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Scaling BIM implementation up from housing pilot projects

Master’s Thesis submitted for examination for the degree of Master of Science in Technology.

Espoo 04.03.2019
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Tiivistelmä

Rakennusalalla ei ole onnistuttu hyödyntämään digitalisaatiota kuten muilla aloilla. Tietomallintaminen on digitalisaation keskeinen osa sillä se toimii perustana esimerkiksi esivalmisteiden, IoT:n sekä koneoppimisen tehokkaalle hyödyntämiselle sen lisäksi että sen käyttöönotto itsessäänkin tuo hyötyjä. Tietomallintaminen mahdollistaa virheettömän ja täsmällisen tiedon käytön hankkeissa sekä niiden välillä, mutta se edellyttää virheettömän ja täsmällisen tiedon tuottamista alusta lähtien. Jotta tarkoituksenmukaista tietoa kyettäisiin tuottamaan, useita näkökulmia on huomioitava, joka puolestaan edellyttää yhteistyötä.

Tämä tutkimus käsittelee tietomallintamista tyypillisissä asuinrakennushankkeissa Suomessa holistisesta näkökulmasta. Holistinen näkökulma ottaa huomioon teknologian, prosessien ja ihmisten samanaikaisen kehityksen, joka on tarkastelun kohteena. Yksityiskohtaisemmalla kategorisoinnilla luodaan käsitys kohdeyrityksen, YIT:n, tietomallintamisen käyttöönoton nykytilasta ja käyttöönoton riippuvuussuhteista, joita myös analysoidaan.

Tutkimuksen tarkoituksena on edistää siirtymistä tietomallintamisen käyttöönoton pilotoinnista laajempaan käyttöönottoon kohdeyrityksen asuinrakentamisen liiketoiminnassa. Tietomallintamisen nykytilan kuvaus ja analysointi pohjautuu perusteelliseen käsitykseen tietomallintamisen käyttöönotosta, sekä sen tekijöistä ja niiden riippuvuussuhteista. Laajan kirjallisuuskatsauksen avulla luodaan yleinen käsitys käyttöönotosta ja riippuvuussuhteista, mikä mahdollistaa keskittymisen oleellisiin asioihin tapaustutkimuksissa. Kirjallisuuskatsaus tarjoaa teoreettiset raamit, joka tukee tutkimusdatan hankkimista ja analysointia. Tutkimusdata kerätään puolistrukturoiduilla haastatteluilla, jotka suoritettiin kaikissa kohdeyrityksen Suomen Asumisen yksiköissä.

Tulosten mukaan teknologian, prosessin sekä ihmisten samanaikaista kehitystä hidastaa pääasiassa kompetenssien ja tiedon puute. Monet tekijät kuten riittämättömät ohjeet ja uudenlaiset teknologiat vaikuttavat tietomallintamisen käyttöönottoon, mutta sen kehitys kulminoituu kompetenssien ja tiedon puutteeseen. Osittaisesta samanaikaisesta kehityksestä huolimatta, tietomallintamisen käyttöönoton hyötyjä on todettu kohdeyrityksessä. Tärkeimmiksi hyödyntämiskohteiksi nähtiin suunnitelmien yhteensovitus, määrälaskenta sekä visualisointi. Sen lisäksi painotettiin yhteistyön, selkeiden roolien ja vastuiden, sekä prosessien harmonisoinnin merkitystä. Analyysin tuloksena luotiin raamit tietomallintamisen käyttöönottoprosessin kehittämiseen, joka sisältää suosituksia ja huomioonotettavia seikkoja niin hanke- kuin segmenttitasollakin. Se pyrkii suuntaamaan käyttöönottoprosessien harmonisointia liiketoimintayksiköissä.

Avainsanat BIM käyttöönotto, BIM kehitys, pilotointi, skaalaus

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Abstract of master's thesis

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Abstract

Construction industry has not succeeded in exploiting the digital transformation of business, like other industries have. Building Information Modeling (BIM) is the centerpiece of digitalization in construction industry as it lays the foundation for efficient use of methods and technologies such as prefabrication, IoT and machine learning, in addition to the benefits its implementation entails. BIM facilitates the use of correct and accurate information through and across projects, but its premise is that correct and accurate information is provided into the system from the beginning. To enable the use of correct information, various aspects need to be considered, which in turn presumes collaboration.

This study explores implementation of BIM in typical housing projects in Finland from a holistic point of view. The holistic point of view considers the coevolution of technology, processes and people, which is under inspection. With more specified categorization, dependencies within the implementation process and understanding of the current state of BIM implementation at the case company, YIT, is established and analyzed.

The purpose of this study is to advance the shift from piloting BIM implementation to larger scale implementation in the housing business of the case company. Based on establishing an in-depth understanding of BIM implementation, identifying its most important elements and their dependencies, the current state of implementation is described and analyzed. With rather extensive literature review, an in-depth understanding of the implementation of BIM and its elements, in general, is developed, which enables focusing on the relevant matters in the case studies. The literature review provides a theoretical framework that supports data collection and analysis. Research data is collected with semi-structured group interviews conducted for all housing units of the case company in Finland.

The results indicate that coevolution of technology, processes and people is mostly hindered by lack of competencies and knowledge. There are many factors that contribute to the implementation such as insufficiency of instructional materials and novelty of technologies, but the development of BIM implementation culminates in lack of competencies and knowledge. Despite only partial coevolution, benefits of BIM implementation, have been observed in the case company. The most important BIM Uses were perceived to be design coordination, quantity take-off and visualization. In addition, the importance of collaboration, clear roles and responsibilities, and harmonization of processes were emphasized. As a result of analysis, a framework for development of the BIM implementation process, which contains suggestions and considerations both at project and business segment level, is developed. It aims to provide the direction for harmonizing the BIM implementation processes across the business units.

Keywords BIM implementation, BIM development, piloting, scaling up

Acknowledgements

I'm grateful for having this opportunity to write my master's thesis on a topic which is of particular interest to me. Especially during my master's studies, it became increasingly clearer that I wanted to write my thesis about BIM as I became more and more convinced of its potential to impact the way we build. After having provided a theoretical foundation at the university, my goal was to build an understanding of the practical side of BIM during the thesis writing process. Luckily, I had the opportunity to discuss about the thesis topic with Marko Oinas, Senior Vice President of Business development and Strategy in YIT's Housing Finland and CEE segment, and the topic was developed rather effortlessly as there was a need to study the BIM implementation process within the Housing units of YIT. I want to thank YIT for the opportunity to write my thesis on this interesting topic and for the funding of the thesis.

Firstly, I want to thank my advisor Marko Oinas for providing the direction for the thesis and helping to approach the topic from the perspective of YIT. Marko had a significant part in the selection and framing of the topic, he helped me to focus on the relevant matters and supported the writing process whenever needed.

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Abbreviations

AEC industry	Architecture, Engineer and Construction industry
BCF	Building Collaboration Format
BEP	Building Information Modeling Execution Plan
BIM	Building Information Modeling
COBie	Construction Operations Building Information Exchange
COBIM2012	Common BIM Requirements 2012
DBB	Design-Bid-Build
IAI	International Alliance for Interoperability
ICT	Information and Communication Technology
IFC	Industry Foundation Classes -standard
IoT	Internet of Things
IPD	Integrated Project Delivery
MEP design	Mechanical, Electrical and Plumbing design
NIBS	National Institute of Building Sciences (United States)
VDC	Virtual Design and Construction
WHO	World Health Organization

1 Introduction

1.1 Background of the study

The construction sector has a significant effect on global economy but is well-known for its low productivity (World Economic Forum 2017). The productivity challenges stem from the nature of construction business, which can be characterized as fragmented, project-based and conservative. The megatrends that are urbanization, sustainable development and digitalization are drivers of the current market development, and new innovations are needed to respond to the existing and future challenges. Affordable housing concepts, modularization, BIM and virtual reality amongst others indicate that there is no lack of innovation in the industry, rather, the challenge seems to be focusing on the right innovations and implementing them (World Economic Forum 2017). There lie possibilities in combining innovations and technologies, in which BIM has a central role by facilitating and enabling that through providing and integrating data (World Economic Forum 2016). BIM implementation has grown increasingly in the last decade all over the world (Smith 2014), and it seems that to gain competitive edge and to even keep up with the competition, implementation of BIM is a necessity, especially in Finland, one of the forerunners of BIM implementation (Wong et al. 2010, Aksenova 2018).

The case company YIT has identified the challenges and strive to tackle them with the Performance -programme amongst others. The purpose of the programme is to improve productivity by reducing production costs. BIM, being part of the programme, had already been implemented at the Housing Finland and CEE business segment, in which this thesis was conducted. The segment incorporates all housing units in Finland and in six other units in their respective countries. This thesis considers all ten units in Finland. At the time this thesis was initiated, BIM vision for 2019 had been presented in the segment, which stated that starting from 2019, BIM will be implemented in all housing projects. The objective was to have at least one BIM pilot project started in all units in 2018 to have experience of BIM implementation for the scale-up.

This thesis studies implementation of Building Information Modeling (BIM) in housing projects and scaling up the implementation at the case company. In general, the purpose is to gather the experiences of the pilot projects. Through scaling up, the effect of BIM implementation can be expanded across the segment. Implementation and scaling up are considered from the holistic point of view, i.e., considering the aspects of technology, processes and people. Although the focus is on the design phase of a project, construction phase cannot be left out. A further limitation is placed on the delivery method of a project. This thesis focuses on developer contracting housing projects.

1.2 Research problem and objectives

BIM provides means to tackle the presented challenges by improving collaboration, information flow, predictability and decision-making, which reduce costs, duration and waste, and improve quality and safety. It is evident that BIM reflects the principles of lean philosophy – systematical reduction of all types of waste and increase of transparency.

Achieving the benefits of BIM presumes successful implementation, and furthermore, enhancing the impact of implementation presumes scaling up. Implementation of BIM is a substantial comprehensive change and a rather intricate process incorporating several aspects and elements to be considered and developed concurrently. Successful scaling of BIM implementation in the units of the case company with variety of characteristics requires understanding the initial state and planning the scale-up. Dissemination of knowledge and information, resource allocation and support are essential elements of scaling up. The challenge is to figure out how the implementation process should be developed based on the pilot projects.

BIM implementation is a lot about change management. Changing the processes and practices of project execution is a substantial and complex task, and therefore it could be best to first implement BIM into the simplest processes where the effects are most noticeable. A considerable challenge, especially in a large organization, is to get everyone on board. Finding the balance between not hindering the development too much and pushing forward too fast is important for establishing and maintaining an appropriate level of motivation.

Residential construction is characterized by routine, standardized design solutions, simple geometries, repeatability and high degree of prefabrication, which implies that the benefits and focus of BIM are on repeatability and prefabrication. In contrast, for one of a kind megaprojects simulation of the performance of the building in in various environmental circumstances might be more important. Object-based parametric design enables more efficient utilization of established design solutions as their virtual duplicates can be stored in a data repository. To exploit the knowledge capital and building data that the company has acquired, it should be gathered in a data repository, and presented in usable formats.

An advantage of a large organization is that methods, procedures and technologies can be tested rather extensively. The challenge is to harmonize and standardize BIM processes, methods and practices across the units while considering the different characteristics of the units and maintaining flexibility. The merger of two large construction companies, YIT and Lemminkäinen, was confirmed in January 2018, prior to the initiation of this thesis. Such a large merger emphasizes the need to harmonize business processes and practices, including those related to BIM. It provided an additional point of view to this thesis.

The preceding paragraphs provide the first impression of the topic of this thesis, by describing the research problem from various point of views. To summarize, the challenge is to discover the best direction for the development of BIM implementation. By ''the best direction'' it is meant a direction of development that takes different perspectives into account to enable a sustainable change. The main objective of this thesis is to describe the current situation and identify the most important elements and their dependencies of BIM implementation for the scale-up at the case company. This is pursued by studying BIM implementation from the holistic point of view and establishing an in-depth understanding of it. In general, the study aims to contribute to the scale-up of BIM implementation by providing a framework for development of the implementation.

The following research questions were established to guide both the literature review and case studies:

- What can be learned from BIM pilot projects for full-scale BIM implementation in housing business?
    - What can be learned from BIM pilot projects for full-scale BIM implementation in housing business?
    - What practices, methods and procedures of pilot projects should and should not be implemented in the following BIM projects, and how these should be implemented?
    - How to ensure all units with different characteristics have prerequisites for BIM implementation?
    - How to exploit the BIM experiences of two merged companies that have established their own BIM processes?
    - How the implementation is scaled up?

1.3 Structure of the study

This thesis consists of a literature review and case studies. First, a theoretical framework of the topic is provided in the first two parts, first one of which covers BIM implementation from holistic perspective. It starts with defining what BIM is and what it is not, followed by exploring the motives and approaches to BIM adoption. BIM implementation with its objectives, processes, roles, challenges, risks and the role of standards and guidelines, is studied next. The last chapter of the first part focuses on the role of collaboration in BIM implementation.

The second part of the literature review investigates piloting and the shift towards larger-scale exploitation of BIM implementation. The purpose of the theoretical framework is to create an understanding of the process of BIM implementation as well as its objectives and prerequisites to support the empirical part of the study.

The empirical part consists of introducing the empirical research methodology, i.e., how the research data was collected and analyzed. After that, the results of the data collection and analysis of eight case studies supported by the theoretical framework are presented in detail, case by case. Based on the theoretical framework and the case studies, a framework for guiding the development of BIM implementation in the housing projects of the case company is conducted. The thesis is discussed, and research topics for further studies are presented in the final chapter.

2 Building Information Modeling

The roots of BIM reach all the way to the 1970's when Charles Eastman presented the basic principles of BIM. The weaknesses of 2D drawings were recognized: to represent a real building element, at least two drawings are needed, which consequently means that part of the information is redundant as at least one dimension is presented twice (Eastman et al. 1974). Since then, BIM concepts, technologies and capabilities as well as standards and guidelines have been researched and developed, but the implementation of BIM in projects practically begun only in the mid-2000s (Azhar et al. 2012).

Part 2 covers the definition of BIM, BIM adoption and implementation with its objectives, challenges and overall process as well as roles, collaboration and soft skills. Standards and guidelines are briefly introduced as well. Chapter 2.3.3, which covers the BIM execution plan, considers the implementation at project level. Lastly, the role of collaboration in a BIM project is explored.

2.1 Definition of BIM

Defining and understanding the concept of Building Information Modeling, its elements and terminology is fundamental for being able to plan and execute implementation. Implementation is an organization-wide change, which requires development in all functions. For successful and smooth collaborative development of BIM processes, tools and practices, people should understand the concepts and terminology.

Secondly, understanding the expectations and opportunities of BIM realistically is important because of somewhat inflated marketing of BIM. BIM can be perceived as a technology driven change, and indeed there is a high supply of technical solutions in the market. Software solutions are often oversold with inflated value propositions.

It seems that there is no common understanding of an exact or commonly agreed definition of BIM, which might be a consequence of the complexity of the concept. The acronym BIM implies that it is about the physical building, information related to it, and the virtual model of the building. The acronym could also be interpreted as Building Information Management, which puts more emphasis on processes and activities than the model. BIM can also simply stand for a Building Information Model. It is good to keep in mind that a model is by its definition, a representation of a real thing – a building in this context – and that a model is always imperfect.

Different emphases might result in understanding BIM in different ways, not seeing the holistic view of it and even misunderstanding the concept. For example, perceiving BIM merely as 3D design application seems to be major part of the reason for building operators' slow BIM adoption (World Economic Forum 2018).

A few definitions of BIM from relevant organizations and research publications are presented as follows:

Eastman et al. (2008) define BIM as ''a modeling technology and associated set of processes to produce, communicate, and analyze building models''. Building models are comprised of building components, which are represented by intelligent digital objects that include data required for analyses and work processes.

Autodesk (2018) defines BIM as a process, which includes creating the 3D model, and utilizing it to facilitate coordination, simulation and visualization. The model also helps owners and users improve planning, designing, building and managing the building.

National Institution of Building Sciences (United States) defines BIM in National BIM Standard as ''a digital representation of physical and functional characteristics of a facility; it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.'' (NIBS 2007).

Gu and London (2010) define BIM as ''an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository. The building information involved in the BIM approach can include both geometric data as well as non-geometric data.''

The common factor of these definitions seems to be the virtual model of a building. Other emphasized elements of BIM are information related to the building, processes, technology, life cycle of the building and collaboration. The definitions seem rather compressed and present the concept in an abstract manner. Understanding new concepts can often be easier through practice or comparison, and therefore, BIM is compared to 2D and 3D design next.

2.1.1 Understanding BIM through comparison

The difference between traditional design and BIM-based design is easily misunderstood as merely the difference between 2D CAD and 3D CAD. The advancement from 2D to 3D can be seen basically as addition of a third geometrical dimension to the design drawings, but when advancing from 3D to BIM, interlinking non-geometrical information with geometrical information is essential to understand as it changes the nature of design. In CAD design, the focus is on the drawings and independent views, whereas in BIM-based design the focus is on the data and intelligent objects. While in CAD design all independent views must be updated manually as one view is changed, in BIM, all views are automatically updated because they are generated from the same data source – the model.

BIM uses an object-oriented parametric modeling technique to create the models. (Azhar et al. 2012.) It means that when a model element is modified, an adjacent element is automatically adjusted to maintain the relationship between the objects. The model elements are described by attributes and parameters, e.g., material of a wall, name of a wall, width of a line, and thermal conductivity of a wall. Another way to look at attributes and parameters is that they are modifiable settings assigned for the elements that enable different functionalities. A thickness of a wall can be modified by changing the value of a thickness attribute of that particular wall object. The distinction between attributes and parameters is difficult to establish as they are covered a bit differently in different software and publications, but in principle, attribute is a quality of the item, whereas parameter is the measure of the quality. Considering a concrete wall object, one of its attribute would be ‘’material’’ and the parameter of that attribute would be ‘’concrete’’. Similarly, the parameter of a ‘’thickness’’ attribute could be ‘’150 mm’’. However, the concepts are a bit more complex, and for example attributes and parameters can have other attributes and parameters, kind of in a hierarchical way.

All the parametric data, relationships and rules form the model database, which is the core of BIM. One significant difference between 3D CAD and BIM is that in BIM, the visual 3D model seen on a computer screen is derived from that data, rather than the objects being modeled first and then assigned with different parameters and attributes. Additionally, the use of parameters and attributes is more advanced. By creating a database including standardized objects, which can be used and modified later, rework can be diminished significantly as model objects do not need to be modeled from the scratch every time. Intelligent parametric modeling allows efficient utilization of the model, e.g., quantity take-off and quick implementation of changes to objects of similar type. An example of an air conditioning unit model object containing data about the supplier, operation and maintenance procedures, flow rates and clearance requirements tells about the vast range of information that the model contains (Azhar et al. 2012).

Another fundamental distinction between 2D CAD, 3D CAD and BIM, is how the design software understands the drawings or models. A drawing of a wall in 2D and 3D CAD is understood as a wall by people simply because we have established the connection between the specific combination of lines in the software and what that combination of lines represents. 2D and 3D CAD software do not make that connection but understand the drawing merely as combination of lines. BIM software, however, does understand the meaning of the object, but only because a person has told that to the software.

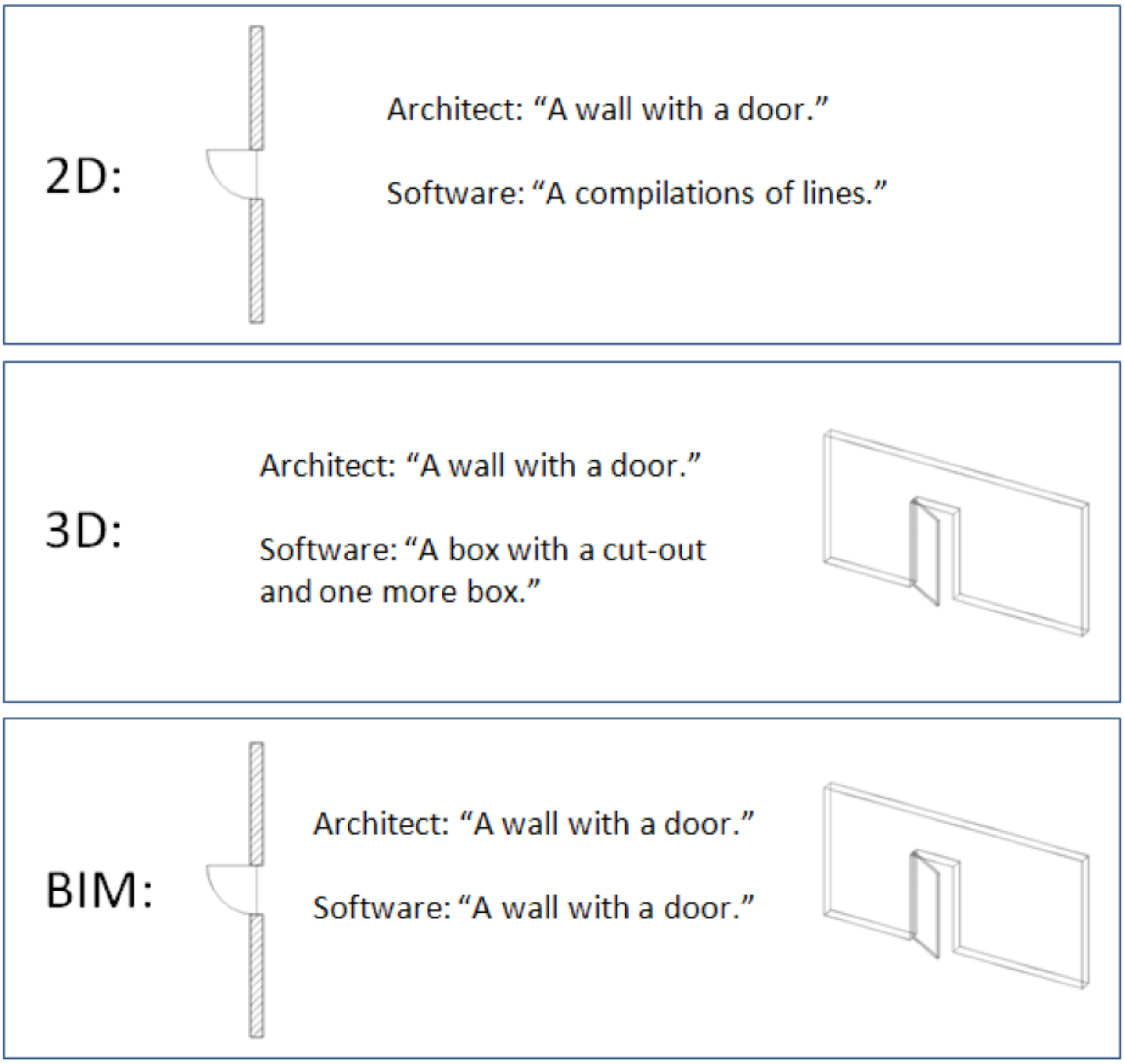

Figure 1 A simple comparison of different design techniques (Jóhannesson 2009)

From the processes point of view, BIM contains all aspects, disciplines and systems of the building, and enables closer, more accurate and efficient collaboration between all stakeholders than the traditional process. (Azhar et al 2012.) In addition to collaboration, communication is the other important element of the foundation of BIM process. Collaboration and communication should not only be enhanced but also begun earlier in the project. The viewpoints of subcontractors, material suppliers and manufacturers are considered even more in the design production process to optimize quality, constructability, aesthetics, affordability, timeliness and seamless work flow. Figure 2 depicts the difference between traditional process and BIM process.

In terms of project delivery method, implementation of BIM in IPD (Integrated Project Delivery) projects is considered more feasible than in traditional delivery methods such as Design-Bid-Build (DBB), in which closer collaboration with the general contractor typically begins only after the bid has been won. That being said, developer contracting suit BIM implementation well, because the construction company acts as the owner and general contractor, and is responsible for design, execution and sales.

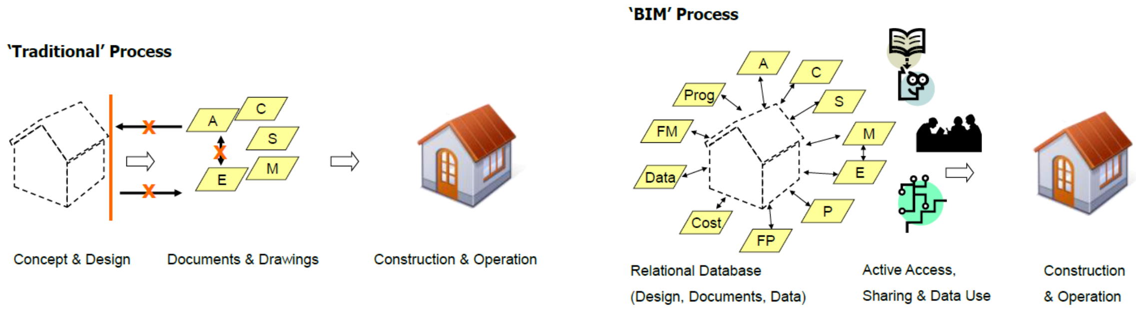

Figure 2 A comparison between a traditional and BIM-based process (Azhar et al. 2012)

The aim of the model creation process is that the model corresponds to the real time understanding of the actual building all the time, which is achieved by constantly refining and adjusting the model in real time. Up-to-date and more accurate information provides improved grounds to make decisions, whether it is about decision to start the project, setting up a budget for the project or something else.

2.2 Adoption of BIM

This chapter explores adoption of BIM. The purpose of this chapter is to study the motives and approaches of different actors in the AEC industry to adopt BIM. First, an important distinction is made between adoption and implementation as it seems that the terms are used interchangeably in various publications. In this thesis, adoption is a more sustained and established way of integrating BIM into existing business than implementation. When BIM methods, practices and tools are used in projects to some extent, and all the aforementioned are still evolving, BIM is being implemented into projects, but when BIM-based project delivery with established methods, practices and tools has become the norm for the organization, BIM has been adopted. In a way, adoption is the long-term objective of BIM implementation.

According to Singh and Holmström (2015), it is well-established that adopters of new innovation can be categorized as innovators, early adopters, the early majority, the late majority and the laggards. Software developers can be seen as innovators, design and engineering companies represent the early adopters with construction companies, and operations and maintenance companies seem to be lagging further behind (World Economic Forum 2018). Innovators can be characterized as pioneers, developers and risk takers. Early adopters require some evidence of feasibility, benefits and sacrifices of the innovation, but are eager to adopt it. The early majority need more proof of concept but are still willing to adopt. The late majority and laggards are quite skeptical and conservative but will eventually adopt the innovation, if the concept is proven. The categorization can be reflected to attitudes of members of an organization: some people are more resistant to change, whereas some are eager to adopt the innovation.

For an organization the rate of adoption can be a strategic choice in that being the first to adopt might give significant competitive edge or it can even be inevitable for the business to survive. Maslow's theory of hierarchy of needs basically states that if the lower-level needs are not fulfilled, the higher-level needs are not even desired (Singh and Holmström 2015). Singh and Holmström (2015) consider primary and secondary needs that correspond to Maslow's higher and lower-level needs. If the adoption of BIM is seen critical for business, it is a primary need, and if it is not critical but rather seen as an opportunity to gain competitive advantage, it is a secondary need. The adoption can be critical even though the survival would not directly depend on it, e.g., if the competitors are increasingly adopting BIM, it creates peer pressure to adopt. The need becomes critical, because the adoption of BIM is considered as the dividing line between being competent and incompetent.

The pressure to change comes from several directions. In a way, software vendors are driving BIM adoption as they develop new products that early adopters test and help develop by providing feedback. Testing novel technologies such as augmented reality, might lead other organizations and individuals to understand that the organization is eager to adopt BIM – inducing pressure. This way the organization will attract motivated people who seek an innovative environment, which increases human capital and competencies of the organization. (Singh and Holmström 2015.)

