIM involved area.

5.9. How do you detect any collisions between designs? Or work clashes?

The VDC coordinator would collaborate with design team and perform collision detection using Solibri and Navisworks.

5.10. How do you plan the weekly tasks and activities on construction site?

Again, that depends if they used the model in the planning or not. The project team goes into meetings and they discuss the LBS for the two weeks or so and they use the BIM 4D model sometimes and the Revit model for the construction site model and for logistics.

5.11. How do your site engineers and workers perform their work on site and how is information exchanged with them?

We have a slogan that "VDC for everyone" that at least everyone in the company is able to navigate the 3D model on Trible connect or Solibri and we are trying to educate everyone for a minimum ability to use BIM in their tasks. In the company we always design our reinforcement rebars on Tekla on all projects so we can order them directly using Tekla and deliver them on site with IDs where everyone has access to tablets with Trible connect another Trible tool that supports viewing Tekla models and they check the rebars delivered and place them in place. We are using Dalux more on our construction projects, a great tool to view the models and link them with detail drawings and sharing models.

5.12. How do you assure and control the quality of your on-site production?

We use Dalux to perform quality control on some projects, or Trible connect which we use a lot nearly all of our projects.

5.13. Can you take us through the process of using BIM on projects? How do you implement BIM in a construction project (steps?)

We do have some standard template so we see how the project will look like and what VDC tools are to be used during the project. It is more of a schedule than a BEP. It is the ICT agreement only that organises the use of BIM and if it is a turnkey contract we have a work shop to draft an ICT agreement meeting the minimum requirement for the ICT agreement and also our standards of using BIM on our projects and what make sense to us and help us executing the project.

5.14. How do you exchange project data/models with external parties?

Normally in Denmark we use Byggeweb to share the data with all parties on the project and it is a requirement by the client. Internally we use Dalux to select personnel who can view the models, or

we just use our internal servers to share them if Dalux ids not used on the model. And Trible connect offers everyone a viewer of the model and drawings to store and share information with all our staff. We have few projects where we used BIM 360 and it is a very interesting tool, but it is still not a complete tool, because of the legal aspect of using it where Autodesk did not issue the complete service in Europe like they have in the US. But we have our eyes open on the software market so we can investigate all potentials in making our methods better.

5.15. Is it anything else you would like to add about BIM?

I think coming out with ways of digital collaboration is the most important thing today in our industry because everyone has the tools and the staff to work digitally but we still don't know how to collaborate with each other. In the company and in collaboration with Arkitema and an engineering company worked on an exciting project to come up with a collaboration scheme to use BIM in all phases of the construction project after working together for almost 3 years. It is not something with everyone yet because of the high competition in the industry.