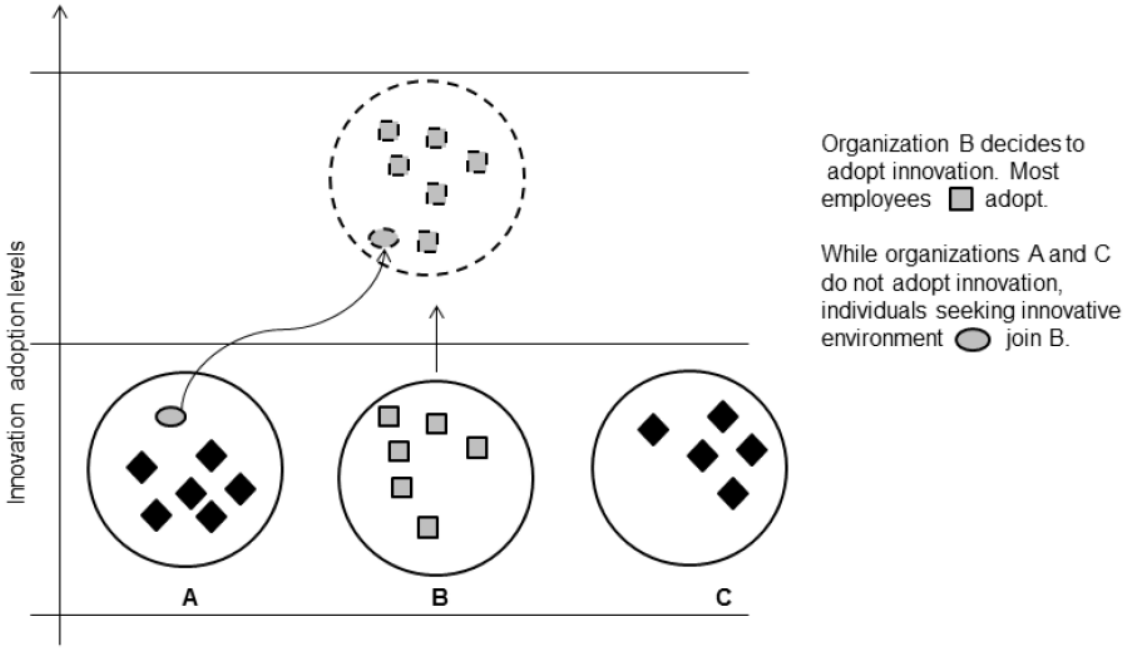

Figure 3 Dynamics between organizational and individual BIM adoption behavior (Singh and Holmström 2015)

Government and other regulative bodies have a lot of power to influence the adoption through mandates, regulations and guidelines, financial incentives and promoting training. (World Economic Forum 2018.) Academics and researches do their bit by developing theories and new methods for solving problems and answering questions about BIM adoption and utilization. Research helps different organizations to identify and focus on the important matters, to adopt BIM, and to develop their own BIM path.

A study of Succar and Kassem (2015) supports these views by studying the BIM adoption on macro level and introducing several adoption models for understanding and assessing BIM adoption. Their macro Diffusion Dynamics model describes how peer and non-peer organizations can influence the adoption decision of an organization.

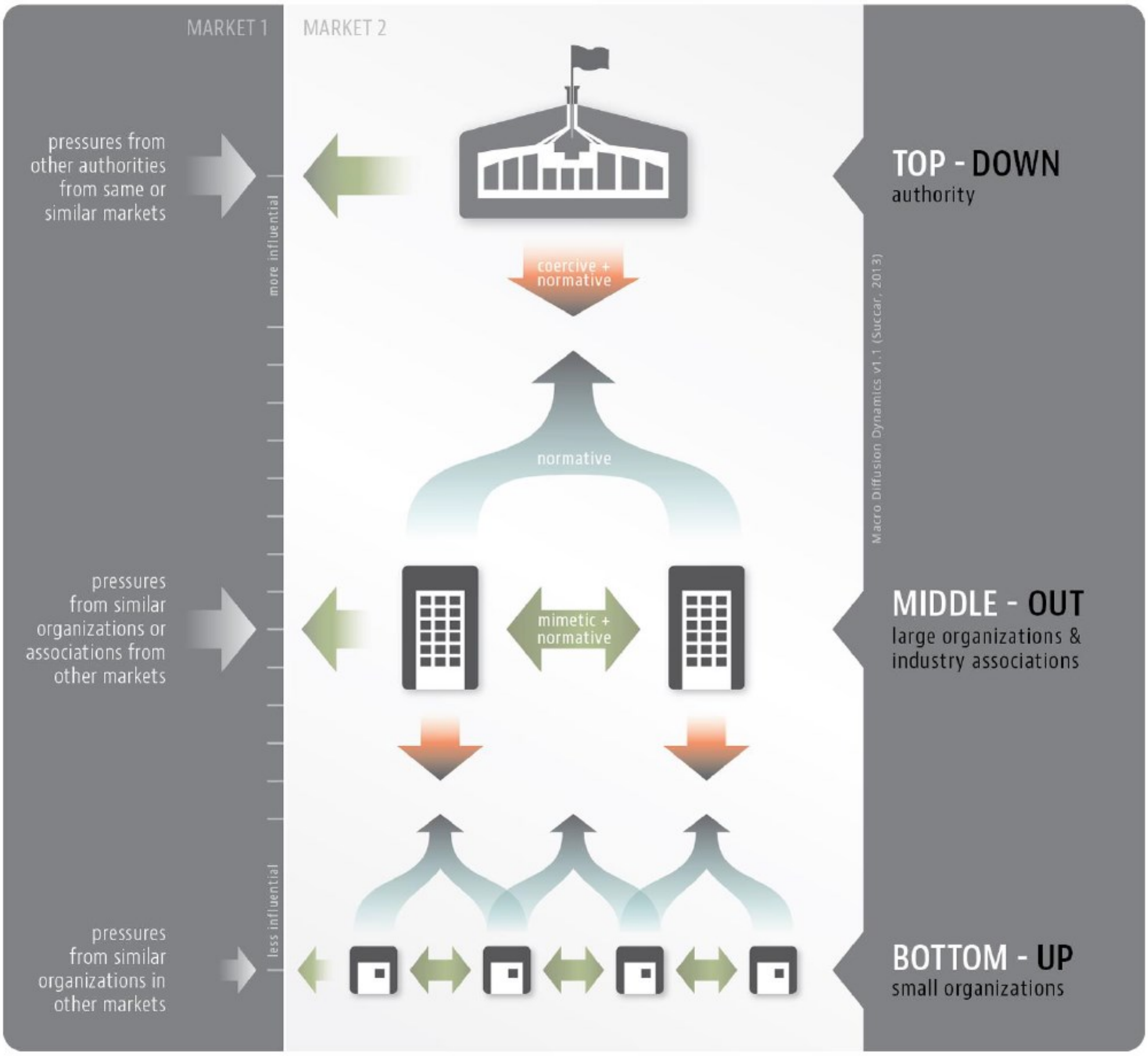

Figure 4 Macro-Diffusion Dynamics model (Succar and Kassem 2015)

In a follow-up study of Succar and Kassem (2017), it was found that the Middle-out Dynamic model applies in Finland, i.e., large construction companies adopt BIM internally at first, and then push it into the smaller companies in the supply chain, into the regulatory bodies and into their competitors, similar large construction companies.

The study of Singh and Holmström (2015) concludes that for most stakeholders participating in their empirical study the revenue generation was more important than beginning the adoption of BIM despite the recognized need and acknowledged benefits of it. The theory of hierarchy of needs partly explains the motives of organizations and individuals for BIM adoption, and the Diffusion Dynamic model by Succar and Kassem (2015) supports it.

World Economic Forum (2018) suggests that BIM adoption worldwide has been slow despite its various benefits, but it could be accelerated by motivating the actors in a right way and helping to understand the benefits of BIM by highlighting the great potential of value creation rather than the costs of adoption. Aksenova et al. (2018) suggest that in Finland, the forerunner of BIM development and implementation with many successful research and technology programmes, the adoption remains slow due to unchanged business models. In practice, even though the challenges of implementing BIM without changing the processes are acknowledged, people still want to use BIM in the traditional, comfortable ways. Changing the mindsets of people is necessary for reconfiguring business practices in order to capture the full potential of BIM.

2.3 Implementation of BIM

Succar and Kassem (2015) define BIM implementation as ‘’the set of activities undertaken by an organizational unit to prepare for, deploy or improve its BIM deliverables (products) and their related workflows (processes).’’ Eastman et al. (2008) state that the company should firstly develop internal knowledge about BIM technologies, and secondly, appoint lead personnel to lead the implementation. Implementation process is individual for each organization due to different organizational structures, established practices, processes, people, tools etc. Thus, two direct competitors could have fundamentally different approaches to the implementation.
Prior implementation, BIM processes, practices and methods need to be developed to guide the implementation in practice. It requires planning and coordination due to interrelatedness of functions and different characteristics of each project. To capture the potential value of BIM, it must be implemented into functions of the company such as contracting, procurement, cost estimation and control, production, sales and marketing. At project level, BIM might not be chosen to be implemented in all functions. Depending on the needs of each project, the implementation could be carried out into any number of functions. This is to say that the implementation process is intricate due to functions and activities being interrelated.

Ideally, BIM is implemented in projects with collaborative delivery methods such as Integrated Project Delivery (IPD), because BIM relies on correct and accurate information, and collaborative delivery methods facilitate and promote information sharing as all stakeholders are working towards a common goal. (Messner et al. 2011.) In projects delivered with less collaborative methods such as Design-Bid-Build or developer contracting, it is important to plan BIM execution process thoroughly before defining the roles and responsibilities. Support of all team members should be confirmed for ensuring successful implementation. If the support and commitment is lacking, it could lead to unfairly divided workload and result in unsuccessful implementation. Thus, from legal point of view it is important to state in contracts that BIM practices are to be used in the project. (Eastman et al. 2008.) Even if the responsibilities, rights, protocols and incentives are defined in the BIM Execution Plan, a document to guide the implementation, it does not bind anyone legally. There exists a risk that stakeholders are not actually fully committed, and the implementation will not be executed or will be discontinued at some point. It might also an issue related to lack of competencies or established processes instead of lack of commitment.

2.3.1 Main objectives of BIM implementation

The motives and reasoning behind implementation were discussed in earlier chapters. This chapter presents the objectives of implementation that stem from the motives, which include gaining competitive edge and business survival.

The main objective of BIM implementation is to enhance existing processes to decrease project delivery time and cost, and to increase productivity and quality. (Azhar 2011.) BuildingSMART Finland (2012) defines the objectives as follows:

- To provide support for the project’s decision-making processes

- To have the parties commit to the project objectives by means of using the building information model
- To visualize design solutions
- To assist in design and the coordination of designs
- To increase and secure the quality of the building process and the final product
- To make the processes during construction more effective
- To improve safety during construction and throughout the building's lifecycle
- To support the cost and lifecycle analyses of the project
- To support the transfer of project data into data management during operation

Epstein (2012) introduces partly the same objectives: improvement of profitability, quality of works, production efficiency, competitiveness, ability to collaborate and openness to new business opportunities. She points out that the implementation is a business decision. Therefore, the decision should be made by those responsible for the business and results.

As an investment, the main objective of BIM implementation is to generate value for the company through implementation into individual projects. Value is an outcome of short- and long-term sacrifices and benefits. Successful implementation presumes the benefits exceeding sacrifices. Benefits were presented in the previous paragraphs. Sacrifices include procurement of BIM technology, effort and resources required for changing work processes and practices, increasing knowledge and capabilities, and planning and executing the implementation. There are also sacrifices such as risk of losing proprietary knowledge, and other uncertainties. However, assessing the benefits and sacrifices is difficult, because there is a lot of uncertainty related to them. Fragmented nature of construction business adds on to the uncertainty as the processes, competencies and technology of one stakeholder might affect others. Hardin and McCool (2015) suggests that the success of BIM depends on how well utilization of BIM is planned and communicated within the project team, which should be done at the beginning of the project.

2.3.2 Ecosystem perspective

BIM implementation into an organization can be considered as an integration of ecosystems: the existing business ecosystem and the new BIM ecosystem. The business ecosystem should be modified to meet the needs of the BIM ecosystem. BIM ecosystem is formed by three elements: products, processes and people, that are interdependent on each other (Gu et al. 2014). In this study, the element of products is considered as technology. Understanding the co-evolution of the ecosystems and the systemic challenges and opportunities of it is key for developing a suitable BIM strategy (Singh 2016.).

Evolution of the elements of BIM ecosystem should be aligned so that the elements support each other. (Gu et al. 2014.) The dependencies of these elements have been well-established. Simply put, the people must know how to use the tools. If only the tools are evolving, and people do not know how to use them efficiently, the implementation might not create any value. The statuses of an ecosystem can be categorized as established, partially aligned and skewed. Figure 5 illustrates the differences. In a well-established system, work becomes more and more routine-like, which itself increases efficiency. It is clear that an organization should aim for an established systems integration through co-evolution.

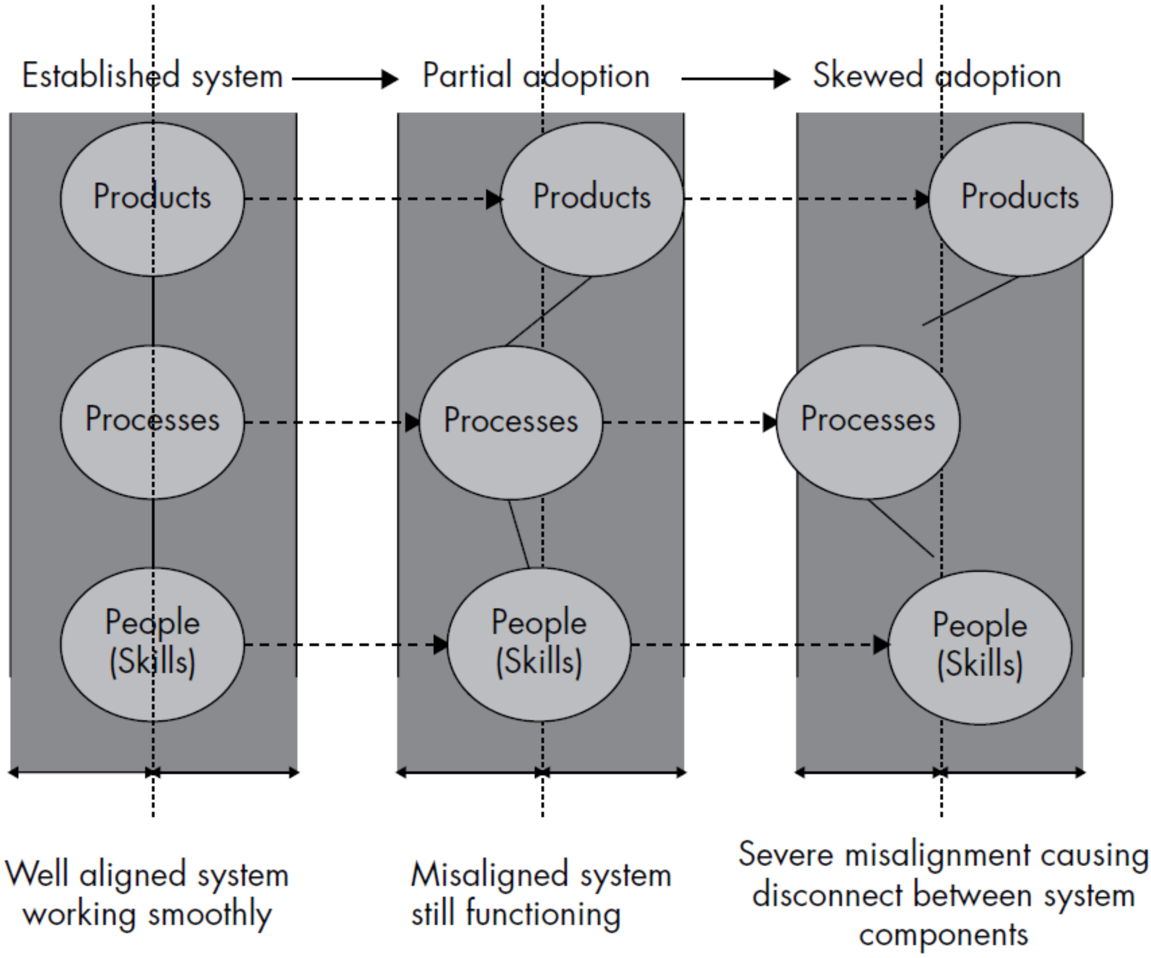

Figure 5 Coevolution of products, processes and people in a system (Gu et al. 2014)

From the perspective of system evolution, adoption of BIM is no different from adoption of 2D CAD. However, the shift from pencil made drawings to CAD was not as vast as the shift to BIM, because the design processes were a lot more alike, so the main changes were mainly focused on skills and products. With BIM, the changes in the ecosystem concerns all domains, and in a larger scale. For example, the products are much more enriched (model objects compared to drawing elements such as lines), new roles and tasks create needs for new skills and knowledge, as do the new processes. It all stems from the needs that the concept of BIM entails.

The part of external stakeholders in the evolution should not be ignored. Moore (1993; in Aksenova et al. 2018) characterizes an ecosystem as a structured network of partners that are interdependent as they are both competing and collaborating. Competition creates pressures to evolve, whereas collaboration brings another set of dependencies on the table. Soft skills such as communication and conflict management could be important in co-evolution in the industry level.

2.3.3 BIM Execution Plan

In this chapter, the goals of a BIM project, the uses of BIM, BIM processes and the roles and responsibilities that come with implementations are covered by going through the purpose and content of BIM Execution Plan (BEP).

BIM Execution Plan is a framework for strategically implementing BIM on a project. (Messner et al. 2011.) Its main purpose is to ensure successful implementation of BIM into projects through motivating people to plan activities and encourage discussion. BEP should aim to convey the vision of the BIM project, and cover project planning at detailed level. Its purpose is to increase transparency and decrease misunderstandings. BEP is meant to be a dynamic tool, to which the project team can reflect activities and tasks. It can also help people that are just getting started with BIM to help understand what BIM is about in practice. This is not to say BEP should not be used in projects where people have more experience and the processes have matured and been standardized.

An organization should have internal BIM standards and a general organizational-level BIM Execution Plan that can be modified for each project to correspond its characteristics and objectives. (Messner et al. 2011.) Internal standards define generally how BIM is meant to be used at organizational level. Building Information Modeling Execution Planning guide developed by participants of Computer Integrated Construction Research Program at Pennsylvania State University is considered an excellent reference for developing a BIM Execution Plan (Baldwin and Sharif 2015), thus, it is the primary reference of this chapter.

Developing BEP should be a collaborative effort that includes designers, subcontractors and other external stakeholders, because participatory collaboration should be part of the planning process as well as the execution. (Messner et al. 2011.) It is important to designate someone responsible for the whole BEP process: compiling, coordinating and updating. A simplistic planning procedure is represented in figure 6 below.

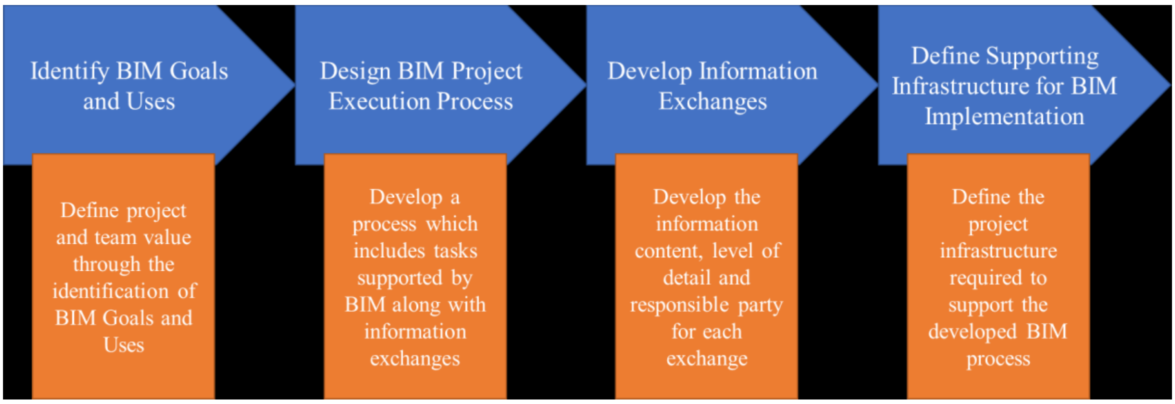

Figure 6 The BIM Project Execution Planning Procedure (Messner et al. 2011; modified by Tuomas Hykkönen)

2.3.3.1 BIM Goals and Uses

Defining Goals and Uses of BIM in the project is the first step of developing BEP. (Messner et al. 2011.) BIM Goals depict what is wanted from the implementation, e.g., reduction of project duration, quality improvement or high field productivity. Defining BIM Goals helps stakeholders understand better the potential value that can be created to the project and each stakeholder. BIM Uses are project activities, in which BIM is utilized to achieve predetermined BIM Goals. These activities include design authoring, programming, cost estimation and phase planning. Following the selection of Goals and Uses, the Goals should be prioritized based on importance to the project and capabilities of the project team. If the team does not have the capability and resources to implement all Uses, and to achieve predetermined Goals, prioritization is needed to decide which Goals will be pursued and which Goals to exclude from the plan. It should also be thought through whether a Goal and its corresponding Uses are feasible and value-creative.

The BEP guide of Penn State has determined 25 common BIM Uses, which are presented below. This is not, however, a comprehensive list of possible BIM Uses (Messner et al. 2011).

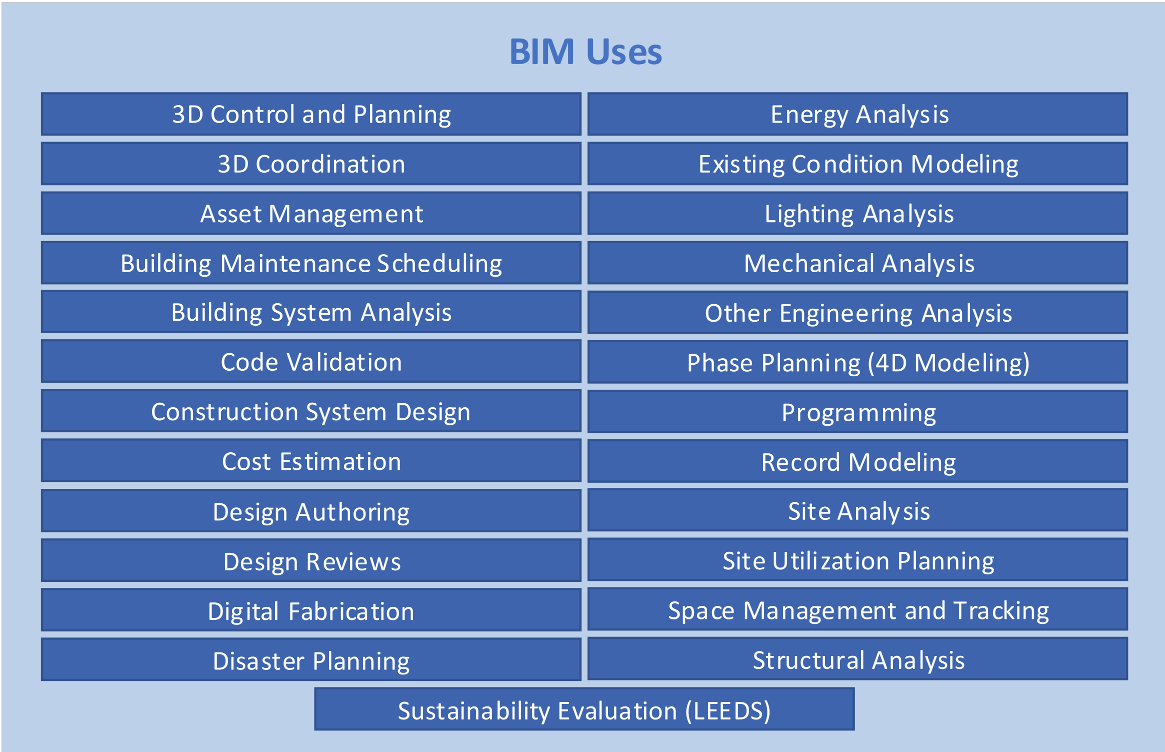

Figure 7 List of 25 common BIM Uses (Messner et al. 2011; modified by Tuomas Hykkönen)

Some of the Uses in the list are more important than other. For a BIM project, some of these are inevitable and seem obvious. Design Authoring, the process of creating a building information model, is in the core of a BIM project – it would be at the very least a stretch to call a project without a building information model a BIM project. Another example, 3D Coordination, is essential in a slightly different way. Sure, it would be possible to make use of models of different disciplines for cost estimation or scheduling, but it goes against the idea of utilizing accurate data efficiently. (Messner et al. 2011.) From the housing perspective, 3D Coordination, and Control and Planning are potential Uses to respond to the commonly recognized challenges of insufficient design coordination and production planning and control. 3D Coordination is actually one of the most recognized and beneficial Uses of BIM, especially from the point of view of time and cost reduction (Jowett et al. 2018; referenced Mcgraw-Hill Construction 2012, Letie et al. 2010, Bockstael and Issa 2016). In contrast, for unique and complex projects various analyses might also be highly beneficial due to less standardized design solutions.

3D Coordination is a process of identifying and eliminating soft and hard clashes with the help of a software and visual observation. The difference between soft and hard clashes is that soft clashes are not actual collisions of building elements, but discordance between the systems. Clash detection operations with BIM software are based on predetermined rules, so the software can identify, for example, whether a window of an architectural model fits into the space in the wall of the structural model or not. A lot of general rules are embedded in the software, but organizations could define their own rules for their own purposes. Even though BIM software enables faster and more accurate clash detection and design coordination, the role and responsibilities of people should not be understated. To get reliable results, the rules have had to be determined and encoded in the software correctly, and the results must be assessed, validated and prioritized.

Descriptions of all the Uses of a project should be included in the BEP, and they should be assigned to responsible parties. Assessment of their capabilities, which includes competencies, resources and experiences, and value to the project and each responsible party should be included too. The responsible parties could demonstrate their capability with previous work, for example. (Messner et al. 2011.)

2.3.3.2 BIM Process Maps and Information Exchanges

Process maps are important instruments for guiding the implementation as they define the path to execute the selected BIM Uses. The purpose of process maps is to clarify the whole process, sequences, tasks, responsibilities and required and created information by clearly visualizing the processes. It helps project participants to see what the purpose of their work in the context of the whole process is and facilitate discussion about topics such as deliverables and their requirements, contractual issues and practical matters. The steps to create the maps include adding the selected BIM Uses into the process map, arranging them sequentially, assigning responsible parties to the Uses and determining internal and external Information Exchanges. (Messner et al. 2011.) The basic principle of the elements of process maps is presented in figure 8.

Figure 8 Information content of a BIM Use within a BIM process map (Messner et al. 2011)

Information exchanges must be planned so that team members know what information is needed by who, and when. The member receiving information is responsible for defining the content of information they need, the level of detail, and the formats it should be submitted in. Determining Information Exchanges of all processes might be a challenging process. A pull-driven approach considers the fact that the required information of a downstream Use is dependent on the created information of the upstream Use. The determined Goal of the Use might help in determining the Information Exchanges at the end of the process.

2.3.3.3 Roles

Compared to traditional construction processes, BIM processes include new tasks and roles, which should be described in the BEP as should the relevant responsibilities. Following the increased BIM implementation during the last ten years, a lot of new BIM related work titles have emerged: BIM Consultant, BIM Development Manager, BIM Engineer, BIM Coordinator, BIM Modeller, BIM Specialist and BIM Manager to name a few (Kuittinen, 2018). Additionally, the most in demand jobs in AEC industry include BIM Engineers, BIM Model Managers, VDC Engineers, BIM Directors, Information Managers and BIM Applications Managers (Kiviniemi 2018; referenced David Philp 2016).

The challenge with the newly emerged titles is that there is no universal description of them, thus, they are currently used interchangeably, and consequently, same titles can mean different things to different people. For example, a BIM Manager can also be called Information Manager, BIM Champion, BIM Integrator or BIM Leader amongst others, depending on their functions and the organization. (Barison and Santos 2010.) The discordance and interchangeability of terms highlight the importance of defining the tasks and responsibilities in the BEP.

Research has been done in order to clarify the roles and responsibilities. Gathercole and Thurairajah (2014; in Berlo and Papadonikolaki 2016) found out in their study that BIM professionals could be categorized into three main roles: BIM managers, BIM coordinators and BIM technicians. BIM managers are responsible for administrative functions of the project, whereas the tasks of BIM technicians are related to modeling. BIM coordinator is seen to have duties within both the administrative and modeling domains. Berlo and Papadonikolaki (2016) further differentiates between BIM manager, who is mostly responsible on strategic issues such as BIM adoption, developing BIM strategy and arranging training, and BIM coordinator whose responsibilities lie in operational issues such as information and model management.

Davies et al. (2015) recognize five types of BIM specialists. The first one being the directors and senior managers who do not actually have much to do with BIM processes or tools but provide the direction and support for BIM adoption and utilization. They are the ones developing business strategies of the company, with which BIM strategy should be aligned. Secondly, there are BIM managers and coordinators that manage BIM processes and operate at project level.

Davies et al. (2015) suggest that there are also the types of BIM managers responsible for implementation and training, similar to how Berlo and Papadonikolaki (2016) describe the role of BIM manager in their study. They should also have the highest technical capabilities within the company and be the primary technical support. Those would be the third group of BIM specialists. The fourth group consists of BIM specialists that also have very good technical skills and knowledge about BIM software and standards but could be lacking the leadership and management skills. Therefore, they would be working with model creation and company level guidelines and instructions. The last group of people might not see themselves as BIM specialists as they would have gathered their knowledge of BIM and especially software-related competencies mainly through practical experience in a specific role such as cost estimator or procurer. Thus, they have BIM knowledge and skills but only within a specific area, and mainly related to the use of software. Because they operate in such specific tasks that they can identify detailed issues for development, they have a very important role in gathering experiential knowledge of BIM implementation.

2.3.4 BIM process according to COBIM2012

In this chapter, BIM processes are described as they are defined and described in the publication series Common BIM Requirements 2012 by buildingSMART Finland (2012). COBIM2012 provides a reference framework for organizations implementing BIM. This chapter briefly describes the BIM processes in programming, schematic design, master plan design and detailed design.

COBIM2012 contains technical requirements and constraints for the modeling process, some of which are presented below:

- Each design discipline creates their own building information models and is responsible for the quality
- BIM Coordinator or other actor defined by the client is responsible for the quality assurance process, namely the 3D coordination, but designers are responsible for checking their own models during the design process when the models are still in the making
- Model elements must be modeled with intended tools, e.g., walls must be modeled with wall tools. If there is no specific tool for a given model element, improvisation is advised
- Model Description Document, which describes the content, precision and purpose of the model as well as restrictions of its use must be submitted along with the models
- All models are handed over to the client in IFC format as well as native file format, and the client has the right to use the models to the same extent as traditional project documents
- The discipline-specific model should include only model elements that belong to that specific design discipline

Needs assessment and programming

Requirements and decisions made in needs assessment and programming phase determine the budget, schedule and scope objectives of the project, and form the base for future planning and decisions. The requirements and needs of the owner and user of the building are mapped. A requirement model is created, which is not necessarily a geometric 3D model but more like a list of principle requirements concerning spaces and their utilization. The requirement model should be at minimum a program plan in a table format. The BIM Coordinator ensures that there is enough time reserved for modeling in the schedule, and that all designers are provided with the initial information.

Schematic design

Based on the requirement model, the architect creates a spatial model, a rough preliminary model used for comparing different design alternatives. An approved schematic model of the architect is selected as an outcome of schematic design phase.

The structural designer creates a preliminary building element model of the whole building, and models detailed type structures based on the schematic model of the architect. The MEP designers create initial system models containing main paths, channels and cable routes. A site model of the construction site, or in case of renovation projects, an inventory model of an existing buildings, can be created in this phase, too. Based on areas, volumes and space types, preliminary cost estimations, energy consumption simulations and life-cycle cost calculations can be done in this phase. The BIM Coordinator works out which models, and with what level of detail, are required in each phase, and for what purposes.

Master plan design

The discipline-specific models created in schematic design are developed further in the master plan design phase. Project participants must agree on the schedule of uploading the models to the common data environment so that the up-to-date models are always available to others for reference. The models enable fast, interactive visualization and analyses, and transparency in the design supports communication and decision-making. Frequent sharing of the up-to-date models enable concurrent design work between all disciplines, which changes the nature of design more iterative compared to traditional design. Design disciplines must collaborate to ensure that the requirements of others are fulfilled, and the models are compatible.

The schematic architectural model is developed into a preliminary building element model. In addition to the spaces, it includes at least the load-bearing structures, walls categorized according to main type, and windows and doors without type information. The accuracy must me adequate for applying for a building permit.

Detailed design

Morel creation and utilization procedure in detailed design phase is similar to the master plan. The level of development in all models is increased. Frequent submittal of all models must be ensured so that up-to-date models are always available for others. A suitable submittal frequency is approximately one week. The models will be approved for use in the preparation for construction, e.g., sending requests for tendering to subcontractors.

The architectural model is developed into a building element model, i.e., the model elements should represent the actual building element accurately. The model can be used for quantity take-off and design coordination. It also acts as the main reference to models of other disciplines.

2.3.5 Challenges and risks of BIM implementation

This chapter considers challenges and risks related to BIM implementation from the point of view of a construction company. First, a remark is made about the current state of BIM related education in Finland. Currently, there is a shortage of competent and capable employees in the Finnish AEC industry. (Jäväjä 2018.) This industry-wide challenge concerns all actors in the field and demands refocusing the national education programs more towards BIM. If the gap between required and present levels of competence is not decreased as demand for BIM increases, it could hinder BIM adoption.

Zahrizan et al. (2013) categorize challenges as non-technical and technical challenges. Non-technical challenges include resistance to change, fundamental understanding of new roles and responsibilities, understanding how the benefits of BIM are accomplished, and education. Managing non-technical challenges provides good operational preconditions for utilization of technology. (Tulenheimo 2015.) Utilization of technology is a key challenge to be considered as it is a potential bottleneck for BIM implementation. Technical challenges include identifying, procuring and upgrading suitable technology, interoperability, compatibility and complexity. (Zahrizan et al. 2013.) Reliability of technology is another challenge to be mentioned, especially as BIM technology tends to be rather novel. Many of the challenges can create a significant obstacle for the implementation. Potential challenges must be identified and managed adequately depending on the challenge and its nature. Unsolved challenges do not necessarily totally water the implementation, but the success of implementation will consequently remain partial.

Arayici et al. (2011) identified the following challenges of BIM implementation:

- Overcoming the resistance to change, and getting people to understand the potential and the value of BIM over 2D drafting
- Adapting existing workflows to lean oriented processes
- Training people in BIM, or finding employees who understand BIM
- The understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently
- The required collaboration, integration and interoperability between structural and the MEP designers/engineers
- Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers

It could be concluded from the theory of coevolution of products, processes and people, that the challenges are consequently interdependent as well. Whereas non-technical challenges affect utilization of technology, technology affects attitudes, will, responsibilities, competencies and understanding the concept of BIM. Misused, unreliable or too novel technology could lead to developing wrong competencies, increase of resistance to change or misunderstanding BIM. Planning of implementation helps overcoming and preventing potential challenges and avoid confusion and frustration that consequently increases resistance to change, which hinders the implementation process.

Regardless of assessment and preparedness of challenges some uncertainty always exists. Azhar (2011) suggests that BIM as an integrated concept dims the level of responsibilities, which enhances risk and liability. BIM risks are categorized as legal and technical. The following risks relate to the prediction that collaboration increases with BIM: risk of losing proprietary data, knowledge and information, risk sharing, accuracy of data and technological compatibility. Increasing collaboration presumes greater level of communication and sharing of data, knowledge and information. Sometimes proprietary design data can be necessary to share, and a problem could emerge if the owner, for example, perceives entitled to own all the parts of the design. Here it is assumed that a designer is the one sharing proprietary data, but it could also be the owner that provides some model elements for the designer to use in the model. Azhar (2011) suggests that the best way to prevent conflicts is to define ownership rights and responsibilities in the contract documents. Monczka et al. (2000) also suggest using formal confidentiality or nondisclosure agreements that commit all parties to nondisclosure of information.

A new cost of design and project administration process, increased need to ensure and update accurate BIM data, carries a risk of incorrect data being produced and used. Accuracy of data is naturally one of the main interests of the owner, but should it be a responsibility of the owner, designers, lead designer, BIM coordinator or someone else to ensure correctness of data might be unclear. Apart from correct data, accuracy of data can signify compatibility of the models of different design disciplines. If designers use the models of each other's as reference, it might be difficult to find the root cause for an error. The responsibilities should be defined and made clear to all relevant stakeholders. Accuracy of data is also partly a technical risk. The existing project management tools are mainly incompatible, but BIM software are developed to be compatible, meaning that data can be transferred between software. IFC standard is key for data transfer, but it too conceals a risk of losing data. In general, some data or functionality is always lost in IFC data import and export because software must interpret the transferred data. E.g., a designer could be producing accurate data, but the receiver perceives only inaccurate data. Ensuring use of accurate data should be contractually addressed. (Azhar 2011.)

2.3.6 Standards and guidelines

Standards and guidelines are needed for quality assurance. Globally, many organizations implementing BIM use national standards and guidelines that have been developed with consideration of a specific national environment and its characteristics. However, there exists only few international standards. Industry Foundation Classes (IFC) standard, which was developed by buildingSMART, an organization formerly known as International Alliance for Interoperability (IAI) that was formed by international software vendors and researchers in 1996 (Berlo and Papadonikolaki 2016), is the most commonly used one. In Finland, the use of IFC compatible software in all publicly procured BIM projects is demanded by Senate Properties, a facility management company owned by the Finnish state.

IFC describes the building and construction industry data, and is used as an open file format, which is not bound to any specific BIM software, and is used for transferring files between software. For example, design authoring software have their own native file formats, but if a designer wants to use another discipline's model as reference, the model must be converted from the native into IFC format, and imported in the receiving software, which must support the IFC format. Important to understand is that when changing the format of data, there will be loss of data of some sort. It can depend on the software the data was created, the receiving software or IFC settings. Untransferred data or lost functionality of data could be a result of the way data was created, it could be inability of the receiving software to interpret the data or it could simply be defined in the IFC settings that some specific data will not be converted.

The IFC standard is an essential development in BIM, but in addition, standards and guidelines are needed to guide the implementation processes and procedures. For example, in Malaysian construction industry a few years ago BIM was difficult to implement, because people did not know where, when and how to begin. (Zahrizan et al. 2013.) What they were lacking was national BIM standards and guidelines, which led to organizations to develop their own BIM strategies, education and developing new roles and responsibilities. Since then the Malaysian government has stepped forward and promoted the utilization of BIM, which has accelerated the implementation, although slowly (Latiffi et al. 2016). By mandating the use of BIM, governments can have an even bigger role in BIM development. Without national guidelines, the actors of the industry would develop their own methods, procedures and practices, which could lead to conflicts between actors. Government has been the main driver for BIM implementation in many countries such as the UK, Malaysia, Denmark and China (Ganiyu and Egbu 2018; Herr and Fischer 2018), but the development of practical standards and guidelines by the government is still lacking (Herr and Fischer 2018).

In Finland, the main source of guidance for BIM implementation is the Common BIM Requirements 2012 based on the BIM Requirements developed by the Senate Properties in 2007. A major shortcoming of guidelines is that they do not commit anyone to anything. Other standards and guides to be mentioned are BEC 2012, a standard for modeling of concrete elements; BCF (Building Collaboration Format) standard to exchange intelligent messages between BIM software, COBie (Construction Operations Building Information Exchange) standard for delivering asset data, and the BIM Execution Planning Guide by CIC Research Program of Pennsylvania State University that was discussed in chapter 2.3.3. BCF and COBie are international standards, similar to IFC.

2.4 Collaboration in BIM

This chapter focuses primarily on the social side of a BIM project, collaboration and its elements. The themes of this chapter are participatory collaboration, decision making, and value creation.

Collaboration, by definition, means working together with one or more individuals or organizations. The aim is to take the views of all team members into account in order to make right decisions. Improving decision-making enables value creation. Added value, knowledge capital and trust are the principle elements of collaboration (Ståhle and Laento 2000).

BIM enables more accurate and efficient collaboration amongst all stakeholders earlier in the project, compared to the traditional project delivery (Bernstein et al. 2012). However, collaboration should not be increased just for the sake of it, but the amount of collaboration should be assessed based on the type of the project. In complex mega projects where the project network of stakeholders is vast, close collaboration is inevitable for project's success. Multidisciplinary design captures the importance of collaboration well: to connect all building systems so that they perform in the intended manner, the designers must communicate how their systems depend on and affect other systems.

In housing, standardized design, high rate of prefabrication and repeatability imply that the picture of the end product is relatively clear. Collaborative effort could therefore be of more use in processes rather than in product development. That is to say that with better collaboration, processes and methods of all project stakeholders could be made more efficient.

BIM does not necessarily have to mean a significant increase in collaboration – building information models can be ordered from the designers without close collaboration. However, it has been proven that the more collaborative a BIM project is, the more beneficial the BIM implementation is (Bernstein et al. 2012).

Figure 9 demonstrates the impact of collaboration on cost savings, which imply that collaborative BIM is more beneficial than BIM without collaboration. A North American MEP company divided their projects into three categories: 2D, Lonely BIM and Collaborative BIM projects. In 2D projects, the proportion of change order costs was almost a fifth of the base contract. Lonely BIM and Collaborative BIM projects diverged in that in the former, BIM was used only in-house, whereas, in the latter the models and data were exchanged with several project participants. The proportion of change order costs decreased by 7,25 percentiles when Lonely BIM was implemented. Even a more remarkable change was observed between Collaborative and Lonely BIM projects – change orders decreased from 11,17 % to 2,68 %. (Bernstein et al. 2012.)

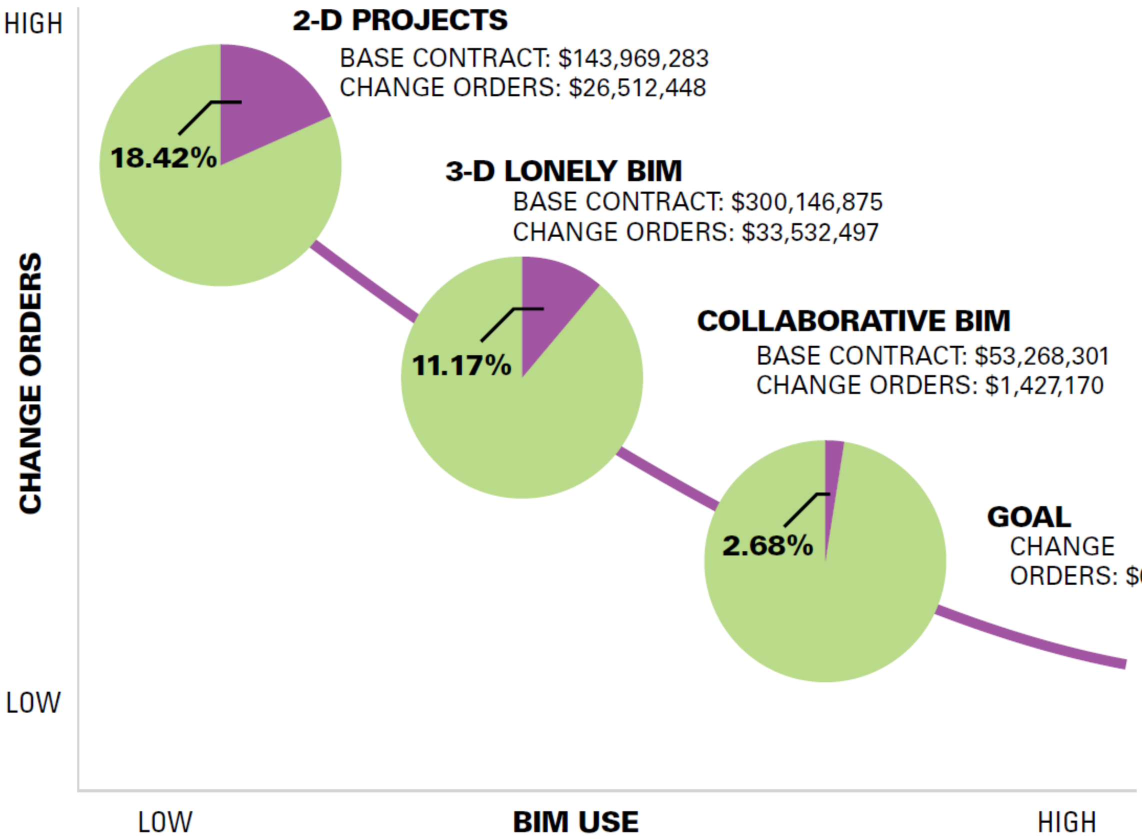

Figure 9 The effect of collaborative BIM implementation to change orders (Bernstein et al. 2012)

2.4.1 Participatory collaboration

The purpose of participatory collaboration in BIM-based projects is to involve and commit relevant stakeholders more intensively and earlier in the project to decrease information loss and waste of resources. The benefits of earlier involvement of all relevant stakeholders assume that the larger the knowledge capital of the team the better decisions can be made (Jowett et al. 2018; Monczka et al. 2000).

Monczka et al. (2000) suggest that the most important factor that affects achieving the project goals is the extent of participation. Also, Bond-Barnard et al. (2018) found that success of project management is more likely when collaboration increases, which is directly dependent on trust within the project team. Defining and agreeing on goals and metrics for determining common direction, monitoring progress and resolving conflicts is important in inter-organizational projects. (Monczka et al. 2000.) The main responsibility of defining goals belongs to the project owner, but other participants can help in setting those goals by providing their opinions on achievability and reasonability. Agreeing on defined project goals is not enough, but all participants should be committed to them as well. Open communication and information sharing are the basis of profitable collaboration and decision making. It is critical for participatory collaboration that communication is direct, and communication channels are established and used. However, open communication entails a risk of losing proprietary knowledge. One way to manage the risk is using formal confidentiality and nondisclosure agreements.

Mayo and Woolley (2016), who studied teamwork from the viewpoint of collective intelligence and its utilization, present a psychological view on collaboration. First step of exploiting collective intelligence is sharing relevant knowledge amongst the team members, and secondly, the shared knowledge must have an impact on the work of the team. Sharing knowledge presumes that members have to know who the others in the team are, so they know to whom to go for information, and with whom to share it. Another presumption is that those with relevant knowledge must speak up.

Knowing who are in the team and speaking up seem obvious, but there are a few things to consider. Team members do not necessarily realize that they have relevant and unique knowledge to share, even when participating into discussion. The so-called common knowledge effect concludes that there is a tendency for team members to focus on knowledge that everyone already knows, because unique knowledge is just not thought of, and might go unspoken. Secondly, team members might do incorrect assessments of own or others' knowledge based on the roles. For example, a person with unique information might withhold the information due to assuming that the person responsible for the issue under discussion already has that information or has better knowledge about the situation. Psychological safety denotes confidence that speaking up does not lead to embarrassment, rejection or punishment, and indicates the level of team atmosphere. All team members can contribute to the establishment of positive atmosphere, although it is initially a responsibility of the project manager. (Mayo and Woolley 2016.)

Mayo and Woolley (2016) present a couple of methods to enhance knowledge sharing. For example, it has been shown that collaborative planning in the beginning of the project helps team members to recognize their own knowledge, which improves the ability of the team to utilize the knowledge. Asking questions clearly about whether anyone has contradicting information or information that has not yet been discussed benefit the team, too. Team atmosphere can be improved by showing appreciation for inputs, e.g., by emphasizing the importance of utilization of all information to enhance the team's work and learning.

Impact of the shared knowledge on the work of the team can be reinforced by the team leaders through repeating and calling attention to knowledge they aim to reinforce. Promoting the value of diverse opinions has been shown to increase the consideration of those values and the ability to exploit discussion of alternative thoughts. Consequently, it helps team members to think the issue at deeper level, which has a positive effect on decision making, problem solving and creativity. (Mayo and Woolley 2016.)

2.4.2 Soft skills

BIM as a collaborative method emphasizes the importance of soft skills such as communication, conflict management, negotiations, teamwork and leadership. (Davies et al. 2015.) As important as soft skills are in any collaborative work, relatively little attention has been put to those non-technical capabilities of people in BIM research and development (Davies et al. 2015; referenced Zhao et al. 2015). For example, the Built Environment 2050 report created by BIM 2050 Group, which suggests that the root causes of inefficiency of the construction industry lie in the ‘’lack of soft skills and poor cultural integration of education and skills, such as interdisciplinary teams and emotional intelligence’’ (Davies et al. 2015). Also, according to Davies et al. (2015) and Deutsch (2011), the biggest barrier for improving BIM within organizations are people. Tulenheimo (2015) supports this by stating that support from capable people throughout the organization form the basis for successful implementation. Soft skills include effective time management, ability to provide effective solutions to conflicts, ability to maintain good relationships, ease in helping to solve personal problems, communication and negotiation skills, authority and leadership skills (Davies et al. 2015 referenced Sumner and Slattery 2010; CIOB 2013).

Communication is considered the most noteworthy soft skill in BIM projects, and also in traditional projects. (Davies et al. 2015.) However, in BIM projects the importance of communication might be considered to be higher because of increased collaboration between all project parties. In addition, the form of it might change too, i.e., communication might experience a shift of some degree from written to oral and visual communication. Communication is an important means to increase transparency, which in turn, highlights the meaning of responsibility. For example, the progress and accuracy of modeling of is can be made more transparent to all project participants through Model Description Documents, model review meetings and clash detection.

Having responsibility does not mean only being accountable on the performance of the tasks, but also being the leader of planning and managing the execution of agreed tasks. The leader needs authority to bring forward and defend their own point of view and opinions, otherwise other parties might do their work in their own way. (Davies et al. 2015.) Transparency helps highlighting issues, but leadership and authority is needed for presenting and defending differing views. To achieve mutual agreement, negotiation and conflict management skills might are needed, too.

In addition, negotiation and conflict management skills are needed when defining roles and responsibilities and agreeing on various project related matters. (Davies et al. 2015.) Conflicts over roles and responsibilities are certainly possible in BIM projects, especially if parties are not familiar with these and the processes. For example, the responsible person of developing BIM execution plan must engage different participants in discussion, decision making and planning in general, which requires negotiation skills. Avoiding, detecting and solving design clashes is another matter, in which negotiation and conflict management skills are needed.

Soft skills should not be considered separately from technical skills. Good communication, defined as sharing information between people (Davies et al. 2015), depends on how clearly and understandably the message is formatted, but also on whether the message is transferred in the first place, which might depend on technical skills or technology. Person’s technical skills could be limited to knowing how to communicate through a software, which should perhaps be enough, but when errors occur, and a message cannot be sent through the software, a skilled person can figure out and solve the problem.

In chapter 2.3.3.3, roles of some identified BIM specialists were described. Considering soft skills, the senior management should typically have leadership skills, BIM managers and coordinators should have interpersonal skills for managing and training people, and people in specific roles that utilize BIM, but are not exactly BIM specialists, should also have interpersonal skills. Interpersonal skills relate to interacting with people, relationships and communication. The role of BIM technician, who is primarily expert of BIM software and standards, does not necessarily require any particular soft skills such as leadership or people management. (Davies et al. 2015.)

3 Scaling up from pilot projects

This chapter focuses on piloting as well as on transition from piloting phase to the large-scale implementation of BIM, meaning implementation of BIM into all projects of an organization. Based on the definition of adoption presented earlier in this thesis, large-scale implementation does not equal adoption of BIM, or the full and complete transition from traditional to BIM-based project execution. Scaling up is defined by ExpandNet and WHO (2011) as ‘’deliberate efforts to increase the impact of successfully tested pilot, demonstration or experimental projects to benefit more people and to foster policy and programme development on a lasting basis’’. Scaling up is essentially an organizational, managerial, political and capacity-building task (ExpandNet and WHO 2010). ExpandNet is a global network of public health professionals and scientists seeking to advance the practice and science of scaling up successful health innovations tested in experimental pilot and demonstration projects. Although the ExpandNet and WHO source is written in reference to health field, the theory is applied in this thesis, too.

3.1 Piloting

BIM is a comprehensive innovative organizational change. It is also a huge investment that requires a lot of resources, so naturally, the organization aspires to ensure a positive impact on business. Piloting is a good way to verify the feasibility and cost-effectiveness of a new concept or a product, and to learn for future scaling up (ExpandNet and WHO 2011). Appropriate execution of a pilot project takes into account the circumstances and characteristics of the project in such a way that they correspond to business as usual. (ExpandNet and WHO 2011.) In essence, if the circumstances of pilot projects are significantly different, e.g., excessive resources are allocated, the outputs of the pilots do not reliably indicate feasibility and cost-effectiveness of the implementation, because these circumstances cannot be sustained later on. On a similar note, the type of pilot projects should be the same as those, which BIM is implemented in after the pilot phase.

The number of pilot projects executed prior to scaling up is an early decision for the organization to make. A lot of companies are executing just one or two pilot projects before scaling up (Epstein 2012). The rate of learning and potential impact on business should be considered when planning piloting. In principle, the faster piloting is performed the faster the learning and acquirement of experiential knowledge occurs, and the faster the scaling up can be done. More important than pursuing the benefits through a rapid scaling up is to plan and execute the implementation well, and keep in mind that BIM implementation is a continuous process. Doing things correctly in the first place helps ensuring the sustainability of the implementation. However, if piloting takes too long and the scaling up is dragged on, the competitors might begin to gain competitive advantage.

Because the effect of pilot projects on business is uncertain, the proportion of pilot projects should be small enough to not have a significant negative effect on revenue. Larger organizations typically are able to have more projects ongoing at the same time, and the impact of one project is less significant on business. In this sense, larger organizations could have higher risk-bearing capacity, which makes it possible for them to execute more pilot projects in shorter time, acquiring experiential knowledge and preparing for scale-up faster than smaller organizations. Of course, besides the number of pilot projects, the impact depends on the project characteristics such as scope and complexity. Also, the knowledge and skills can be higher within a smaller company, which would indicate that less pilot projects are required for a prepared transitioning to large-scale implementation. Executing several pilot projects at the same time enables implementing learnings in other pilot projects right away, which helps to improve processes, demonstrate benefits of BIM and improve general attitude towards BIM faster. However, because issues occur randomly, testing new solutions to observed issues might not be possible at ongoing projects. Good communication between projects is essential to be able to exploit several ongoing pilot projects in that way.

Acquiring experiential knowledge

Learning is another pivotal aspect of piloting. Especially acquiring experiential knowledge of new processes and use of tools is valuable for the whole organization as the experiences are quite individual for each organization. (Ganiyu and Egbu 2018.) Prior to practical implementation, theory of BIM, its processes, tools, terminology etc., should have been learned at some level. In the piloting phase, the focus of learning should be on acquiring experience-based knowledge. In principle, theory is needed to understand BIM, its processes and use of tools, and to guide the implementation process, whereas experiential knowledge helps understanding more specifically what works for the specific organization, which processes and activities are valuable for it, which require improvement, which tools are suitable for it, what are the skill and knowledge levels within the organization, and what is the general attitude towards the change. Experiential knowledge guides the organization to make decisions such as the BIM Goals to be pursued, but also rather specific ones such as which software to use and how.

Learning does not end in piloting, which is very important to understand, because the effect of implementation is most likely not on the desired level after piloting. BIM implementation to all projects is an iterative process, which presumes continuous learning. Burnes (1996; in By 2005) states that organizational change is an open-ended, continuous process rather than a temporary change consisting of well-defined activities.

Planning the pilot projects

Pilot projects should be designed so that they enhance the potential for the future scale-up. ExpandNet and WHO (2011) suggest 12 aspects to consider from the time pilots are designed throughout the implementation process:

1. **Engage in participatory process involving key stakeholders**

Those stakeholders that have been part of the pilot projects are more likely to support scale-up than those who have not. Relevant current and future stakeholders should be assessed, as well as their input, and their feedback on the implementation process should be obtained.

2. **Ensure the relevance of the proposed innovation**

The innovation should be assessed based on its feasibility, cost-effectiveness, equity, cultural appropriateness and community preferences. Pilot projects should promise substantial improvements that are based on sound theory. Obtaining feedback indicates whether or not the objectives are met. Pilot projects should not include processes or activities that require resources that are not likely to be available when scaling up. Modifying or rejecting activities that are not creating value should be considered.

3. **Reach consensus on expectations for the scale-up**

Expectations for scale up might differ depending on whether people have been involved in planning of pilot projects or not, and of course whether the project is successful or not. Expectations and ideas about to what extent the innovation is to be scaled up, and in which business units, tend to differ between the units and possibly projects as they are mainly based on the experiences of the project team members.

4. **Tailor the innovation to the socio-cultural and institutional settings**

The innovation should be integrated into current processes and systems so that the existing social organization, values, norms and traditions are considered with the factors that might support or constrain the implementation. Larger political, bureaucratic and economic environment might affect to the implementation. Thus, certain flexibility should be maintained for the implementation design.

5. **Keep the innovation as simple as possible**

The components of the innovation should be assessed for essentiality and whether they are simple enough to be implemented without lowering the expectations of success. Not all components of the change should be implemented at once, only the simplest ones. Components of the innovations in the context of this study refers basically to the BIM Uses, e.g., 3D Coordination is simple enough, and an essential component of the innovation.

6. **Test the innovation in the variety of socio-cultural and institutional settings where it will be scaled up**

Pilot projects should be executed in all business units where the scale-up is planned.

7. **Test the innovation under routine operating conditions and existing resource constraints of the health system**

The resources, operating conditions and environment including all appropriate factors should be similar in pilot projects and after scaling up. Often the reason for failed scale up is that pilot projects have been allocated more resources than typical projects.

8. **Develop plans to assess and document the process of implementation**

The steps that were taken to achieve the objectives in pilot projects, should be documented for smoother scaling up in the future. Documentation includes information regarding inputs, human resources, worker skills, management issues such as supervision, leadership, incentive structures, costs, financing, logistics and functioning of the information systems. Besides providing guidance for future implementations, concise information about results and processes can be prepared from the documentation.

9. **Advocate with donors and other sources of funding for financial support beyond the pilot stage**

There might be some special inputs requiring financial resources that are needed for transitioning from pilot to large-scale implementation. Financial or other kind of support should not be limited to pilot projects but ensured for the large-scale implementation too. People providing the financial resources should be kept aware of the results and progress of the implementation.

10. Prepare to advocate for necessary changes in policies, regulations and other system components

Even though the implementation should be designed to fit the existing social organization, its values and norms, and other business systems, modifications need to be made for standardized protocols, practices, processes and tools.

11. Develop plans for how to promote learning and disseminate information

Insights about what works, when and how, are important for training and learning. Training and mentoring, which are ways to share the insights, require resource allocation and planning. In the piloting phase, those issues that help improve the implementation process for the scale-up are especially important. There should be some kind of channels for raising awareness of the pilots, disseminating information and lessons learned across the organization.

12. Plan on being cautious about initiating scale-up before the required evidence is available

The results of feasibility and cost-effectiveness should be proven before initiating scale-up because of the risk of benefits of implementation not realizing. If the decision to scale up is done after a couple of successful pilot projects, but eventually majority of the pilots encounter various problems, that creates remarkable pressure to solve the problems on the go. Premature scale-up might lead to waste of resources and loss of credibility.

3.2 Developing a scaling up strategy

The organization should develop a scaling up strategy, which requires systematic planning of how pilot projects can be exploited on a larger scale. (ExpandNet and WHO 2010.) The purpose of this is to ensure that the proven practices, procedures and policies of pilot projects are transferred to future projects successfully by focusing and clarifying the actions.

As this chapter focuses on the scale-up, and the concept of scale is an important element of it, its definition and meaning should be clarified. Scale is a core element in natural and social sciences, and research results often depend on the scale the analysis was done at. (Menter et al. 2004) Especially when planning scaling up, two important fallacies should be avoided:

1. What works at one scale will work at another
2. What is good for one person is good for everyone

When expanding the implementation of BIM from pilot projects, it should be identified and assessed what works in pilot projects and why, and whether it will work in other future projects. In this study, the second fallacy could also be phrased ‘’what is good for one business unit is good for all business units’’.

The framework for scaling up developed by ExpandNet and WHO (2010) includes the elements as well as the strategic choices to be made for the scale-up. The framework is presented in figure 10. Next, the elements of the framework are presented along with the principles of scaling up, following presenting the process of developing the scaling up strategy.

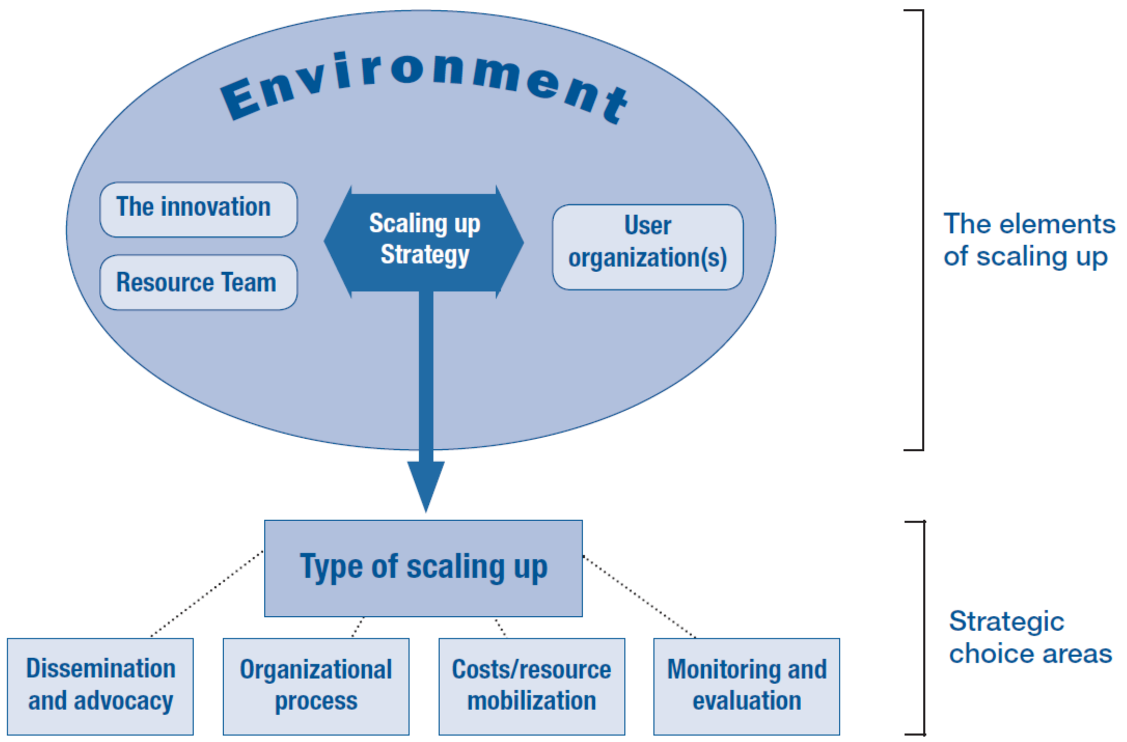

Figure 10 Framework for scaling up (ExpandNet and WHO 2010)

In this study, ***the innovation*** refers to BIM, consisting of several components, which are to be scaled up.

User organization refers to the organization looking to adopt and implement the innovation on a large scale.

Resource team refers to various actors such as policy-makers, researchers, service providers and technical experts that promote and facilitate wider use of the innovation.

Scaling up strategy refers to the plans and actions needed to implement the innovation in project execution.

Environment refers to the external conditions and actors that might affect the scale up. These include socio-economic and cultural conditions, policies, politics and bureaucracy.
The strategic choice areas:

Type of scaling up

Vertical scaling up is institutional in nature and involves not only the organization implementing the innovation but other relevant stakeholders too – including policy makers, investors, suppliers and subcontractors. (Menter et al. 2004.)

Horizontal scaling up means replicating and adapting the innovation implementation geographically and involves people mainly from the implementing organization. (Menter et al. 2004.)

Diversification refers to testing and adding another innovation during the scaling up process of the primary innovation. The need for diversification usually comes from a new need identified during scaling up.

Spontaneous scaling up refers to scaling up process without deliberate guidance.

Regardless of the type of scaling up, strategic choices need to be made about the following areas:

- Dissemination and advocacy
  - Personal: training, technical assistance, policy dialogues, cultivating champions and gatekeepers
  - Impersonal: web sites, publications, policy briefs, toolkits
- Organizational process
  - Scope of scaling up (extent of geographic expansion and levels within the innovation)
  - Pace of scaling up (gradual or rapid)
  - Number of units involved
  - Centralized or decentralized
  - Adaptive or fixed process
  - Participatory or donor/expert-driven
- Cost/resource mobilization
  - Assessing costs
  - Linking scaling up to macro-level funding mechanisms
  - Ensuring adequate budgetary allocation
- Monitoring and evaluation
  - Special indicators to assess the process, outcome and impact of scaling up
  - Service statistics
  - Special studies
  - Local assessments
  - Environmental analysis

The four principles that form the foundation for scaling up process are:

1. ***Systems thinking*** – the scaling up happens in a complex environment with interactions and influences. Interrelationships of innovation, organization, resource team and the environment form a system, in which scaling up occurs. Change in any of the four elements affect other elements. The balance between these elements should be pursued.

2. ***Focus on sustainability*** – Policy and programme development within all dimensions of the innovation is sustainable.

3. ***Enhancing scalability*** – Scalability means how easy or difficult the innovation is to be scaled up. Assessing and enhancing scalability is part of the strategic planning of scaling up.

4. ***Respect for human rights, equity and gender perspectives*** – Values of human rights lie in the roots of scaling up, and participatory and customer-centered approaches should guide the process.

Along with the four principles described above, the underlying considerations, which are planning the implementation with the end in mind and executing pilot projects in similar conditions in which the scaling up takes place, should be kept in mind. The following nine steps describe the process of composing the scaling up strategy. Some steps incorporate questions or considerations to be assessed and actions to improve the presented issues, which are modified to suit the purpose of this thesis.

Step 1. Planning actions to increase scalability of the innovation

Begin by clarifying what is the innovation

All the components of the innovation, especially the ones being scaled up, should be identified and communicated within the organization. These include, but are not limited to, technologies, processes and training.

Assess the ”CORRECT” attributes

Assessing the so called ”CORRECT” attributes indicates scalability of the innovation. The attributes and actions that potentially improve scalability are described in table 1.

Table 1 Attributes to be assessed and actions to enhance scalability (ExpandNet and WHO 2010; modified by Tuomas Hykkönen)

Attribute	Description	Actions to improve scalability
Credibility	The innovation is based on sound evidence and promoted by recognized actors The results of piloting have been documented and evaluated	Document results in clear and concise ways that can be readily shared with key stakeholders Collect further evidence Test the innovation in a realistic setting
Observability	Effects of the innovation are measurable and seen in practice	Provide opportunities for stakeholders to see results in pilot/experimental or demonstration sites
Relevance	The innovation addresses a defined problem, need or policy priority	Express clearly what needs are addressed

		Find ways to better communicate its relevance to policy makers and other stakeholders
Relative advantage	The innovation is advantageous compared to existing practices, and the costs of implementation are exceeded by the benefits	State and communicate its advantage Establish costs and assess cost-effectiveness
Ease of installation and understanding	The concept of innovation is easy to understand and implement The degree of change from existing norms, practices and level of resources along with potential conflicts are assessed	Simplify/streamline the innovation, but ensure that the essential components are maintained during scale up Anticipate and minimize potential conflict Identify where/how additional human and financial resources can be mobilized through existing channels Establish required channels for communication
Compatibility	The innovation should be compatible with the existing organizational values and norms as well as the current business environment The values of the innovation are maintained when the scaling up proceeds Some components require local modification to be relevant for changes in local context	Package the innovation in ways that enhance compatibility Build indicators into the monitoring system to assess maintenance of values and plan ahead to actions needed to maintain values Identify ways which minimize the changes that have to be made Identify needed local adaptations while ensuring the essence of the innovation remains intact
Testability	Small scale experimentation, e.g., in form of piloting, is possible in all business units before scaling up	Expand the innovation incrementally

Step 2. Increasing capacity of the user organization to implement scaling up

The organization should have the following attributes to facilitate successful scaling up:

- The members of the organization perceive a need for the innovation and are motivated to implement it
- The organization has appropriate implementation capacity, decision-making authority and leadership
- Timing and circumstances are suitable for scaling up

Table 2 compiles the questions to be considered about these attributes and suggests actions to increase the capacity to scale up.

Table 2 Attributes to be assessed and actions to increase capacity within the organization (ExpandNet and WHO 2010; modified by Tuomas Hykkönen)

Attribute	Description	Actions to increase capacity
Perceived need	There is a perceived need for the innovation There are individual advocates/champions of the innovation in the organization	Strengthen perceived need and motivation through advocacy using informal and formal channels
Implementation capacity	The organization has the capacity in the following areas: - Technical skills - Training - Leadership/coordination - Human resources - Monitoring/evaluation - Hardware, software and other tools - Supervision - Values that support the innovation - Policy and legal framework necessary to introduce the innovation	Begin expansion in areas where capacity is stronger Identify opportunities for sharing resources within the organization Advocate for needed policy/legal change Identify other ways of building necessary capacities during expansion Test capacity strengthening before wide-scale expansion Decrease possible negative impact on other processes

	Different ways to strengthen capacity are tested in the pilot projects Scaling up can be done without negative impact on other processes	
Timing and circumstances	There are/are not impeding changes within the organization that affect scaling up Potential changes provide opportunities or constraints	Adjust the scaling up strategy to maximize opportunities and minimize constraints arising from impeding changes

Ensuring and building necessary capacity is a component of the innovation and scaling up process. (ExpandNet and WHO 2010.) For example, if pilot projects are allocated human resources with adequate knowledge and skills about the innovation and its implementation, but it is known that the knowledge and skill levels are not adequate across the organization, effort must be put in training to increase the capacity. This example is not only about having enough personnel but also having the competencies to implement the innovation.

Step 3. Assessing the environment and planning actions to increase potential for scaling up success

Environment refers to the external organizations and conditions such as bureaucracy, policies, politics, socio-economic and cultural contexts, and people's needs and rights, which change constantly and differ between regions and more so between countries. For example, government mandates guide and direct innovation implementation and scaling up within organizations. In contrast, there might lie great opportunities for collaboration with external organizations and individuals. Table 3 compiles questions to be assessed and suggests environment related actions to increase scaling up success.

Table 3 Environment related questions to be assessed and actions to improve scaling up success (ExpandNet and WHO 2010; modified by Tuomas Hykkönen)

Questions	Actions
Is there support or opposition for the innovation? Which stakeholders should be engaged in implementation? What informal and formal political connections can be helpful? How can champions be recruited? How can opponents be neutralized or co-opted?	Reduce opposition through advocacy with influential individuals or groups Look for informal and formal channels Build a network of supporters

Are opportunities or constraints likely to change as scaling up proceeds? What aspects are likely to change?	Build flexibility into the scaling up strategy to accommodate change
Are there related initiatives that could serve to expand the innovation?	Collaborate when and where appropriate
How will the different components of the environment be monitored to keep track of changing circumstances?	Ensure that environmental assessment is and ongoing process and is linked to decision-making

Step 4. Increasing capacity of the resource team to support scaling up

The key task of the resource team is to ensure that technical, managerial and financial resources are available to support scaling up. The team typically includes individuals that have participated in development and testing of the innovation, so they have a good understanding of its strengths and weaknesses. They are guided mainly by policy makers, technical experts and prominent opinion leaders. In a way, the resource team is the systems integrator, integrating the innovation to the existing organizational system.

The resource team should have the following characteristics:

- Effective and motivated leaders with a unifying vision, authority and credibility
- In-depth understanding of the capacities and limitations of the organization
- Capacity to train personnel of the organization
- Understanding of the environment where the scaling up is done
- Ability to identify and help generate financial resources
- Skills and experience with scaling up
- Availability to provide support long-term
- Large enough to successfully provide support, training, advocacy and networking

Step 5. Making strategic choices to support vertical scaling up (institutionalization)

Vertical scaling up requires understanding of political processes and policies, regulations and financing mechanisms. Even though in private sector non-governmental organization's interactions with government and larger policy system is narrow, it cannot be ignored in the scaling up process. The issues that should be assessed are changes regarding policies, procedures, legal activities, financing, training approaches, regulations, norms and guidelines.

Step 6. Making strategic choices to support horizontal scaling up (expansion/replication)

Main concerns of horizontal scaling up consider figuring out how the innovation is disseminated to new geographic sites and projects, how the expansion is organized, how resources are mobilized, and how the processes and impacts of the innovation are monitored and assessed. The challenge of horizontal scaling up is how to adapt the implementation of the innovation to suit the different environmental contexts.

Key questions to be considered, and recommended actions within each strategic choice areas are presented in table 4.

Table 4 Attributes to be assessed and actions to increase capacity within the organization (ExpandNet and WHO 2010; modified by Tuomas Hykkönen)

Strategic choice area	Key questions	Actions to improve scalability
Dissemination and advocacy	How the innovation will be communicated/transferred to different units? (training, technical assistance, peer to peer, IEC materials, reports, policy briefs)	Use the experience gained from pilot projects about communication/transfer between units (face-to-face contacts are critical dissemination approaches)
	Are key aspects of the innovation tailored to meet the environmental contexts and communicated to different units clearly and concisely?	Revise the way the innovation is tailored to different contexts
Organizational process	How many units are expected to implement the innovation?	Evaluate scope and pace of scaling up
	What is the time period during which expansion will take place? Will the implementation be phased of rapid?	Establish targets considering - the nature of the innovation - strengths and capacities of the resource team and organization - opportunities and constraints in the environment
	What are feasible short-term and mid-term expectations, and long-term goals?	
	What adaptations to the innovation implementation are needed for different units?	Adapt different components of the innovation to the needs of different units

	Are new partners going to be involved in supporting or implementing scaling up? Will scaling up process be participatory?	Establish effective coordination strategies among new partners based on common interests Involve key stakeholders in decision-making areas where they can provide expertise
Costs / resource mobilization	Will the costs of expansion be the same for each unit? Are economies of scale possible? Can expansion be more efficiently organized? Are resources for expansion available or do they need to be mobilized, and if so, how?	Assess costs of implementing the innovation
Monitoring and evaluation	How will the process and impact of scaling up be monitored and evaluated? Will the impacts observed in pilot projects be the same after scaling up?	Decide relevant indicators to monitor Use existing statistics for monitoring and evaluation if they can provide relevant and reliable information Create simple procedures to track the process of expansion As the scaling up proceeds, use the information gathered from monitoring expansion to improve it in the future

One approach to the horizontal scaling up is to begin expanding the implementation in those business units where the competencies are at the highest level, and then use the developed expansion model in other units. In contrast, rapid expansion entails a risk of losing vital innovation components that tend to be most difficult to implement and most different from existing practices. Thus, it is recommended to embrace a more incremental expansion and recognize the value of learning.

Step 7. Determining the role of diversification

The need for diversification usually comes from a new need identified during scaling up. The new innovation can be based on a necessary need, or its purpose could be to reinforce the impact of the primary innovation.

Step 8. Planning actions to address spontaneous scaling up

With the approach of scaling up without deliberate guidance, lessons can be learned that could otherwise be missed. The lessons learned can help making the guided scaling up process more efficient and effective, thus it is recommended to exploit spontaneous scaling up, but in a complementary manner. Spontaneous scaling up entails a risk that the innovation or its components are replicated incorrectly, and consequently the presumed benefits will not be realized. Here, the aforementioned fallacies can be recognized. Spontaneous scaling up also highlights the importance of monitoring scaling up processes as well as the consequences of the implementation.

Step 9. Finalizing the scaling up strategy and identifying next steps

Creating the strategy for scaling up is more than going through the recommended actions presented in steps 1–8 – it requires vision of what is most important in each setting. That means identifying the most important perspectives and questions, defining actions and making decisions for the near future, also keeping the long-term goals in mind. The outcome should be a prioritized list or table of doable specific actions that form the strategy for scaling up. Reasoning for the actions could be included if necessary. An example of created strategy is presented in table 5. After the strategic plan has been developed, more detailed operational plans should be prepared. It should at least include more detailed descriptions of actions, the responsibilities and a timeline.

Table 5 Components of scaling-up strategy – an illustration (ExpandNet and WHO 2010)

Broad category	Recommendations	Degree of priority
Enhance the credibility of the innovation	Bring district managers and other stakeholders to the pilot site.	Medium
	Test innovation in settings that differ from the pilot site to assess the feasibility of large-scale expansion within the routine programme.	High
Streamline / simplify the innovation	Hold meetings with key stakeholders to determine what constitutes the essence of the innovation and whether it can be simplified to facilitate expansion.	High
Work with strengths in the user organization	Plan initial expansion in areas where there are champions in the user organization.	High

Address environmental constraints	Organize workshops for religious leaders to address their concerns about the innovation.	High
Strengthen the resource team	Add someone with strong advocacy skills to the team. Add more trainers with skills in organization development.	High Medium
Advocate for policy commitment supportive of the innovation	Engage with the ongoing health sector reform process to gain donor and government commitment for the innovation.	High
Pace of expansion	Introduce the innovation into lead districts that can act as demonstration sites before broader expansion. Develop a timetable for broader expansion.	High Medium
Involve new partners	Seek support and commitment from agencies working in areas where the innovation is being expanded.	High
Costs / resource mobilization	Collaborate with similar initiatives and benefit from economies of scale. Identify costs of replication.	Medium High
Dissemination and supervision	Finalize training modules and develop a timetable for the training of trainers in the government programme. Integrate oversight of the innovation into supervisory schedules.	High High
Diversification	Explore possibility of pilot testing an added component to the innovation	Low
Spontaneous scaling up	Conduct a focus group study to assess whether and how the innovation is spreading from individual to individual and one service setting to another	Medium

Logistics	Advocate with funding agencies to ensure consistent availability of logistics.	High
Monitoring and evaluation	Create a simple monitoring system that supplements the existing service statistics during scaling up.	High

3.3 Change management

To shift from traditional construction to BIM-based construction is an enormous change at organizational level. Burnes (1996; in By 2005) states that organizational change is an open-ended, continuous process rather than a temporary change consisting of well-defined activities. When planning for the change, it is important to keep the end in mind (ExpandNet and WHO 2011), by the definition in this thesis, the end denoting the state of BIM adoption. Change must be managed at organizational level as well as project level. This chapter introduces couple of approaches to change management.

According to By (2005), change management is defined as ‘’the process of continually renewing an organization’s direction, structure, and capabilities to serve the ever-changing needs of external and internal customers’’. Thus, change management relates very strongly to the organizational strategy. It also relates to uncertainty management in that change is often difficult to predict, which is why change management is characterized as reactive, fragmentary and temporary (By 2005; referenced Burnes 2004; De Wit and Meyer 2005; Luecke 2003; Nelson 2003).

Kempster et al. (2014) view change management through three change dynamics: rational planning, politically governed change management, and emergent bottom-up oriented change management.

<u>Rational planning</u>

Rational planning is built around understanding the three states of change: understanding current state, identifying desired future state, and designing transition state (Kempster et al. 2014). Transition must be rationally planned and gradually executed. Piloting is a powerful method to support a planned and organized, strategically driven change. Kempster et al. (2014) describe piloting as a structure, through which the plans are realized.

<u>Politically governed change management</u>

Politically governed change management focuses on the interests, conflicts and power of individuals within the organization, and in contrast to rational planning, is not at all a linear, rational process, nor is it aligned with the needs of the organization. It is a rather subjective change perspective that leans on experience and routines, based on which, a solution to a problem is formed. If leadership is distributed, different experiences and views are prone to cause conflicts and hinder progression of change. However, different views and experiences are valuable in change processes, and thus, politically shaped and rationally planned change perspectives complement each other. (Kempster et al. 2014.)

Emergent and bottom-up oriented change management

The promotors of emergent and bottom-up oriented change management perspective criticize other approaches for that senior management is not capable of being aware of the challenges and how to solve them within all parts of the organization. Political approach is also criticized as being insufficient. (Kempster et al. 2014.)

The emergent bottom-up approach is supported by thoughts that if the changes are implemented and rooted in the day-to-day operations from the start, and the employees are supported and given power to drive the change, the implementation will more probably be effective than in the former top-down approaches. (Kempster et al. 2014.) Emergent bottom-up approach emphasizes localized learning, understanding, designing and experimenting. The responsibilities of senior management include making the changes and progression visible throughout the organization and allocating resources. The bottom-up approach is also seen to increase commitment amongst the employees. However, this depends on how the implementation progresses and how they are supported by senior management.

The three perspectives to change management should be considered in a complementary way rather than divergently, to achieve efficient change management. (Kempster et al. 2014; referenced Johnson-Cramer 2003.) Distributed leadership approach and piloting as a change management tool fosters this consideration. The perspectives, leadership approach and piloting address important aspects of change management: learning, commitment, participation and resistance.

Distributed leadership emphasizes that there are several persons employees sharing the responsibilities. Kempster et al. (2014) point out that ''…a pilot creates the opportunity for distributed leadership and distributed leadership enables pilots to create successful change: in a sense two sides of the same coin''.

Kempster et al. (2014) acknowledge the experimental nature of piloting, and how it emphasizes the role of learning. This supports the emergent bottom-up change management approach, but as Kempster et al. (2014) suggest, all three approaches should complement each other, thus, appropriate planning of change is required, as are divergent point of views and different experiences, which contribute to the common knowledge base. A considerable practical challenge of combining these different approaches, which in a way are developed to address the shortcomings of each other, is people management. In order to exploit the common knowledge capital, which would include different contradictory views and experiences, soft skills are required from the leaders regardless of centralized or distributed leadership. Soft skills such as communication, conflict management, relationship management and emotional intelligence are essential for collaboration in change management process just like in BIM project delivery.

As mentioned in the previous chapters, the barrier for better development of BIM seems to be people, resistance to change and managing change. (Davies et al. 2015.) People leading the change need to be decisive and firm to accomplish changes step by step, but on the other hand flexible, open to new ideas, willing to discuss problems and solutions.

4 Case studies

This part of the thesis covers the qualitative empirical research methodology based on case studies, which was chosen for the research method of this thesis. In qualitative research, understanding the research subject is emphasized (Hirsjärvi 2009), and the findings are made relevant through understanding (Denzin and Lincoln 2018). This study approaches the research problem from a holistic point of view. Thus, various elements of BIM implementation as well as the scaling up process were studied extensively in the literature review. The goal of the literature review was to build a relevant foundation for the empirical part of the study. The study aims to deepen understanding of BIM implementation as a whole and explain the intricacy of it. Therefore, qualitative research methods suit the frame of reference of this thesis well. In qualitative empirical research, the gathered research data is studied and analyzed, following conclusions supported by the theoretical framework.

Data for the case studies was collected from focused semi-structured group interviews, discussions, attending meetings and workshops. The primary research method was conducting the interviews, but secondary data was gathered from BIM related meetings and workshops, e.g., concerning development of internal guidelines of the case company. The meetings and workshops were attended prior to the interviews. Therefore, they contributed in understanding the state of BIM implementation and provided information about the key matters, which helped compile relevant questions for the interviews. Discussions conducted throughout the study, especially with the BIM manager, helped to understand various matters – from detailed to wider matters. Semi-structured interviews provided reliable and comparable qualitative data, and due to open-endedness, there remained a possibility for discussion of other aspects that were not thought about prior to the interviews.

One of the primary objectives of the study was to find out the most important aspects of implementation that could be considered in the scale-up. Semi-structured group interview suited well for the purpose, because a less structured interview fosters fruitful discussion around the specific topics, and the most important issues emerge impulsively. A partial purpose of the interviews was to transfer knowledge and information between the units by the interviewer and the interviewees. There is a risk that, if the interviewees first acquire knowledge about the experiences etc. from other business units, their responses might be distorted. To prevent the risk, the experiences from other units were communicated only after the interviewees had presented their views and opinions. At best, presenting experiences from previous interviews enabled continuation of the conversation, and new perspectives were found.

The aim of the interviews was to collect such research data that could be connected with theory and analyzed for meaningful conclusion. Before creating the questions, categories that would cover the holistic view of BIM implementation were developed. The categories formed the core of the interview questions and were chosen, at first, based on the literature review, attended meetings and workshops, and discussions with the personnel of the company. Based on the first two interviews the categories were only slightly modified. Therefore, it can be said that the selection of categories based on the theoretical study and the meetings, workshops and discussions was successful. The interview questions were created so that all categories had an adequate amount of questions as it was not certain that fruitful discussion would emerge. Therefore, there was in a way a surplus of questions to ensure sufficient amount of research data. The most important questions were selected from each category to ensure that at least the most prominent areas were covered. The purpose of the questions was to initiate, deepen and guide the discussion so that all categories were at least somewhat covered. The questions were prepared in Finnish, and the interviews were also conducted in Finnish. The interview questions are presented in Appendix 1. The categories are presented next.

Technology

Technology-category includes matters related to different software, both for authoring and utilization purposes, as well as hardware and ICT (Information and Communication Technology). Also, the importance of selecting suitable software belongs in this category.

Processes

Processes-category covers the overall BIM implementation process, subprocesses of functions, how the models are utilized

Guidance / Instructions

Guidance / Instructions -category includes matters related to BIM execution plan, internal guidance and external guidance. External guidance focuses mainly on guiding and instructing the designers.

Benefits / Utilization of BIMs

Benefits / Utilization of BIMs -category incorporates matters about building information models: what models are created, what is required from the models, what is the quality of the models like, for what are the models utilized and what benefits, if any, have been observed.

Roles / BIM coordination

Roles / BIM coordination -category covers different roles in a BIM project and their responsibilities. Also, different roles of a company implementing BIM are considered. BIM coordination is mentioned separately in the name of the category, because of its significance to a BIM project.

Competencies

Competencies-category incorporates matters related to required and possessed competencies, as well as building them. Competencies incorporate skills and knowledge, ability and capability required for the implementation – technical skills as well as knowledge about processes.

Collaboration / Competencies of others

Collaboration / Competencies of others -category concerns questions about the success of collaboration with both internal personnel and external stakeholders, mainly with designers and external BIM coordinator. Competencies of external stakeholders are also considered in this category.

The purpose of the categories was to find out the most important elements of the implementation. The categories were conducted from the BIM ecosystem view studied in the literature review. Technology and Benefits / Utilization of BIMs categories were conducted from the products element of the ecosystem, Processes and Guidance / Instructions were conducted from the process element, and the others, Roles / BIM coordination, Competencies and Collaboration / Competencies of others were conducted from the people element of the BIM ecosystem.

A narrative or a statement could have, and often had more than one category assigned to it, which implies that the topics of interviews were highly intricate. The categories overlapped a lot, and it was a challenge to assign appropriate amount of time for the right categories. A narrative often had a key point, around which the rest of the narrative revolved. If utilization of models was discussed for a minute, it could include issues related to basically any or all the other categories. As the purpose of categorization and measuring time was to find out the most important subjects, some interpretation had to be done to assign the correct categories to correct narratives. This is one of the limitations of the analysis method. By categorizing, and measuring time or repeatability of narratives, some important matters could be excluded. Additionally, a single point, presented in a short time, and only in one interview, could be an important point. Those kinds of findings cannot be perceived by the categorization alone. Other considerations are that some people talk faster than the others, and some ramble more than the others. Some like to present a point shortly, whereas others like to go into detail and/or emphasize the point by repetition. Another consideration was to ensure that all categories were covered, which was not a given despite having the interview questions of all categories. Sometimes the discussion derailed and focused more on another category or a whole different topic. That was permittable, but it had to be made sure that the discussion returned to the original topic so that all the interviewees had the opportunity to present their views.

The analysis process was as follows:

- Audiotaping the interviews
- Transcribing the interviews verbatim
- Categorizing the interviews
    - Assigning a category or several categories to narrative
- Calculating time spent discussing each category
- Creating bar charts to visualize the categories
- For qualitative analysis, the most important matters were compiled by categories from the transcriptions

Transcribing the interviews verbatim enabled returning to specific matters so that the original, non-interpreted or non-modified narrative could be investigated. Therefore, specific matters could be connected with other specific matters as well as larger entities, which is important for developing an understanding of the researched topic especially in qualitative researches.

In total, eight interviews, that included ten business units, were conducted. In one of the interviews, personnel of three units were present because of the units locating in the same area. All units had at least one ongoing BIM pilot project when the interviews were conducted. Some of the units had been implementing BIM into several projects, some of which had been finished years ago. Recall bias was possible but not significant as all units had ongoing BIM projects anyway. Also, because interviews were conducted for groups, the effect of recall bias is reduced. In all units one of the projects was designate as the formal pilot project. At the beginning of the study, the purpose was to focus on the formal pilot projects, but as many of them were still ongoing, it was seen that adequate data about all the topics of the study in all units could not have been collected in the extent that a qualitative research requires. Because the phases of the projects varied, it would not have been possible to get adequate information of certain matters such as quality of models or collaboration with the designers. The interviews were extended to consider other ongoing and previous projects, too. Due to the framing of the study, the interviews focused on the design phase, but construction phase was not excluded as leaving it out could have affected the results negatively.

The interviewees were project personnel working in different roles in the BIM pilot projects. The roles of the interviewees can be seen in table 6. Apart from one interview, the BIM manager of the business segment participated too. Having a BIM specialist who was able to provide a more general viewpoint of the implementation was beneficial in a couple of ways. First, the overall picture of the statuses of different aspects of the implementation, e.g., development of processes, technology and utilization of models, could be presented with arguments. It was possible to direct the focus on the most relevant issues in the case company and ensure truly meaningful discussion about ongoing developments. Also, issues and their details were possible to be clarified and explained due to the knowledge of the BIM specialist. The other interviewees are presented in the table 6.

Table 6 presents the interviewees by case, the experience of BIM implementation, whether or not the pilot project was a typical housing project, date and duration of the interviews. Validity of the research data is obviously one of the considerations of the study. Pilot projects were studied for scaling up purposes – what should be considered for successful scaling up, was one of the research questions. Based on the theoretical framework, to ensure the validity of the data from the interviews, the characteristics of the pilot projects should be similar to the projects following the pilot phase. (ExpandNet and WHO 2011.) A typical housing project in the context of this study depicts a developer contracting project. In one instance, the pilot project was an untypical housing project, but it did not matter as the business unit had other typical housing BIM projects ongoing and finished.

Table 6 Introduction of the cases

Case	Interviewees	Typical project?	Experience prior to the interview	Date	Duration (min)
1	HoDC, PM, PE	Yes	1. BIM project	18.9.2018	60
2	HoDC, PM, PM, PE, PE	No	Several BIM projects	25.9.2018	100
3	HoDC, BIMCo, PM, PM, ProcM	Yes	Several BIM projects	31.10.2018	66
4	HoDC, PDM, CEM, PE	Yes	A few BIM projects	1.11.2018	103
5	HoDC, PM, PM, PDM, CEM, PE, ProcE	Yes	1. BIM project	6.11.2018	110
6	PM, PM, PM, PE, PE, CEE, CEE	Yes	A few BIM projects 1. BIM project	8.11.2018	119
7	HoDC, PE, PE, PE, PE	Yes	1. BIM project	14.11.2018	80
8	HoDC, PE, PE, PE, ProcM, ProcE	Yes	1. BIM project	15.11.2018	83

Legend		
HoDC = Head of Developer Contracting	BIMCo = BIM Coordinator	CEM = Cost Estimating Manager
PM =Project Manager	ProcM = Procurement Manager	ProcE = Procurement Engineer
PDM = Project Developer Manager	PE = Project Engineer	CEE = Cost Estimating Engineer

4.1 Data collection and analysis

In this chapter, the findings of the interviews are presented and analyzed by case. The findings of each case are organized by category. Chapter 4.2 concludes the findings and analysis.

All but one of the formal pilot projects were typical developer contracting housing projects, on which the interviews focused. However, the discussion did not exclude BIM projects of different delivery methods such as alliances in business premises and DBB in those business units where developer contracting was not the only form of business. The pilots were selected by the project personnel as pilot projects based on the typical characteristics of housing project, meaning that the gathered research data is valid in this sense.

Simplified overall BIM process maps were derived from some of the interviews. Prior to the interviews, the BIM manager was asked to describe the current BIM process taking into consideration all business units and their diverging approaches. The overall BIM process, which in a way is the average of the BIM processes of pilot projects, or the most common process, is pictured in figure 11 and Appendix 2. The orange color depicts that the process is based on 2D design, blue depicts a BIM-based process and green depicts the process of creating combined models.

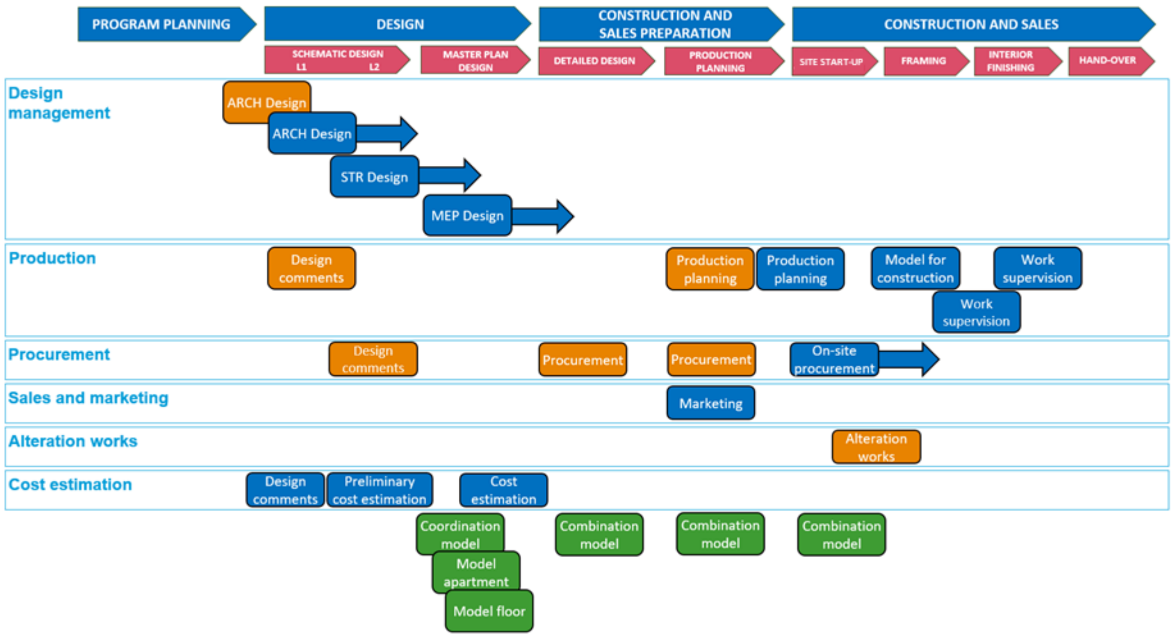

Figure 11 Overall BIM process of the case company depicted by the BIM manager (Kangasmäki 2018; translated by Tuomas Hykkönen)

The attitudes towards BIM were mainly positive, and it was perceived to have been improved significantly over the years.

In all cases, the interviewees had been in some kind of training, external or internal, or it had been arranged in the near future. The training had been versatile in that the software in use as well as concepts, terminology, and fundamentals of BIM were covered.

The instructional materials including the BIM execution plan, classification guide and design software specific project templates of the client, were used varyingly in all projects.

4.1.1 Case 1

In Case 1, the first BIM project was in the design phase. BIM had not been implemented into the project from the beginning. The BIM pilot project was the last of the four projects in the area, and the primary design solutions had already been finalized in the three other similar buildings, which limited the possibility to utilize BIM for that purpose. The main objective was to create the models and utilize BIM in design coordination. Architectural, structural and MEP modeling were ongoing, and the geotechnical model was meant to be produced for the final combined model. Being the first BIM project, it was seen that so far, the project had progressed reasonably well. The approach to implementation was to build competencies and gradually utilize the models to a greater extent.

Technology

Technology related discussion was limited to software to be used in the project, and the use of future tools. It was seen that a mobile device with a suitable BIM software would be useful in the future projects for exploring the models on site. That would, however, require more from the models in terms of quality. There were two programs to be used for cost estimation, Solibri Model Checker and the project management tool of the case company, iTWO. It was seen more desirable choice to use Solibri for quantity take-off as it was perceived as a simpler program for that purpose. However, iTWO was seen to be used for quantity take-off in the future as it is a more versatile program, even just from the perspective of quantity take-off.

Processes

BIM had not been implemented from the beginning, so the design process started with 2D design, and there was no need to create a spatial model or any kind of a preliminary model. 2D design and BIM-based design are done concurrently and building information models are seen as supplementary element to 2D design at the moment. However, the models were seen as the primary design form in the future. BIM meetings, where the focus was primarily on the models, were differentiated from typical design meetings, which adds to the view that BIM is seen as a separate entity from design.

BIM-based design is seen as a more parallel way compared to traditional design. Some information is needed for model creation earlier than previously, and it should be made clearer what information is required in each project phase.

The modeling process begun with creating the models of the basic floor, a more or less repeatable floor with only the apartments, not the first floor of the building, but the second one typically. The architectural, structural and MEP models were combined for design coordination, following the coordination, and copying the other similar floors afterwards. This was found to be a good procedure as the design errors could be eliminated and design solutions checked in an early phase of the modeling process.

Guidance / Instructions

The BIM documents of the case company such as BIM execution plan and instruction material for the designers were used in the project. The documents were first looked through amongst the internal personnel and later with the designers and the BIM coordinator. The designers gave positive feedback of the guidelines; they included adequate and accurate information needed to instruct the creation of models according to the designers. It was seen that fully understanding the guidelines requires certain level of knowledge about BIM in general. Thus, it was good that they were first looked through together with the internal personnel.

Benefits / Utilization of BIMs

The main BIM Use was design coordination using architectural, structural and MEP models. The benefits of utilization of BIM in design coordination were difficult to estimate especially due to the coordination being outsourced. Creation of models lengthened the design time mildly. Besides design coordination, the models were supposed to be used afterwards for training BIM-based cost estimation. In the project, cost estimation was performed traditionally using 2D design drawings, which was meant to be used for comparison with the BIM-based cost estimation. The models were also to be used on site, and there was willingness to implement BIM into marketing as well, which would require the interior design to be BIM-based. On site, the models can be used for visual exploration, quantity take-off and production planning to mention a few.

The most important stressed matter that was discussed about the utilization of models was the correctness of model data. The data must be correct for each purpose so that the people using the models can trust them. Correctness depicts the quality of the models. A good quality model is free of errors and depicts the design according to what has been agreed upon. The most benefits are induced by having the focus of coordination more on the large-scale issues than in details such as incorrect naming. For quantity take-off, the correctness and accuracy of data, i.e., naming conventions, accurate and correct dimensions and classification, is necessary for efficient utilization.

Roles / BIM coordination

The external BIM coordinator was perceived as competent, which contributed remarkably to the success of the implementation. It was seen that part of a successful coordination was that the coordinator had previously been involved in other BIM projects of the case company, and therefore, had knowledge of the process, how the creation of models would be managed, and what is desired from the coordination. An internal BIM coordinator was seen as a good possibility, but an external coordinator would be used in the following projects as the experience so far was positive. The internal coordinator should have competence for the task – it should not be assigned to someone with inadequate understanding and skills for coordination.

Having good quality models through successful coordination depends a lot on the designers and the coordinator. There are both competent and less competent coordinators and model creators available. The significance of the client's role in the model creation was also recognized.

Competencies

The client has the responsibility of knowing what is created, what kind of a model and what information it should contain, in a rather detailed level. Besides that, the client's task is to guide and instruct the designers to create the models in the specific scope and quality that is required. Guiding model creation in the right direction and in detail can be a challenging task in a first BIM project. It was seen highly important to know exactly what data the model should contain, both the model objects and non-geometrical data – the attributes.

Training needs were primarily related to software, namely Solibri and iTWO. A more general training was wished to be had at first, and afterwards some more focused training should be arranged. Ensuring relevant training was seen essential for the scale-up. Training should be timed so that the learnings can be applied to real work right away when they are still fresh in mind. One way to build competencies is to learn to use tools, discuss and figure out problems together with the coworkers.

Collaboration / Competencies of others

There was no need for intensive collaboration with the designers as the primary design solutions were already developed. However, the collaboration had been adequate, and no major issues had emerged, which could have been expected due to a lot of things being new: the process, terms, concepts, requirements from the models etc.

The model creation was successful, despite the geotechnical engineer having some difficulties in producing a compatible model. One challenge to be considered is the availability of competent modelers. As BIM is implemented into more projects, it might be a challenge to get a good model creator to all of them. Also, a good designer does not equal a good model creator. As could be expected, relationships had been established with certain designers. Maintaining good relationships is desirable, but, if the designers are not able to develop their competencies and produce good quality models along with the rate the demand increases, the value of maintaining relationships could diminish.

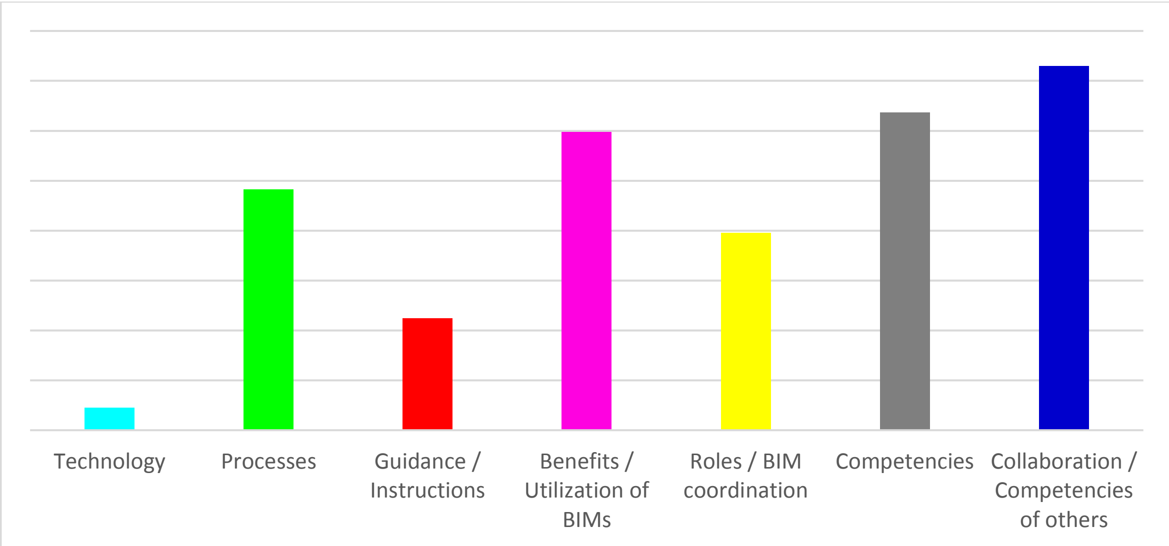

Figure 12 Relative duration of discussion by category in Case 1

Figure 12 illustrates the most discussed categories in Case 1 based on the time-analysis. The emphasized issues in Case 1 include:

- All designers in the area might not have adequate competencies, which presents a challenge for the future
- Collaboration and competencies of the BIM coordinator and architect being perhaps the most important reasons for the success of implementation
- Arranging software training at the right time and for the right persons
- Accuracy of the model data is fundamental for being able to utilize the models

The time analysis corresponds quite well with the qualitative findings.

4.1.2 Case 2

In Case 2, BIM had already been implemented into several housing projects, but the formal pilot project was ongoing, in the design phase. The personnel had contributed in the development of BIM not only in their own business unit but also on the segment level. They were keen on developing the BIM processes and the best practices.

The formal pilot project was not a typical developer contracting housing project, so the experiences of such project cannot be directly applied to following BIM projects. There was a great deal of differences compared to other BIM (and traditional housing) projects that related to the overall design process as well as the construction process, instructions and guidance and working practices. Still, this kind of a different project provides knowledge and perspectives that cannot be gained from typical pilot projects. Besides observing totally new matters, it can deepen and widen the knowledge of some areas of BIM implementation.

One of the most important realizations in Case 2 was the requirement-oriented implementation, which means that BIM is implemented in terms of the actual needs and requirements of the project. Defining the objectives of BIM implementation properly and clearly at the beginning of the project is fundamental for success. Another important aspect was the significance of illustrating the overall BIM process.

Technology

The differences that BIM software, both design and utilization software, has on the creation and utilization processes and possibilities were discussed. Creation, interpretation and presentation of model data depends a lot on the software and the way they are used, i.e., the same information can be placed on different attributes depending on whether it is created in ArchiCAD or Revit Architecture and opened in Solibri Model Checker or iTWO. ArchiCAD and Revit design software had been the most used software in architectural modeling. IFC-export settings could influence the exported model data as well. It is essential to know what data is exported and where it can be found from for the utilization of models.

The instructions and guidelines of the client that the designers should comply, should consider the differences between the modeling software. Also, the software used for utilization of models should be considered in the instructions as they interpret data from different design software differently. In Solibri, model data created in ArchiCAD can be interpreted differently than data created in Revit. This applies to iTWO as well. Additionally, Solibri and iTWO interpret model data, created in either of the design software, differently. Interpretation means the way the software adapts the data into its own language so that it can understand it. One example of the interpretation is the transfer of classifications of model objects. An object created with a wall tool might not be interpreted as a wall object, if the export and interpretation of data is unsuccessful.

The importance of suitable BIM software had been noticed in the formal BIM pilot. Having the most suitable tools for the purpose, whether it is about quantity take-off or modeling timber structures, enables the most efficient performance. Software also affect the flexibility of the process. For example, the modeling tools of MEP systems were perceived to be behind architecture and structural software in that creation of models was significantly slower. This had been considered in the overall process so that MEP modeling had been set to begun only after the design and models of other disciplines had progressed enough so that there would not be any major changes in design after the beginning of MEP modeling.

Processes

The business segment should have a harmonized BIM process map to make the process clear and understandable. The overall BIM process should be directive and flexible rather than dictating and overly restraining. It should be harmonized in that all business units can implement BIM with the same proven principles but also have the freedom to make differentiations based on their possibilities and needs, which result from business environments being different. Each unit have different characteristics in terms of roles, responsibilities, competencies, backgrounds, projects, external actors and policies. Processes, practices and procedures vary, too. The process map should include the level of development of the models, and possibly the roles and responsibilities as well.

It was seen that ensuring the right direction of modeling from the beginning of design process has great significance to having a more reliable cost level. Basically, the right design decisions should be made from the beginning to minimize remarkable design changes that have substantial effect on costs. A more reliable cost level is possible to be derived in the early phases from a preliminary architectural model that includes the elements that affect costs the most. Therefore, the model could include elements of other design disciplines too. Spatial model could also be used for the same purpose. In that case, relevant cost information should be linked to spatial elements such as apartments, rooms, floors and buildings. If a preliminary model is to be utilized, the elements that have the most effect on costs should be defined. Even in this rather simple task, variation occurs due to different projects. For example, a parking lot is an important cost element in those project that includes one, but not all projects do. Keeping in mind the harmonization aspect, there should be flexibility to include or exclude the costs of a parking lot.

It was perceived that BIM is still seen as a separate process from the design. This is perceived, amongst other things, in meeting conventions. Design related matters had been considered from somewhat different perspectives in design meetings and BIM-meetings, which are separate meetings.

Requirement-oriented modeling was one important concept that the business unit had realized over the years. Part of the thinking is to focus on the essential things, whether it is ensuring the best design solutions or accuracy of data, naming conventions and classifications. The implementation process should be designed to meet the prerequisites and actual needs of the project and personnel. The view of a cost estimator or procurer probably differs from that of a project manager, so collaboration is required to come up with the requirements, and determine the preconditions.

Guidance / Instructions

The BIM instructions and guidelines focused mainly on architectural modeling. It was seen that they should be extended and developed so that they consider the differences of software. The feedback of the development process of guidelines so far had been positive. Besides the differences of technology, new BIM Uses that could be relevant in the near future, such as BIM-based construction permit process, should be considered rather sooner than later in the guidance materials.

Benefits / Utilization of BIMs

It was perceived that when the first BIM projects have been finished, the benefits become more notable, and the additional value of BIM implementation can be assessed. It should be noted that the possible additional value should be assessed only on those parts where BIM was implemented in, not on the whole project as it could distort the assessment. In addition, in the first pilot projects, the benefits might not be great, or they could even be negative.

The accuracy of model data was emphasized. The more accurate the data, the less the utilization of models requires additional work from those utilizing the models. The causes of inaccurate data should be tracked down and analyzed before planning and performing the change. Those that utilize the models are often the ones having to do the additional work. When someone cuts corners, it affects sequential tasks, i.e., if MEP designers model the plumbing only approximately in terms of location, it can have a big impact on design of other disciplines. The models must be exact so that the quality of them can be trusted to be adequate, and they can be utilized without an excessive assessment of quality.

The models had mainly been used for design coordination, both rule-based and visual, and cost estimation. On site, the models had been used for production planning. It was seen that the benefits of design coordination are realized on site. Positive feedback of the level of design coordination had been received from the sites.

Roles / BIM coordination

Case 2 revealed different approaches to BIM coordination. The business unit itself did not have an appointed BIM coordinator, but coordination had been performed by a project engineer in some projects. The responsibility had also been given to an external BIM coordinator or an architecture company in some cases. It was pointed out that, if the architecture company is doing the coordination, it is important that the same person creating the model should not be performing the coordination too because of a tendency of missing the errors of your own work. However, it was also seen that certain synergies exist in giving the coordination to the lead designer as the tasks of these roles are partly overlapping. In principle, the lead designer has the responsibility of combining the designs of all disciplines and ensure compatibility, but there are different views of the responsibilities of BIM coordination and how BIM implementation affect the responsibilities of traditional design coordination.

The risk of outsourcing BIM coordination is that it will not be performed appropriately. This could be caused by inadequate competencies, lack of time or something else like poor communication. The risk emphasizes the importance of monitoring the coordination process regarding both the technical and functional issues. This arises the question of the responsibility of monitoring. The consensus was that the project manager is ultimately responsible for the design. However, ensuring correctness of the technical matters of models should be performed by someone else, a project engineer perhaps. Technical matters refer to naming conventions, classifications and all other information of the model objects. It is important to understand the different aspects of design coordination for defining the roles and responsibilities. The roles should be clear to all stakeholders, and detailed task descriptions should be defined so that everyone can be confident that all tasks will be performed in the required scope and quality. That is a premise for good quality models that can be used efficiently for the defined purposes.

Competencies

When the roles and responsibilities are clear, it is also easier to develop the right competencies. Let's say that a project manager performs the BIM coordination. It is a task requiring considerable time and effort (which had truly been realized in Case 2 only after performing it in-house), and fundamental understanding of BIM, good technical skills as well as construction engineering skills. It should be thought through whether a project manager needs to learn all the details of coordination, and if there even is enough time to learn and perform the coordination properly.

In development in general, whether it is about development of BIM execution plan, standardizing naming conventions or development of quantity take-off process, conversations had often culminated in understanding the essence of the issue or technical skills. Development must be done in collaboration with relevant personnel. The larger the company the more people could be involved. The challenge can be the mutual understanding of the issue, which might stem from the fundamental understanding of BIM. Therefore, BIM should be understood in the same way amongst internal personnel, at least.

The business units and individuals implementing BIM in a project for the first time should start with moderate implementation, meaning that all the possible BIM Uses should not be pursued, instead, focusing the implementation on one or two BIM Uses is better as it is not too much to take in.

Collaboration / Competencies of others

It was perceived that the designers and external BIM coordinator must be instructed and monitored from the beginning of design to ensure the demanded quality of models. The wide range of level of competencies of external actors is reflected to the models. It was seen that the quality of a model depends primarily on the designer and the BIM coordinator. Therefore, the client should be prepared for extensive guidance.

If the designer is allowed to somewhat diverge from the instructions, it can be faster to make changes to the design, but that can be at the expense of quality. In the long term, it was seen more beneficial to demand the level of quality that the client wants from the beginning as it guides the development of the modeling process in the right direction. Internal participatory collaboration was also emphasized in development of internal processes and practices. Especially those functions that utilizes BIM, should provide their own views.

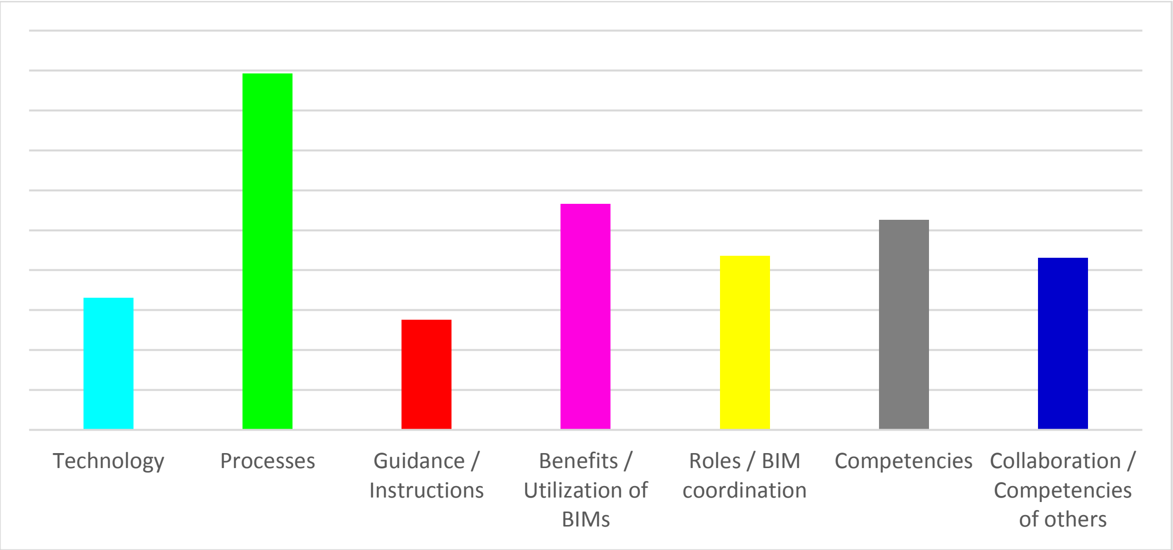

Figure 13 Relative duration of discussion by category in Case 2

Figure 13 illustrates the most discussed categories in Case 2 based on the time-analysis. The emphasized issues in Case 2 include:

- Importance of the harmonized overall BIM process map for guiding the implementation process
    - There were differing views on the BIM process within the unit, which hints about the challenge of harmonizing the process at the segment level
- In design, more emphasis should be placed at the beginning, and the correctness of primary design solutions should be ensured to confirm that the design is going in the right direction
- BIM-based quantity take-off could be the means to get a better picture of the cost level of a project early on
- Importance and challenges of BIM coordination, and the aspects of outsourcing and insourcing were discussed
- Importance of ensuring that the information content is accurate and assigned to the right attributes from the beginning of the project
- Ensuring adequate prerequisites for BIM implementation through training and sharing of knowledge and methods

The scope of discussion was broad, but it seemed to revolve around the processes a lot. The time-analysis supports this view.

4.1.3 Case 3

In Case 3, BIM projects had already been executed for several years. The overall BIM process had become somewhat established. The formal pilot project was a typical housing project and ongoing, but due to experience from years of BIM implementation, it was seen more beneficial to focus on the overall experiences instead of just one project. The business unit did not only do housing but also business premises projects, which provides different kind of experiences. The differences of BIM implementation in different businesses are significant, e.g., as the overall process differs it changes also the other elements of the implementation.

The attitude towards BIM was seen to had been improved over the years. There was more change resistance and prejudice before, but as the benefits had been observed first hand, the attitudes had changed.

Technology

The importance of suitable software, its development and implementation were the main discussion points of the category. The use of Solibri Model Checker and iTWO for cost estimation was considered in Case 3, too. As most of the interviewees had previously worked at the former Lemminkäinen, they were used to using Solibri, but iTWO was a new software for them. Cost estimation was performed in one project with iTWO, so the business unit could compare the two programs based on some experience. It was perceived that Solibri was simpler to use at the time, but iTWO as a more functional and integrated program, had more versatility. It must be noted that the quantity take-off process in Solibri and iTWO differs fundamentally. In iTWO, the quantities can be linked to cost information directly, in contrary to Solibri, with which the quantities must be exported from the program and linked to cost information in another program.

Processes

The design process typically begins with 2D sketching, assessing alternatives and deriving the most optimal design. Before the modeling process begins, programming is fixed. Architects had been expressing that sketching was easier and faster to perform with 2D CAD due to the iterative nature of the work. Furthermore, the model creation process was described followingly. The architect begins the modeling first, and the structural and MEP modeling is begun later. Design coordination is performed four times. First the architectural and structural models are combined and coordinated for cost estimation. When the MEP designers have modeled the systems of the basic floor, compatibility of all models is ensured, which is followed by multiplication of floors, modeling the other parts of the building and performing the coordination of the whole building. A third combined model is created at the end of the design phase for utilization on site. As changes occur during construction, the models are updated and at the end of the construction, the as-built model has been updated.

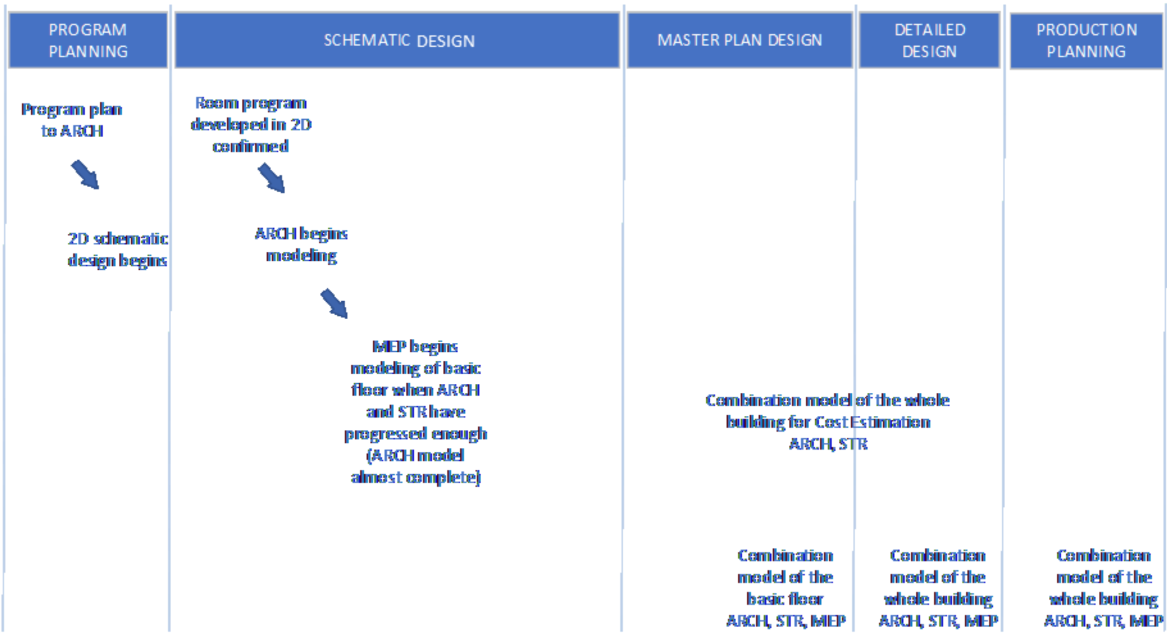

Figure 14 Overall BIM process derived from the description in Case 3

It was seen that some simple modeling procedures do not have to be actively ensured, if the designers are competent enough. For example, the COBIM2012 suggests creating the coordination model as one of the earliest phases in modeling process, but it was perceived as unnecessary phase to be included for example in the overall BIM process description, because amongst the experienced modelers it is taken for granted that the coordinate systems combine.

Guidance / Instructions

BIM execution plan had been created for all BIM projects. Defining the objectives and going through the plan with the designers was seen beneficial in that issues can be discussed and clarified, and a mutual understanding of the objectives and purposes is formed. The agreed matters are written down, which promotes committing to the process.

Benefits / Utilization of BIMs

It was perceived that BIM is implemented for its benefits through the whole process, foremost, in design management, cost estimation and production management. Going back to traditional 2D design could not even be thought of after years of implementing BIM. BIM had become a somewhat integral part of a project execution. In Case 3, the quality of the models had primarily been good for the utilization purposes. The models had been utilized for design coordination, cost estimation and control, procurement and scheduling both at the office and on site, and in some cases for requests for tenders for subcontracting. The most beneficial BIM Use had been cost estimation, which had become significantly faster and more accurate.

The unit desired to implement BIM to a greater extent, in new processes as well as on a larger scale. Marketing and BIM-based construction permit process were seen as potential new processes to implement BIM into. For cost estimation, utilizing more accurate cost information earlier in the design process was seen as an important possibility to utilize BIM.

Roles / BIM coordination

There was an experienced BIM coordinator in the unit who had been performing BIM coordination in all projects. The coordinator performed mainly rule-based coordination, and the visual checking of the primary design solutions was performed by the project manager. Having an internal BIM coordinator in the unit was seen as the best option regarding outsourcing and insourcing BIM coordination. An internal coordinator has knowledge of the actual needs of the client in terms of design solutions and functionalities. The communication with the project manager is also improved if the two are located in the same building, and due to the project manager being the one on top of design management.

Insourcing BIM coordination was seen as the best alternative also with regard to building competencies of the whole unit, because the coordinator understands the work culture, processes and practices of the unit. Not only is the coordination focused on the right matters, but relevant knowledge can be provided to guide the development of processes in the right direction. An external coordinator does not have that knowledge of the processes of the client in such detail, and do not have the same interests to coordination as an internal coordinator. However, a BIM coordinator was seen as a must in a BIM project. The challenge is that competent BIM coordinators can be difficult to acquire due to lack of supply.

Competencies

Approach to BIM implementation was similar to the previous cases: in the first BIM project, scope and objectives of implementation should not be too ambitious. It is easier and more beneficial to start building competencies in small amounts. It should also be kept in mind that with gradual implementation the benefits increase gradually as well. It was seen that perhaps most useful for a BIM project is a competent project manager. Developing competencies should foremost be made possible for project managers.

Collaboration / Competencies of others

The designers used in BIM projects of the Case 3 had primarily been perceived as competent. However, BIM-based design still took more time than traditional design process, which implies that room for improvement exists in that regard as well.

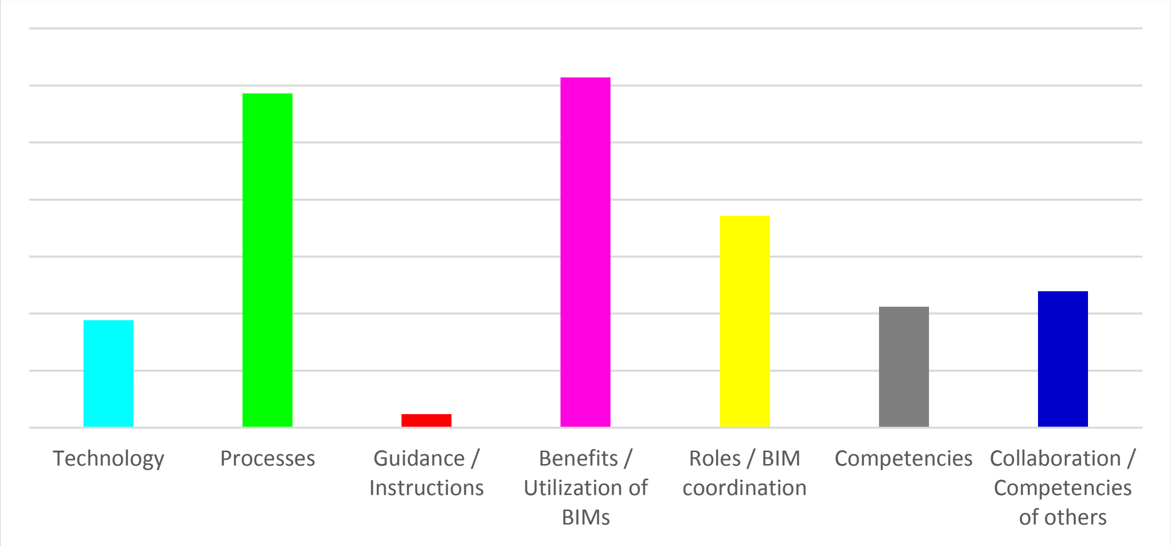

Figure 15 Relative duration of discussion by category in Case 3

Figure 15 illustrates the most discussed categories in Case 3 based on the time-analysis. The emphasized issues in Case 3 include:

- Increasing the utilization rate of the models, the benefits of BIM will be proven
- The quality of the models had been good, and served the utilization purposes of the former Lemminkäinen
- Responsibilities of the designers, BIM coordinator and project manager to ensure the correctness of the design and accuracy of information content
    - BIM coordinator should absolutely be insourced

The model creation and utilization process of the unit, which is illustrated in figure 14 was discussed for some time, which clearly affected the time-analysis.

4.1.4 Case 4

In Case 4, BIM had been implemented into a few housing projects. The unit had also business premises projects, and was involved in a large alliance project, in which BIM had been implemented. The formal BIM pilot was in the design phase, and was discussed amongst the other BIM projects.

Technology

The spectrum of discussion about technology was wide in terms of discussed software. In addition to iTWO and Solibri Model Checker, software for on-site operations were also discussed. It was seen important that site managers and site supervisors should at least be able to use Solibri with ease. iTWO was considered as a multifunctional, all-round software with a lot of functionalities, which is a remarkable feature of the software. Also, in Case 4, the utilization of a preliminary architectural model for preliminary cost estimation was discussed and regarded as a BIM Use to be pursued. iTWO was preferred to be utilized for that purpose since it enables linking the cost information directly to the model. The future functionalities of iTWO and the possibilities to utilize them were discussed as well. The more functionalities it provides, the more the functionalities should be utilized. The integration possibility of iTWO should be exploited as long as it adds value to the whole process.

Processes

The model creation process was rather similar to the one introduced in Case 3. It begun with 2D sketching, after which the architect and structural engineer begun creating their own models. When the models had progressed enough, the MEP modeling begun with creation of the basic floor. It was followed by design coordination, fixing the issues, copying the floors and modeling other parts of the building. For design coordination, it was seen that three combined models should be enough for the project: the first being the combination of architectural and structural models for cost estimation purposes, the second including also the MEP models for design coordination, and the third combined model should be created for the utilization on site, again for design coordination. At the time, there seemed to be little benefit creating the as-built model as there had been no demand from building operators or property owners. Description of the overall BIM process was seen beneficial, although, the current process of the unit was already rather clear to the interviewees.

A thorough BIM meeting with the designers and BIM coordinator was seen important to be arranged at the beginning of the project. In the meeting, the requirements of the client should be discussed and clarified to all stakeholders. The client cannot trust the stakeholders to read and understand the requirements and instructions on their own, so it is better to go through them together.

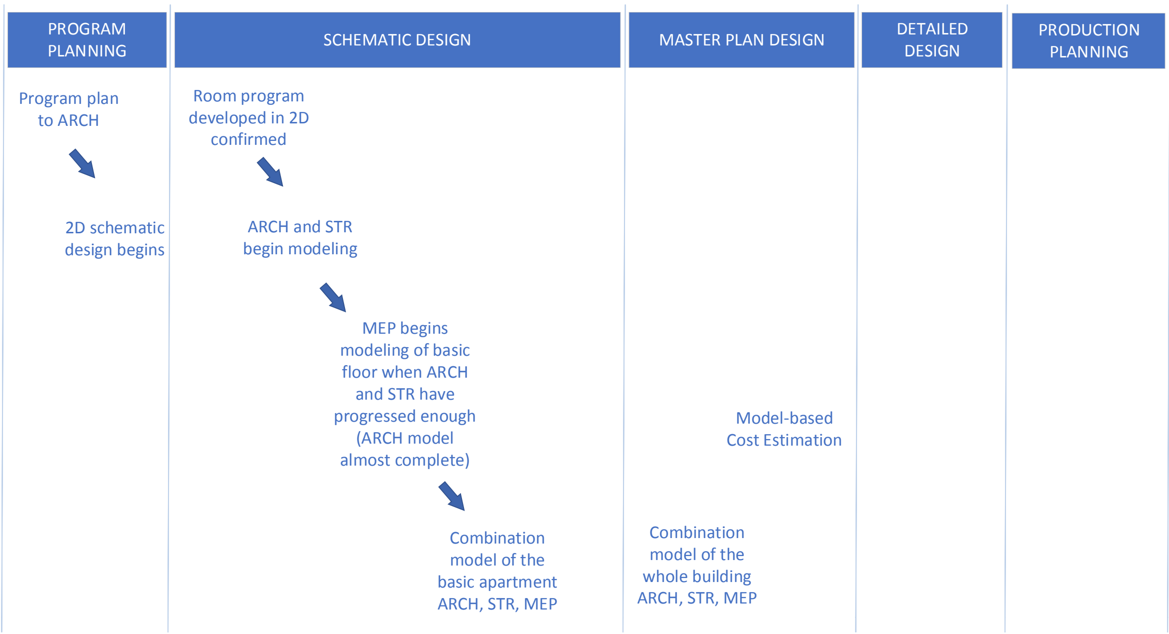

Figure 16 Overall BIM process derived from the description in Case 4

Guidance / Instructions

BIM execution plan had been used in the BIM projects, and it had been proven beneficial. The goals of the implementation, BIM Uses, level of detail of the models and roles had been defined in the plan. The feedback after renewing the BEP template and other instruction materials of the case company had been positive. The BEP had not been utilized actively in that it had not been updated, but being able to check up on what had been agreed upon, was seen useful. An up-to-date BEP can be useful afterwards as the changes in processes can be examined in addition to the design changes.

Benefits / Utilization of BIMs

The purpose of the implementation was seen as striving for more efficient design process, production process, cost management and improving visualization. Cost estimation and design coordination were seen as the most important BIM Uses. Cost estimation had been improved in terms of speed, and BIM coordination had decreased design clashes and additional work on site. A spatial model was supposed to be created in the next project and studied how it could be used for preliminary cost estimation. It had been detected that most of the costs caused by design clashes were between the structural and MEP models. In one of the BIM projects, the design coordination was performed only with those models, which eliminated majority of the most cost affecting clashes. The difference between modeling the space reservations of MEP design and performing that coordination with traditional methods was significant. In the former, there were many fewer clashes than in the latter.

On site, the models had been used for quantity take-off, e.g., quantities of concrete for procurement and production planning, as well as for visualization. The models had improved visual representation of design in that they were more understandable on some parts. Yet, it should be noted that certain things can still be understood better from 2D drawings. It is important to understand the limitations of the models such as lack of details, which are produced with 2D CAD, so the implementation can be planned realistically.

In the near future, the models were seen to be used for sales and marketing purposes, in which the visual aspect is emphasized. For that, the level of detail, furnishings, materials and colors must be at a certain level. The adequate minimum level should be defined, and it should be assessed how much additional work it requires and how much value it creates.

In general, the accuracy of the models had been at least at a satisfied level, but in some instances the information content had required some modifications on naming, classification and categorization.

Roles / BIM coordination

External BIM coordinators had been used in the BIM projects. That demanded quite a lot from design management due to BIM implementation being new to them as well. The coordination had been successful, although it had demanded a lot of instructing and guidance from the client. For cost estimation purposes, the coordination had been good, but for design management, it was seen that at times the coordination was performed with too much attention to detail. The principle in all processes should be to perform it with the required accuracy and scope. Overwork is a type of waste just like inaccurate work, which leads to rework.

The benefits of insourcing BIM coordination were acknowledged, but for the time, the purpose was to outsource the coordination. In term of possibilities, it was seen that the required competencies for BIM coordination existed within the unit. It was seen as a must to have a BIM coordinator in a BIM project, and part of the role was seen to be a support for the project manager. BIM coordinator was seen as a BIM expert who can instruct and provide help with technical matters and understanding different concepts of BIM.

Competencies

Training in the beginning of implementation, in the piloting phase and afterwards, was seen fundamental for being able to implement BIM into a project and any specific function. Training should be focused to the most used software instead of training a little of everything. On the other hand, it could be difficult to find the most suitable tools if most of the tool related knowledge and skills cover only one tool. In the beginning of implementation, at business level, gathering knowledge from here and there, and not only knowledge on tools, is beneficial for discovering the right path of the development of implementation. It was seen important that also personnel on site would have support for using the tools.

Collaboration / Competencies of others

In general, the competencies of designers were seen to vary, but the level of modeling had been adequate in the BIM projects of Case 4. It had been noted that designers had begun to build their own competencies by attending training sessions, which had been caused by the client demanding BIM from them. The same phenomenon had been discovered in the alliance project. The client simply did not allow the use of 2D drawings with the exception of some individual drawings. Simply by demanding BIM from the stakeholders, the development of implementation could be accelerated.

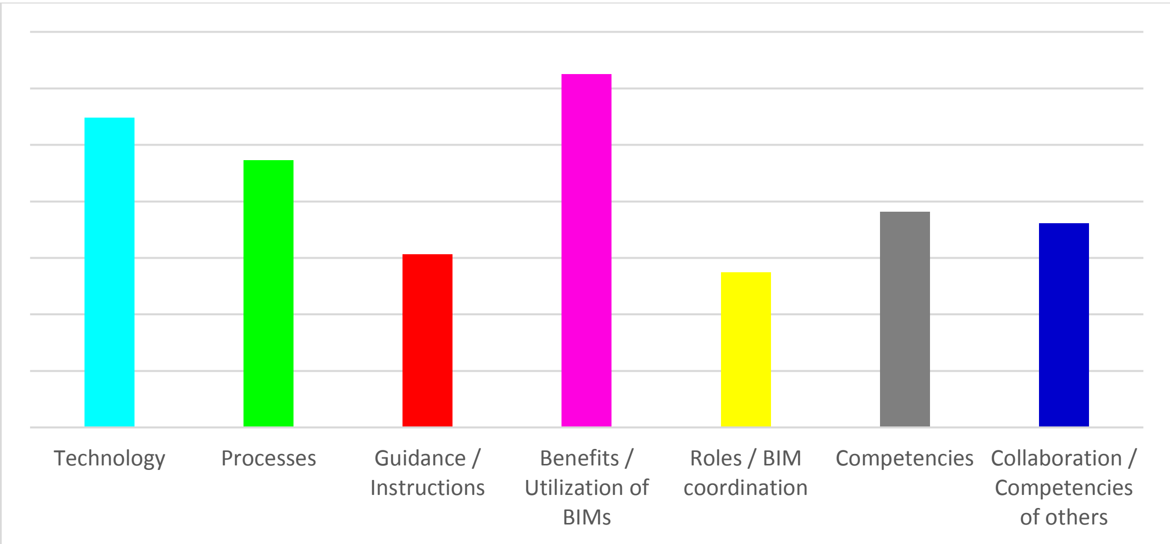

Figure 17 Relative duration of discussion by category in Case 4

Figure 17 illustrates the most discussed categories in Case 4 based on the time-analysis. The emphasized issues in Case 4 include:

- Utilization of the models for various purposes and the potential as well as observed benefits
    - Also, software and hardware related to these issues were discussed broadly
- The role and competencies of the BIM coordinator

- Focusing training on the right software
- Competencies of the designers vary, design management is emphasized in BIM projects
- The instructional materials such as BIM execution plan are useful but only if all project participants understand them

The scope of discussion was broad, and the time-analysis corresponds to it rather well.

4.1.5 Case 5

In Case 5, the first BIM project, which was typical developer contracting housing project, was in the design phase. The unit had a background of creating building information models themselves solely for cost estimation purposes over the years. It was seen quite a different method compared to the BIM implementation into cost estimation in the pilot project. The discussion focused heavily on the formal pilot project.

Technology

Possibilities to utilize models for programming were discussed. In principle, programming could be performed parallel to creation of a spatial model, which could improve programming. Usually programming is followed by the first sketches, but it was seen that with parallel work, the design could be optimized earlier. This approach to early design and planning incorporates a fundamental dilemma: the program plan is created by a project manager and the first sketches by an architect. Project manager could, however, create a spatial model solely for this specific purpose, but it would require having considerable modeling skills. In terms of technology, potential tools for this purpose were discussed. It was seen that it is perhaps too much to ask from a project manager to learn to use a design software, even if it was limited to only creation of a spatial model. As an alternative, it was noted that there are some available tools for programming.

Processes

Sharing best practices, even the smallest ones, was emphasized in the discussion. Everyone developing their own practices and methods for utilization of models was not seen efficient enough. A large organization should strive for exploiting its size. As one of the objectives of the piloting was to harmonize BIM processes and practices, distribution of knowledge should be pursued but also efficient. However, discovering the best practices presumes that different practices have been tested and assessed so that the best ones can be distinguished. In case best practices have already been discovered and there is no potential to improve at the time, time is wasted if the discovered best practices are not shared. By sharing the best practices and methods, it is also ensured that the less efficient ones are not used.

The design process had begun with 2D sketching based on the program plan. The architecture had begun the modeling work when the preliminary drawings were fixed. Structural and MEP modeling had begun when the architectural model had been progressed enough, meaning that certain major design solutions had been fixed. The structural modeling had been lagging behind due to the project being the first one to the designer, too. The designer had also created 2D drawings parallel to the modeling work to keep up with the schedule. The cost estimation had not been performed at the time, and it was under consideration whether to do it with Solibri Model Checker or iTWO.

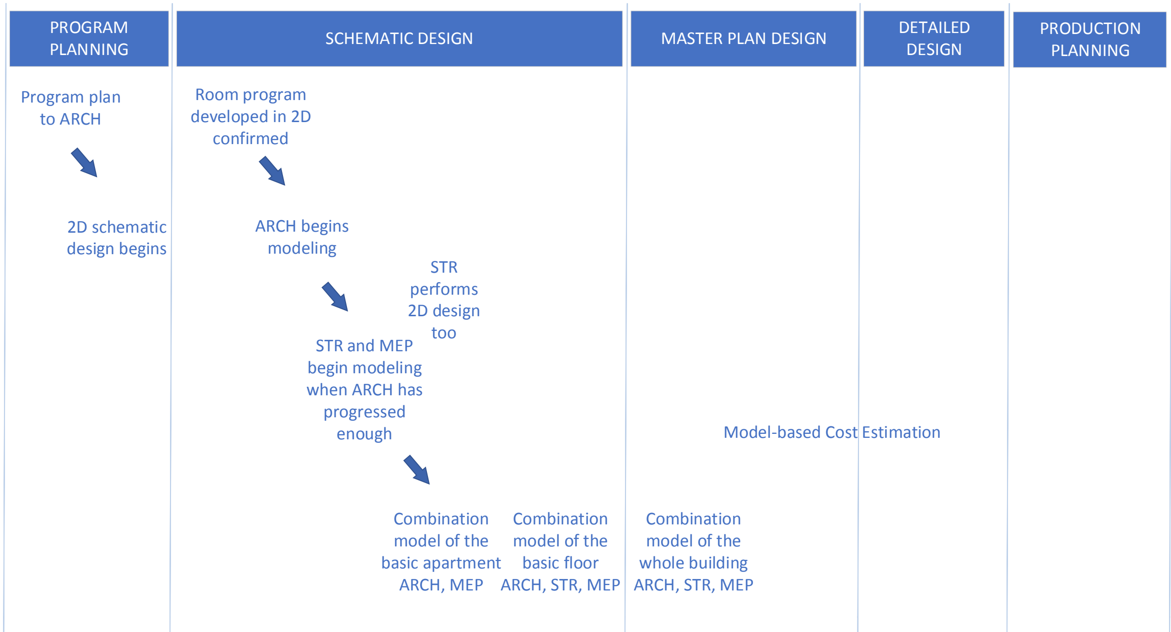

Figure 18 Overall BIM process derived from the description in Case 3

Design coordination was first performed for just one basic apartment, then for the complete basic floor and finally for the whole building. Structural model could not be included in the first phase of design coordination. It was seen that certain systematic errors could be eliminated in the first coordination, even though the apartments are different. Prior to the actual modeling of the building, use of the common coordinates was ensured.

Guidance / Instructions

Similar to instructing designers to create the kind of models that the client requires, it was seen that there should be guidance for internal processes as well. Documentation is one of the means to it, but having a person in the business unit that can help with all kind of BIM related matters was seen better alternative to documentation. These do not, however, exclude each other. Part of the documentation is the description of the overall BIM process, which was seen beneficial for understanding the process.

Benefits / Utilization of BIMs

The purpose of BIM implementation was seen as improving efficiency of working methods. The costs of the implementation in terms of time and resources were seen to be significant. The benefits of BIM implementation are not realized immediately – it takes learning and development to achieve the benefits.

A spatial model was desired to be tested and used for programming. Only a handful of designers were known to create spatial models in the first place, which presented an issue.

The designs were primarily still understood better from 2D drawings than the models, because the personnel had been used to interpret the drawings for years. BIM was clearly seen as a supplementary part of design.

It was seen that the more there are BIM Uses defined at the beginning, the more requirements are placed for the implementation. The requirements affect the overall process and the direction of development in the big picture. For example, in a lot of cases it was wondered whether to use Solibri or iTWO for quantity take-off, and as it was perceived to be easier at the time with Solibri and because the purpose of quantity take-off was mainly to use it in cost estimation, in most of the cases Solibri was used for quantity take-off. But if the models are utilized for majority of the potential BIM Uses that all place their own requirements, an integrative project management software could even be a necessity.

Roles / BIM coordination

The BIM coordination had been outsourced in the pilot project, but in the following projects the aim was to perform the coordination internally. The idea was to distribute the work so that cost estimators would check the appropriateness of model data in terms of their own requirements, and the project manager would ensure that the design is as planned and agreed. An internal coordinator was seen as a central part of BIM development within the unit, and an external one as a temporary solution. Monitoring and controlling BIM coordination was experienced as a challenging task. The role of an internal BIM specialist, namely a BIM coordinator or an equivalent, was seen especially important in the piloting phase as a lot of new terminology, concepts, practices, software, requirements and other things emerge.

Competencies

It was seen that a picture of BIM implementation with all its details would be formed in everyone's minds after they had personally been part of a BIM project. Therefore, it was seen important that everyone has the possibility to be part of a BIM project, and has the resources to implement BIM into their own process. Time is an essential resource, and it is clear that the practical implementation, training and development takes time. Also, some kind of an idea of BIM should be a precondition for being part of a BIM project. The significance of mastering the fundamentals of BIM, terminology, concepts, practices, software, requirements and processes is huge.

It was seen extremely important that those who do not yet experience BIM very beneficial but have enthusiasm and will to learn, are be supported, and the learning should be enabled for them. If BIM is experienced excessively difficult, the motivation may begin to vanish.

Collaboration / Competencies of others

The collaboration with the designers and BIM coordinator had been successful other than the structural modeling lagging behind. It was seen that the modeling work will ease off, if the client can provide pre-modeled objects for the designers to use.

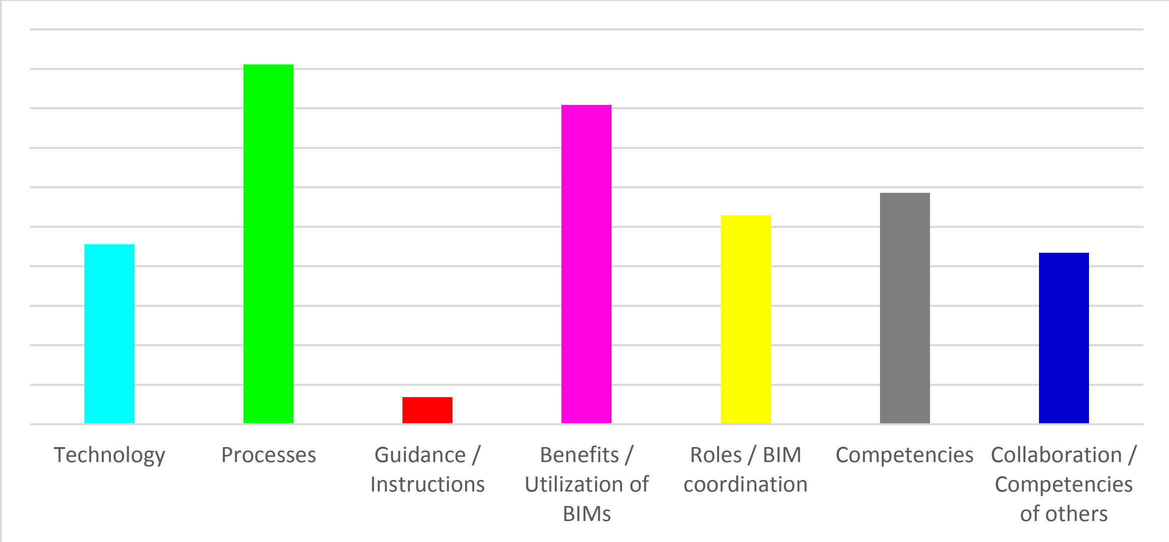

Figure 19. Relative duration of discussion by category in Case 5.

Figure 19 illustrates the most discussed categories in Case 5 based on the time-analysis. The emphasized issues in Case 5 include:

- Utilization of spatial model for program planning to ensure optimal design from the beginning of the design
- Importance of sharing methods between units
- Importance of internal instructions and support, similar to how designers are instructed and guided
- When the motivation to learn exists, it must be supported by enabling the learning process
- BIM coordinator should absolutely be insourced, an external one is a temporary solution to a significant need
- Lacking competencies of the designers are reflected to the modeling process

The scope of discussion was broad, and the time-analysis corresponds to it rather well. However, the Guidance / Instructions category seemed to be somewhat underrepresented in the time-analysis.

4.1.6 Case 6

There were three business units present in the sixth interview. In one of them, models had been created for cost estimation purposes over the years, similar to the Case 5. The project manager of the two other business units could not attend the interview so the discussion was more general. In those two units, BIM had been implemented for several projects, and in the third unit, the first BIM project was ongoing. All pilot projects corresponded to typical housing projects.

Technology

Implementation of software, especially of a versatile one such as the project management software iTWO, was seen as an important element of the whole BIM implementation, which requires investing a lot of time and other resources. That denotes the importance of selecting the right tools. The compatibility with BIM should be kept in mind when developing software and the working methods, even if it was possible to perform operations with traditional methods. Otherwise, some potential of the software is lost and as an integrative software, loss of potential reflects to other functions. However, it might feel easier to use the software in an old way, even if it is not for the best in the long run.

It was also perceived important to ensure the availability and use of adequate software and hardware, and adequate server capacity and software licenses especially for the scale-up.

Processes

The quality of models had been lacking, and therefore, the possibility to modify the models by oneself was discussed. There are programs for that purpose, and it was perceived as a rather simple procedure, but in the long-term it was not seen the right direction for development. It would be faster to modify the model data by oneself than to comment the changes to the designer and wait for the change, but that does not improve the modeling process. The less commenting the client needs to do, the more beneficial it is for them. By pointing out the errors and instructing the designers, the modeling process improves, systematic errors are eliminated, and the models are created correctly at once. Another justification is that the role of the client should be to instruct and guide the design, whereas the role of the designer is to create the design according to the requirements of the client.

To ensure the common principles of modeling and objectives of BIM implementation into the project, all relevant stakeholders should participate in the BIM meetings. By relevant stakeholder, it is meant a function where BIM is implemented in. For example, if BIM is not implemented into sales and marketing, it might not be necessary for them to participate such meeting, although, even observing and listening new things increase knowledge.

In traditional design and planning, lists and catalogs related to 2D drawings are very familiar. In a way, the information of the lists depicts the non-graphical data of building information models. The mindset should be changed in this regard when implementing BIM, because it is not the lists that are desired but the information. It was also seen important for the development to actually demand the implementation internally as well as externally in some way. Implementation of BIM at some defined level or levels should be mandated to prevent projects to be delivered traditionally. In other words, it is important to define BIM implementation for promoting the implementation.

Guidance / Instructions

It was seen that the instructions of the client for the creation of models should be gone through together with the designers and the BIM coordinator. Good instructions make creating good quality models possible, but do not ensure it – guidance and design management is a necessity. Model description documents delivered with the models were perceived very useful. They inform the detailed level of completeness and the stage at which the design process is.

Benefits / Utilization of BIMs

Utilization of the models presumes accuracy of the model data, i.e., naming conventions and classification. In traditional design and planning, unfinished and inaccurate drawings could be used, because persons that utilized the drawings, could also interpret them. In principle, if there is a misspelling, a person can recognize it as a misspelling, but a computer cannot. In this sense, the models have to be accurate and complete, if they are to be used in automated processes. Using false data and information was seen as a significant risk.

Geotechnical models had not been typically created in BIM projects, but it was seen that there is significant potential for cost estimation of groundworks. Geotechnical model differs from other models slightly in that part of the model represents an existing structure that should be removed. So, in terms of a ground level, there should be the initial one and the finished one – the one after construction. Annual repairs and alteration works were perceived as other future functions where BIM implementation could add value.

Roles / BIM coordination

External BIM coordinators had been used in all BIM projects of the unit. An internal one was seen as more beneficial, but there seemed to be lack of BIM coordinators available.

BIM meetings had been held with the designers and coordinators, which was seen necessary, but it was perceived that it is also important to involve some internal functions such as procurement, cost estimation and production, too, and provide their view as well. If it is not clear what the requirements of other internal functions for the models are, it is difficult to guide the modeling process.

Competencies

Learnings should be shared especially from those units that have had a lot of experience and success with the implementation. To promote sharing of knowledge, it was seen that collaboration between business units must be organized. Incentives could be used too. Incentives and training were seen important for successful implementation and development.

Two of the most important learnings from piloting mentioned were to understand to select competent designers/modelers and that both external and internal personnel should be engaged and committed to the modeling process at the beginning of the project to get the process on the right track from the beginning. Case 6 also advocated for gradual implementation, which has been discussed in previous cases.

Collaboration / Competencies of others

The experiences about collaboration with designers varied a lot. There was a very competent modeler in one of the BIM pilots, but in some projects, the designers have struggled with rather simple issues such as combining the coordinate systems. It was seen that struggling with simple issues for a long time frustrates people, which is harmful for the implementation and development.

It was seen absolutely essential to collaborate closely with at least the architect and cost estimator at the beginning of the modeling process to get the classification and naming right at once. Also, controlling the modeling process was emphasized. The pre-modeled objects that the client delivers to the designer for modeling were seen to ease off these kinds of issues.

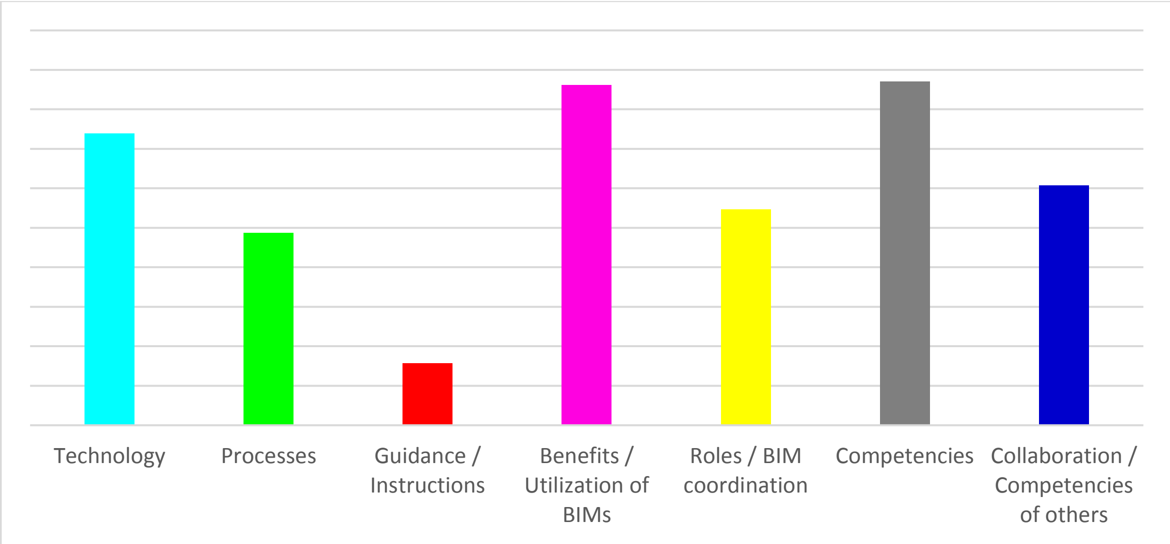

Figure 20 Relative duration of discussion by category in Case 6

Figure 20 illustrates the most discussed categories in Case 6 based on the time-analysis. The emphasized issues in Case 6 include:

- The project management software and its development
- Collaboration and engagement of internal and external stakeholders in projects to ensure project success
- At unit and segment level, engaging internal personnel to develop implementation
- Right kind of training for the right people
- BIM should be demanded more internally as well as externally to accelerate development
- Accuracy and correctness of model information is fundamental for being able to utilize the models
- Importance of choosing competent designers/modelers

The scope of discussion was broad. A little less fluctuation in the diagram would represent the findings better as important matters were found from all categories.

4.1.7 Case 7

The formal BIM pilot project in Case 7 was the first BIM project of the business unit, although there were other BIM projects ongoing as well. All of them were in the design phase.

Technology

There was not a lot of direct technology related discussion in Case 7. It was mentioned in this interview too, that many times the conversations about BIM culminate to skills and knowledge related to tools. The technology driven approach to BIM implementation could be detected in that sense.

Processes

It was emphasized a lot that a lot of effort, especially when BIM is implemented, should be put in the early design phase. When the design begins, whether it is traditional or BIM-based design, the characteristics and functionalities of the building should be as clear as possible for making the right decisions. It was seen that it presumes involvement of cost estimators and procurers due to them having the best knowledge in those areas – costs and procurements.

Guidance / Instructions

It was perceived that even understanding the BIM design management materials such as the BIM execution plan might require some effort. Understanding instruction and guidance materials could come down to understanding terms and concepts of BIM. That implies the significance of first building the foundation of BIM knowledge, before development.

The model description documents had, in general, been too general in that they had typically described what information the model incorporates, but where it can be found from, on which attribute, is left unclear. The challenge in that is that same information can be assigned to different attributes in different models. The problem could be compared to having a pile of paper drawings without a list of the drawings. It would take excessive amount of time to sort out what can be found and where.

Benefits / Utilization of BIMs

It was seen that the economical savings of BIM implementation can be difficult to point out, but at some point, BIM implementation should yield them. Time savings should be observed as well, but at such early phase of the implementation, temporal savings could not be detected yet.

In the pilot project, the models had been used only for design coordination. The idea was to increase the rate of utilization gradually, and in the next project to use the models for cost estimation, too.

The BIM Uses and procedures should be applied so that the same work is not performed in several instances. It might not be realistic to avoid recurring work entirely, but diminishing it should be pursued. For example, the models can be, in principle, used for producing high quality visualizations for marketing purposes. At the time, due to inadequate level of development, the models could not be directly used for creating visualizations but had to be ordered separately. With a better level of development and model content, the client could create the visualizations effortlessly by itself. Visualization is just one example, the main point being that model data must be accurate and correct. It is not only the foundation for utilizing the models in cost estimation and procurement but for exploiting BIM in the future for such technologies and methods as IoT and machine learning.

Roles / BIM coordination

In the pilot project, the project manager had been learning performing BIM coordination. The experience so far had been challenging and the magnitude of the task had been realized. It had been discovered to be extremely difficult to find any external BIM coordinators in the area. Therefore, the plan was to perform the coordination internally in other projects, too. The basic principle of BIM coordination was seen to be the same as in traditional design coordination, and therefore the coordination being the responsibility of a project manager would be natural, although, the project manager would not have time to ensure the accuracy of model data, too.

Competencies

The importance of understanding the basics of BIM and the implementation in the case company had been detected in the pilot project. The client must know in detail what they want from the models to be able to guide the modeling process and ask the right questions.

The learning process was seen to be the following: in the first BIM project, everything is new and familiarization to BIM begins; in the second project, things are clarified, and some things stick in mind; in the third project, the implementation is smoother and probably successful. It was seen that there should be certain freedom to test different things, to succeed and fail. It is also important to have courage to highlight problems, and to discuss and present potential solutions to develop the implementation in the right direction.

Collaboration / Competencies of others

In general, the modeling competencies of designers were perceived to be rather low, but in the future with the younger designers coming in and the competencies of current designers increasing, the quality of the models would increase. In some design offices, younger designers are creating the models, whereas the more experienced designers create the actual design using 2D CAD software.

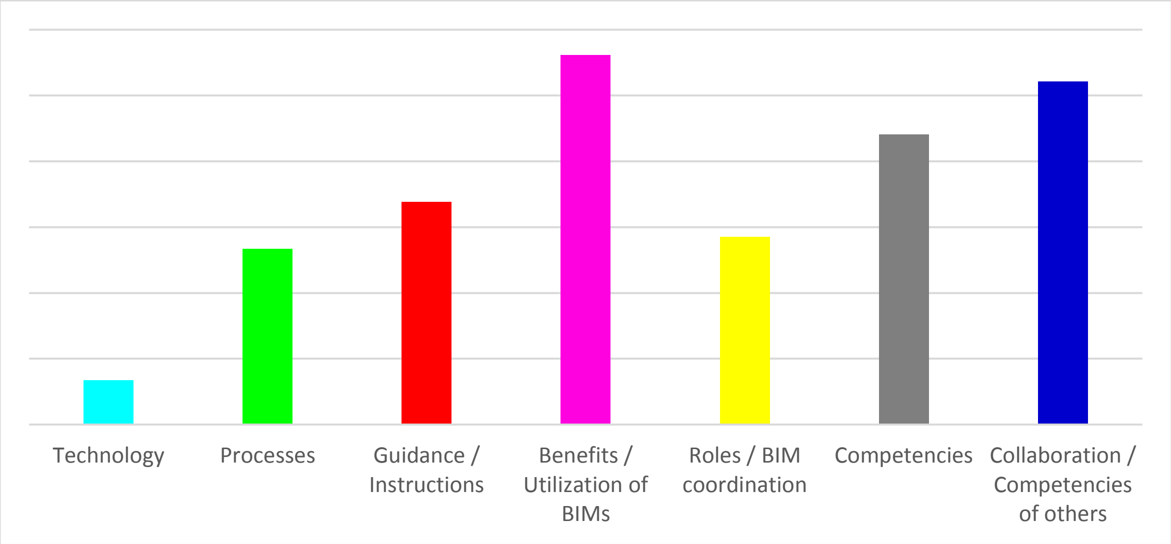

Figure 21 Relative duration of discussion by category in Case 7

Figure 21 illustrates the most discussed categories in Case 7 based on the time-analysis. The emphasized issues in Case 7 include:

- More effort must be placed into the early phase of the project
    - Achieving clearer vision of the building presumes engaging cost estimation and procurement
- Importance of the instructions to the quality of models

- In-depth understanding of BIM terminology, concepts, processes amongst others takes considerable amount of time
- BIM implementation underlines collaboration in that having a common understanding on details as well as larger concepts is not a given

The time analysis corresponds quite well with the qualitative findings.

4.1.8 Case 8

The business unit in Case 8 had similar experience from creating architectural models for cost estimation, as Cases 5 and 6. The BIM pilot project was ongoing, at the end of the design phase, and it was a typical developer contracting housing project.

<u>Technology</u>

The use of iTWO and Solibri Model Checker for cost estimation was discussed in the beginning. Both had been used for cost estimation in that the quantity take-off had been performed in Solibri, and pricing in iTWO, which was the typical cost estimation process in some other units as well. Quantity take-off with iTWO requires a certain kind of foundation work to be done prior the automatic operation of quantity take-off. In essence, formulas that define what information is searched, from which model attribute and model object, must be defined. Due to the pre-determined formulas, the quantity take-off is automated, unlike in Solibri, in which the quantities are first exported to Excel and after that must be manually typed into iTWO.

Some software for creating the site plan were discussed as well. InfraWorks was seen as a more advanced software compared to SketchUp as it includes pre-modeled site objects such as cranes, machines and barracks. It is also compatible with AutoCAD so a 2D drawing can be used as a reference in creation of the site model. In general, programs are developing towards more integrability. Plug-ins provide more direct link up, for example, between a design software and a common data environment. This way examining 2D details on site is easier because the detail drawings can be directly linked to a specific model object. Examining both the model and 2D detail drawings is more seamless.

<u>Processes</u>

The quantity take-off method the business unit had been performing for years, that included utilizing the self-created models was seen significantly different compared to one used in the BIM pilot project. Even though both are BIM-based quantity take-off methods, i.e., the quantities are derived from a building information model, this example illustrates how rather simple processes can be performed in significantly different ways. The benefit of creating the model by oneself is that it is clear what information can be found and from where. In terms of differences of the methods, the focus is on efficiency.

The modeling process of the BIM project was similar to the ones presented in other cases. Sketching had been performed with 2D CAD tools, and the first combined model had been created from the basic floor. The models had been used in BIM meetings for planning and design management. The process map in figure 22 was derived from a project schedule that had been created for the next BIM project based on the experiences of the pilot. A combined model was meant to be created for every BIM meeting.

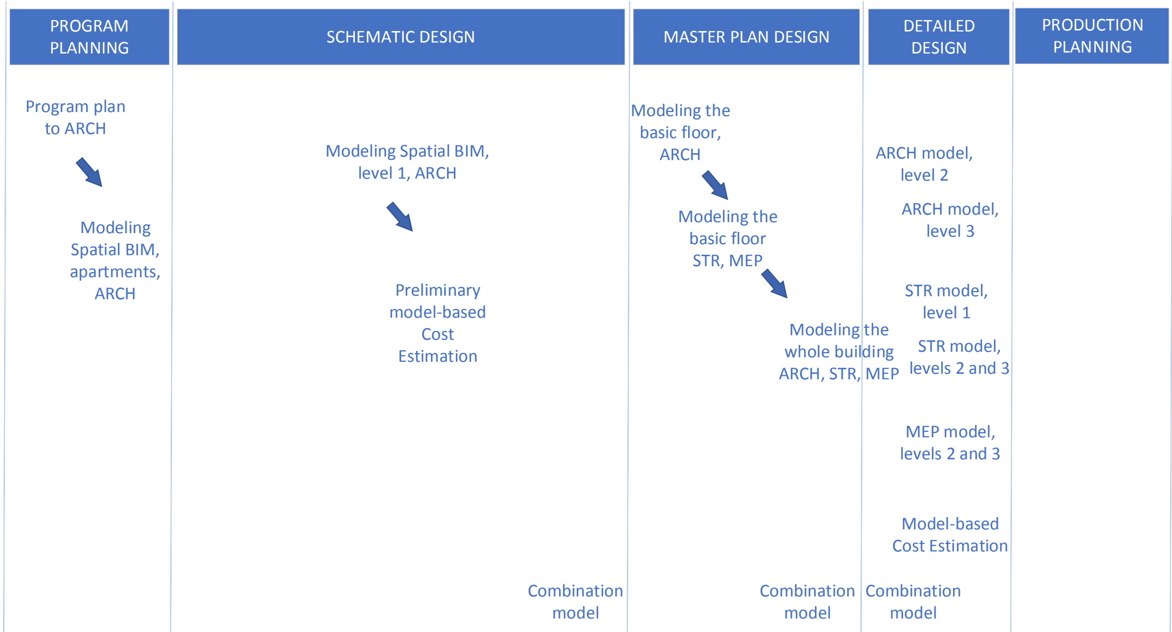

Figure 22 Overall BIM process map derived from a project schedule created based on the experiences of the BIM pilot project in Case 8

It was seen that the design process took more time with BIM compared to the traditional method, and it could be detected from the increased costs of design. However, a common understanding was that if BIM implementation improves the design, it is economically feasible. Unimproved design is obviously not worth paying more. Whether the design had improved or not, could not be said at the time.

One of the mentioned learnings of the pilot project was that the modeling process must be in control of the client. Modeling must not be let to advance too much before errors and contradictions are noticed. BIM coordination must be performed frequently and right from the beginning of the design. It was seen that coordination will be easier when the coordination is performed in-house, and cost estimators and procurers are engaged in design and planning at the beginning.

Guidance / Instructions

The BIM execution plan of the case company had been covered and discussed with the designers in the pilot. The scope and level of development had been discussed in the contract negotiations, which proved to be a challenge with the structural engineer who did not seem to understand why such level of development was required. The objectives of utilization of the models were not clear to the structural engineer, who just recognized the increase of the costs. This is a great example of the significance of soft skills that are needed in BIM projects. Collaboration and communication is emphasized, and it is a two-way path in that the client has also some responsibility to help the designer to understand what and why is required.

The development of instructional materials was discussed, too. Instructions about naming conventions and classifications should be quite extensive if different building elements are desired to be distinguished. For example, timber and metal doors should be distinguished, and suspended ceilings of the apartments should be distinguished from the ones of the corridors. The respective names of all elements should be standardized so that they are the same in every project.

Model description documents had been delivered with the models in the common data environment. The documents had been useful in that it was clear what changes had been made.

Benefits / Utilization of BIMs

The purpose of BIM implementation was seen to be to improve the efficiency of design and production. Visualization of the models was perceived beneficial as the models had improved understandability of the design. Also, visualization was seen to have been improved significantly by creating a model of the site using InfraWorks design software. The need emerged in the tendering phase of a Design-Bid-Build project, in which a site model would increase the quality of the tender. The model could also be used in electronic site orientation.

Other than for visualization, the models had been used for design coordination and cost estimation. The models were used for preliminary cost estimation, but as cost information was not linked to the model automatically, the implementation for that purpose did not entail much benefits. In the next project, spatial models were to be created, and their efficient use for preliminary cost estimation were to be studied and tested.

Procurement, production and marketing were the functions, in which BIM was seen to be implemented in the following projects. The core of BIM utilization in marketing, that is visualization, was discussed. The personnel in marketing were interested in the BIM implementation and saw that the model visualized the project much better compared to 2D drawings. The requirements for the utilization of the models for marketing purposes, which are adequate level of development in terms of interior design, furnishings and surface materials, were identified.

Roles / BIM coordination

One of the architects of the architect office in the pilot project, had been designated as the BIM coordinator. The desired level of coordination had not been accomplished in the pilot. It was seen that an external coordinator sees the coordination process and its purpose from their own point of view, not from the point of view of the client. Thus, an internal coordinator was perceived as the better option. An internal BIM coordinator had already been assigned in the business unit. The coordinator did not have previous experience from BIM coordination, but initially the purpose was to coordinate all projects of the business unit. It was seen difficult to estimate the work load of a BIM coordinator at the time. The coordinator was seen more as a BIM specialist than merely a coordinator. For example, the coordinator had provided assist and training for different software.

Competencies

Developing internal competencies was seen very important. It was emphasized that the client should absolutely know what is required from the models, what models are ordered and why. It is difficult to manage the modeling process if these are not clear even for the client. As central part of the implementation as the BIM coordinator is, the responsibility and competencies should be insourced. It was recognized that learning takes time regardless of the subject, especially in a change of this magnitude, even though the change would entail benefits in the long term. Therefore, motivation and incentives are needed to maintain will to improve competencies.

Collaboration / Competencies of others

With some designers, collaboration had been effortless, but was seen that some might need a bit more guidance and intensive collaboration. It is important to reason the demands in a way that the other party understands it, and to recognize when reasoning is needed. One collaboration related challenge in the pilot project had been the designer not understanding nor correcting the issues that were discussed with the client. The meaning of communication and soft skills are emphasized in such instance. Another observation is that the level of modeling of the designers varies a lot. It was seen that because acquiring qualified modelers is one of the most important enablers of a successful implementation, effort should be put into the selection of designers. Previous experiences should not be overlooked as qualified designers are not necessarily qualified modelers.

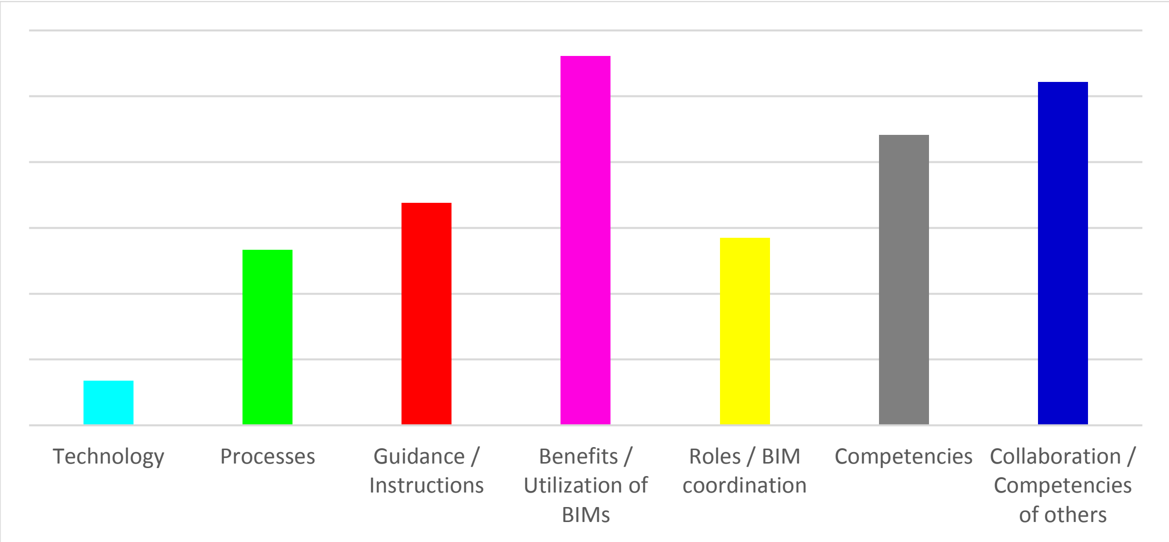

Figure 23 Relative duration of discussion by category in Case 8.

Figure 23 illustrates the most discussed categories in Case 8 based on the time-analysis. The emphasized issues in Case 8 include:

- Motivation and methods to utilize iTWO effectively for creating a reliable preliminary cost estimation
- Potential and observed benefits to different functions such as cost estimation, procurement, design management, production, marketing and sales
- Closer collaboration with the designers from the beginning of a project so errors can be detected and eliminated as soon as possible
- The quality and contents of instructional materials given to the designers to guide the creation of the models are reflected directly in the quality of the models
    - Responsibility of the client to manage model creation presumes knowing what is demanded and why

- Importance of BIM coordination being an internal competence instead of external one
- Choosing competent designers/modelers is important for enabling a successful BIM implementation

The time analysis corresponds quite well with the qualitative findings.

4.2 Conclusion of the analysis

Piloting was ongoing in all business units. In five of them, it denoted the first BIM project. The most advanced business unit had implemented BIM successfully already for years. As the organization of the unit composed mainly of the employees of former Lemminkäinen, it can be concluded that the merger was beneficial from the perspective of BIM. Relevant and valid research data was collected from all intended units, and later analyzed. Any significant hindrances did not emerge.

Generally, the attitude towards BIM implementation was positive, and it was seen that it has improved over the years. It was perceived that change resistance has decreased when benefits have been realized and observed first hand. Regardless of the positive development, BIM was seen as a supplementary part of the design.

Assessing how well the time-analysis corresponded with the most important matters derived from the interviews with qualitative methods was challenging, because so many aspects and matters were emphasized. Figure 24 illustrates the relative time spent discussing each category, and it includes data from all cases. The discussions seemed to revolve around the utilization of models to achieve benefits. In addition to the *what*, the *how* was emphasized as well in utilization of models, which leads to the aspect of requirements, which are represented by all other categories, but above all, the internal and external competencies were underlined.

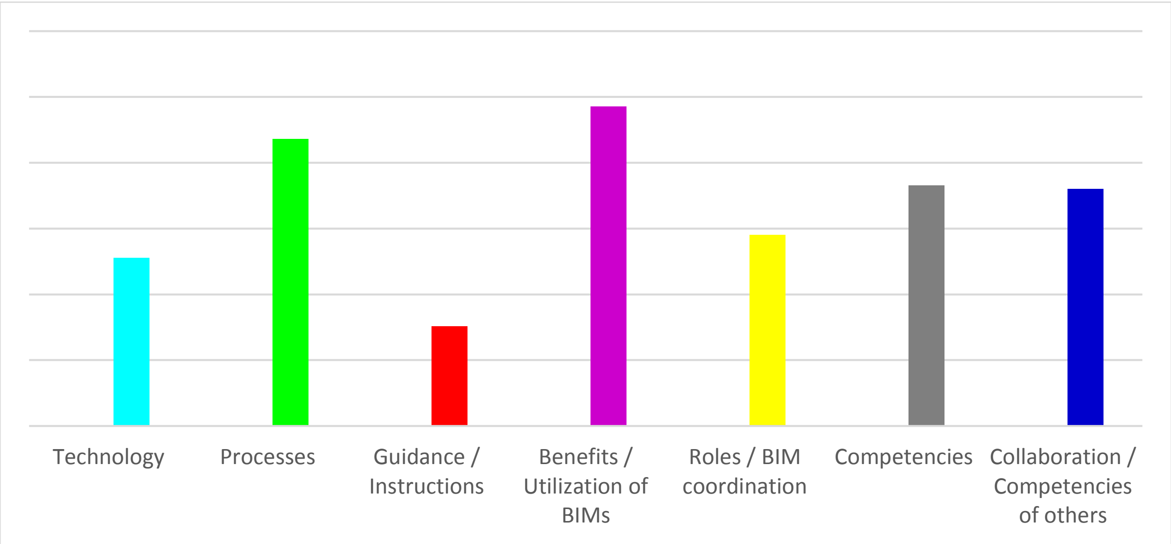

Figure 24 Relative time spent on category including all cases

Understanding BIM

There seemed to be a common understanding of the purpose of BIM implementation: improving the efficiency of processes from design to production, which was emphasized in all cases. BIM was also seen as an integral part of the present-day construction, which implies that the competitors and other actors in the field are implementing BIM, thus, an external pressure to implement BIM exists. As such a large organization, the case company should not settle for keeping up with the competitors but pursue to exploit the increased size, and to be a forerunner at least in the local market.

The approach to BIM has changed over the years. Simple building information models had been created in three business units previously, but only for quantity take-off purposes. The process and possibilities were seen very different from what the BIM implementation in pilot projects considered. Currently, the potential of utilization of models is acknowledged more broadly. Amongst the future functions to implement BIM or enhance the implementation are sales and marketing, alterations work, production and procurement.

Utilization of the models and learning

The existing and new BIM-based processes are currently employed concurrently. Although it hinders achieving the potential benefits of BIM, it has been shown that with little implementation, concrete benefits can be achieved. Most significantly BIM was utilized, and benefitted from, in design management and cost estimation. Benefits were also experienced in construction site operations. The observed benefits include faster and more accurate cost estimation, decrease of design clashes on site (benefit of BIM implementation in design management, although the benefit realized on site) and visualization, which made understanding the design easier. However, understanding the design better from a model is not a given. It was seen that 2D drawings, which have been explored so much that understanding the design is easier from them than from a model.

Benefits could not be observed in all projects as the projects were still ongoing. It was seen that it would take a few projects to implement BIM, before being able to assess the additional value. The design process was seen to have been lengthened in some cases, and in general, design costs had been increased. The model creation process could be questioned. Especially in MEP design the inefficiency is evident as it is caused by undeveloped design software. Other than that, the design processes of some designers are overlapping a lot in that the models are created afterwards, based on the first created 2D drawings. Evidently, there is potential to reduce waste in the model creation process. In the processes of utilizing the models, the same potential exists as tools are not fully exploited and processes are not harmonized.

The more there are BIM Uses defined at the beginning, the more requirements are placed for the implementation. The requirements affect the overall process and the direction of development. For example, in a lot of cases it was wondered whether to use Solibri or iTWO for quantity take-off, and as it seemed to be easier at the time with Solibri and because the purpose of quantity take-off was mainly to use it for cost estimation, in most of the cases Solibri was used for quantity take-off. When BIM is implemented also into many other processes, e.g., scheduling and procurement, the integrability of processes that iTWO provides amongst other things, should be considered. Therefore, in the long term, iTWO should probably be the software to use for quantity take-off, which should be considered in competency development. It is not straightforward to say whether training in terms of quantity take-off should focus on Solibri or iTWO, because both the long- and short-term aspects should be considered.

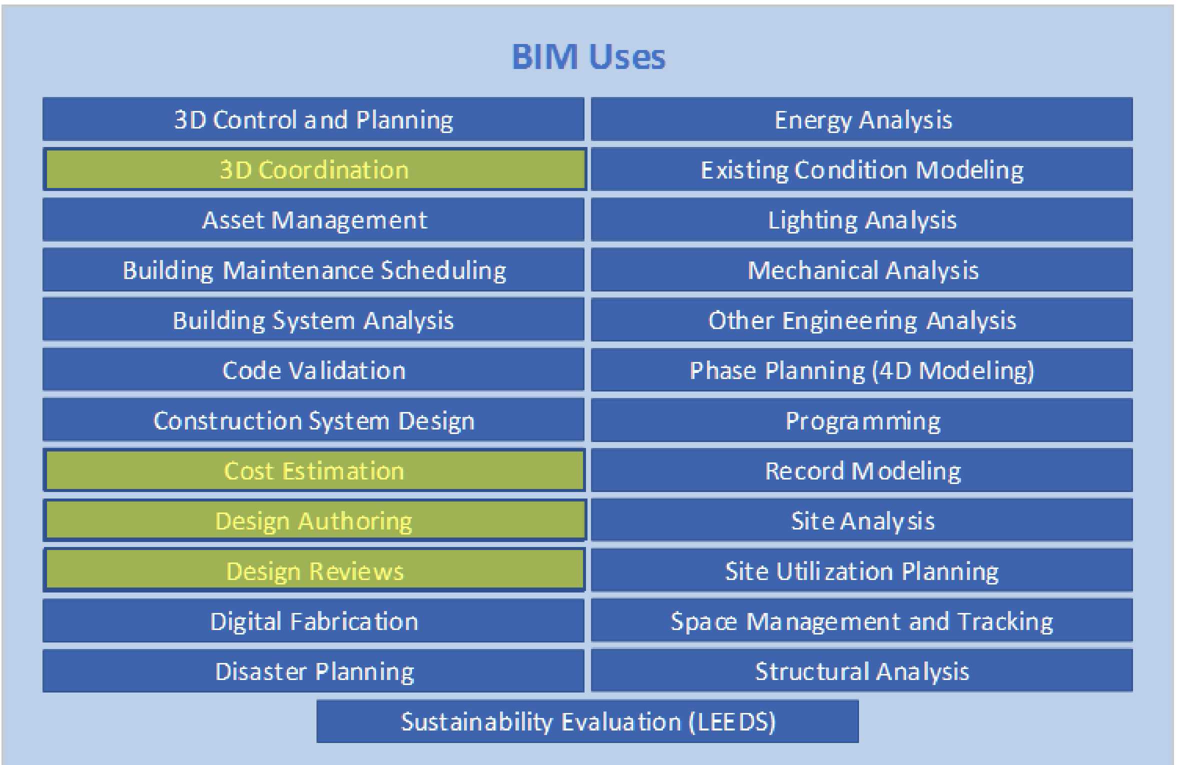

Figure 25 The most impactful BIM Uses in pilot projects

The issue is a bit contradictory, because it was also seen that developing the process and implementing BIM should be done gradually, little by little, which makes sense in terms of maintaining the level of motivation. Motivation is important for learning new things, and therefore, it could be extremely harmful for BIM development in the whole organization to smother the existing enthusiasm and motivation by demanding too much. It was seen that by gradual implementation, the observed benefits would increase motivation. Figure 26 illustrates the role of motivation and other interdependent elements that affect the development of BIM implementation. The looped process of development of BIM implementation was conducted based on the views of the most important elements of BIM implementation, the coevolution of technology, processes and people, and the dependencies discovered in the case studies. The fundamental idea of the looped process is that motivation is needed for developing competencies, which in turn affect the development of design management. Design management is seen as the most important element of design that can influence the quality of the created models. With good design management the potential effect of poor design/modeling competencies can be compensated to an extent. Efficient utilization of the models directly depends on the quality or the models. Benefits of the implementation presumes utilization of the models. The more efficient the utilization, the more benefits can be observed. In turn, the more benefits are observed, the more the motivation to train and learn increases. The process also implies that development of BIM implementation is a continuous process.

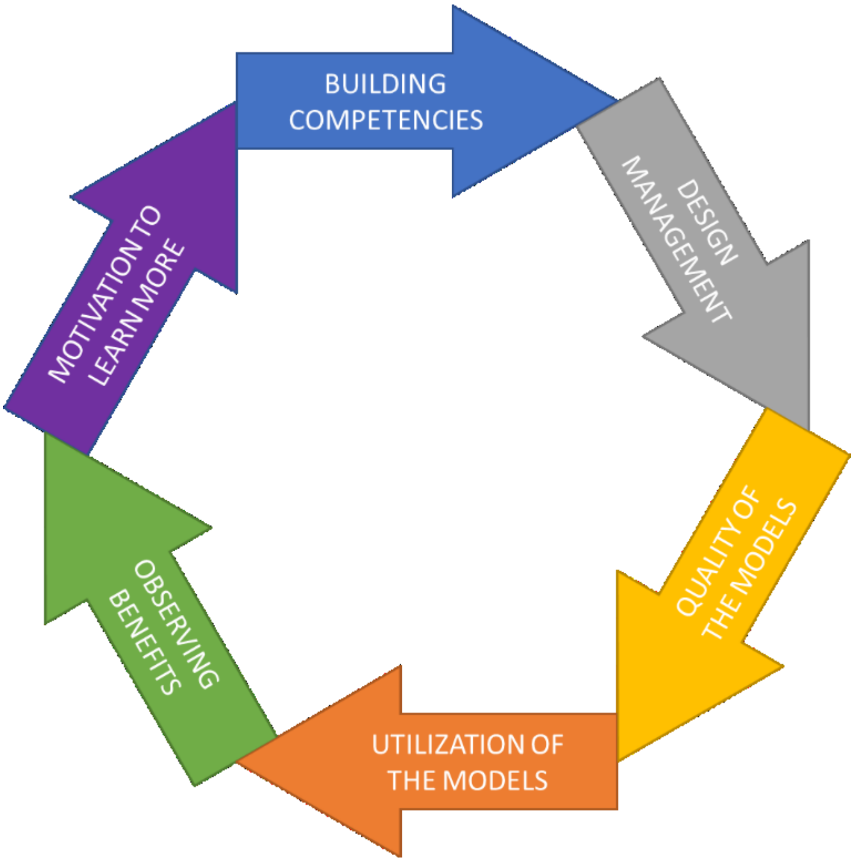

Figure 26 Looped process of development of BIM implementation

Part of the implementation and utilization of technology is to build the technical foundation to be able to use the models with automatic methods for such purposes as quantity take-off and clash detection. Such automatic processes are based on integrated data libraries, where data is linked with the models. Therefore, the possibility to utilize the models efficiently culminate to the accuracy and correctness of the model data as well as completeness of the data libraries. If the model data is incorrect, a program presents the data incorrectly or not at all. A program is not able to make interpretations that would change incorrect information into correct information. In general, accurate up to date information should be used instead of relying on experiential knowledge. Thus, more specific definition of the data that is required from the models is needed.

At the moment, the responsibility of ensuring the accuracy of models is pushed to people utilizing the models. Because cost estimation is the most important function where models are utilized and where the accuracy of non-graphic data matters, cost estimators are often forced to ensure the correctness of data.

BIM process

It is acknowledged that the most cost-effective time to make changes is during programming and sketching. The motivation to utilize preliminary models earlier in the design is conducted from that acknowledgement. The principle is based on lean philosophy. The more correct decisions are made from the beginning, the less rework is required later. Making more correct decisions presumes increasing knowledge capital. That can be achieved with participatory collaboration. Figure 27 illustrates the effect of making right decisions earlier by engaging, using standardized design solutions and BIM libraries.

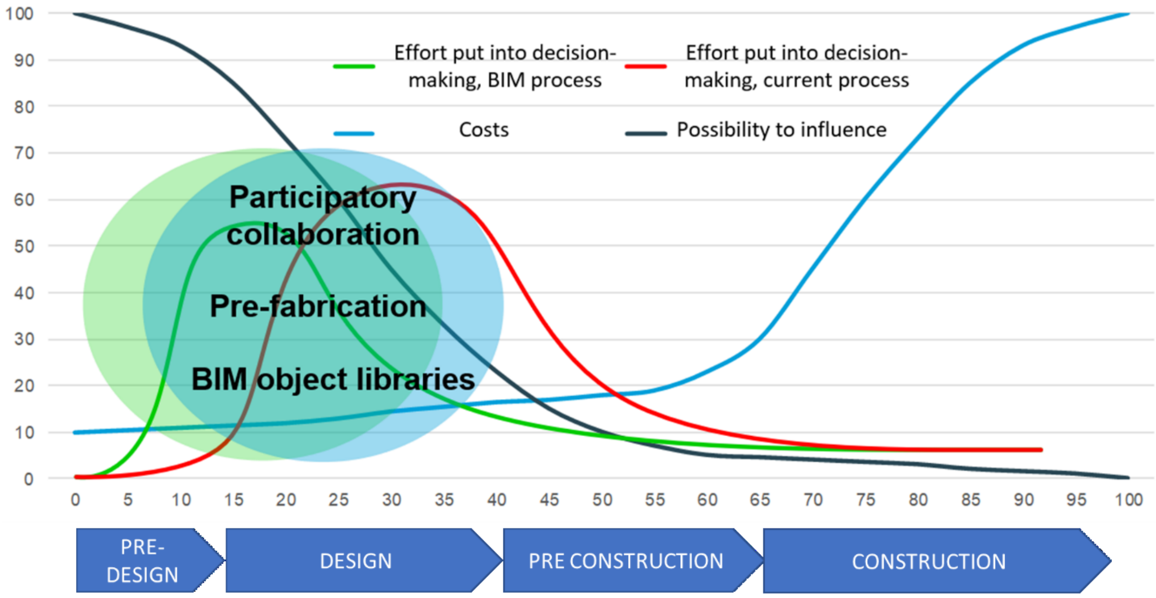

Figure 27 Effect of making right decisions earlier on a project (Courtesy of YIT; Modified by Tuomas Hykkönen)

It is important for the success of the implementation to acquire competent modelers. A project manager, as someone that acquires the designers, should be able to assess their competencies related to BIM. The designers might have significant effect to the success of the implementation, which in turn affects the motivation to further develop BIM processes, practices, tools and competencies, and to implement BIM in the first place. The selection of the designers is one of the earliest possibilities to make right and impactful decisions.

The overall BIM processes of the pilot projects were quite similar in principle, but still varied in terms of model creation and utilization of the models. The models were created, coordinated and utilized with the same principles, in general, but the timings varied a lot, although, the beginning of the design was the same. The design started with 2D sketching, and after the room program had been fixed, the modeling work begun. Design coordination and cost estimation were performed in different phases. The implementation process was not clear, and the overall process was not defined in the BIM execution plan. The need for description of the overall process was recognized, and some saw it more necessary than others. The overall process should be a framework for the implementation without restricting it unnecessarily. It should consider that personnel are not all capable of doing the same things or use the same tools. It should also consider that the possibilities to outsource BIM coordination or acquire competent designers differ between the units.

The BIM process did not differ much from a traditional project, which reinforces the point that BIM is seen too much as a supplementary part of the design. Due to approaching the model as a supplementary part, it could be expected that the potential benefits will not be realized.

BIM coordination and competencies

In general, it was seen that internal competencies should be developed as much as possible and not to overly rely on external stakeholders. For example, the common opinion on BIM coordination was to have the competency and responsibility in-house as it would serve both an individual project and development of the implementation in general. However, the lack of available BIM coordinators on the job market had been discovered. The necessity of a BIM coordinator in a BIM project is absolute considering the varying competencies of designers that limit the quality of the models and their efficient utilization. Thus, it is inevitable to outsource BIM coordination at least in the near future. The experienced issues with some external BIM coordinators culminate in external actors not being able to inspect the models from the client's point of view. If coordination is not performed, the responsibility of ensuring the use of accurate and correct information shifts to the person utilizing the model. Monitoring and controlling the coordination process is emphasized consequently. Tight collaboration, communication and soft skills are needed with coordinators as well as designers. It is critical for collaboration that communication is direct, and communication channels are established and used. (Monczka et al. 2000.) However, open communication entails a risk of losing proprietary knowledge. One way to manage the risk is using formal confidentiality and nondisclosure agreements.

Well-prepared instructional materials, templates and model description documents are important tools for collaboration, but these must be used and obeyed, or they are of no use. Especially the use of instructions and modeling templates of the client might affect the possibility to utilize the models efficiently, e.g., for information take-off. Everyone is responsible for reading guidance and instruction materials themselves. Model description documents are used to prevent using inaccurate information, and they have been somewhat useful. The problem with them has been that they have been too generic. They should be more detailed to be more beneficial.

Based on the results of the case studies, it can be concluded that the emphasis should be shifted more towards arranging internal and external training. Suitable training for each role should be focused for the role and arranged at the right time, which is close to the project so that the learnings can be put into practice when they are still fresh in mind. Internal competencies have been developed by learning on the job and participating both in internal and external training.

The approach to the study considered the coevolution of technology, processes and people. It can be stated that the dependencies of the elements and their development was proven to be intricate and multifaceted, which has been a challenge for the development of BIM implementation. It can be concluded that an imbalance of the evolution of technology, processes and people existed. Even though technology has its restrictions and defects, the tools could have been used for more. The tools were somewhat used with regards to BIM but also with traditional methods, which creates waste in the process. Regarding the processes, there was no common understanding of the overall process. In the most advanced unit, the overall process had been established, and it was meant to be used in the following projects as well. Some units, on the other hand, were actively developing their own BIM process based on their own experiences. Even though the consensus was that processes and practices must be harmonized, the units were developing their own processes. Clearly, more internal collaboration is needed. Considering the competencies of personnel, there were gaps in knowledge, and lack of skills and competencies. It was clear that the shortages hindered the development work more than lack of well-defined common processes or shortcomings of technology, and thus, people and their competencies can be seen as the most critical hindrance for the coevolution.

4.3 Framework to improve BIM implementation

This chapter presents the framework for improving BIM implementation both at organizational level and at project level. It was developed based on the literature review and analysis of the case studies. First, some wider suggestions on the scale-up are presented. The suggestions focused on the BIM implementation in individual projects are presented after that. The purpose is to help focus on the right matters of the implementation in scaling up and projects.

First, the scalability of BIM implementation based on the case studies is assessed using the table of assessing CORRECT attributes that were introduced in chapter 3.2. The descriptions of the attributes that are colored in green, have been detected in the pilot projects. It means that the assessment of that attribute is positive. The actions are also assessed based on the case studies and colored in green as well. It means that those actions can be suggested for future improvement. For example, it has been proven that the effects of the implementation can be measured and have been observed in practice. Also, BIM implementation has been piloted in a realistic setting. Some of the attributes are difficult to assess based on the study. The attribute of relative advantage suggests that BIM should be advantageous compared to existing practices and the benefits of the implementation should exceed the costs. As has been concluded, the implementation does entail benefits in some operations compared to the existing ones, but assessing the created value is difficult especially at this stage. However, in those units where BIM has been implemented for a long time, the advantages are evident.

The attributes and actions that have not been colored in green have not been detected or are not suggested. Collecting further evidence for the scale-up, for example, is not required. Also, it is clear that the concept of BIM is not easy to understand and implement. Therefore, the implementation should be kept simple but with the essential elements incorporated at least in those projects where BIM is not perceived easy to understand and implement, as suggested. Establishing required channels for communication is also a highly important suggestion, as is expanding BIM implementation incrementally.

Table 7 Assessing the CORRECT attributes of scalability based on the case studies (ExpandNet and WHO 2010; modified by Tuomas Hykkönen)

Attribute	Description	Actions to improve scalability
Credibility	The innovation is based on sound evidence and promoted by recognized actors The results of piloting have been documented and evaluated	Document results in clear and concise ways that can be readily shared with key stakeholders Collect further evidence Test the innovation in a realistic setting

Observability	Effects of the innovation are measurable and seen in practice	Provide opportunities for stakeholders to see results in pilot/experimental or demonstration sites
Relevance	The innovation addresses a defined problem, need or policy priority	Express clearly what needs are addressed Find ways to better communicate its relevance to policy makers and other stakeholders
Relative advantage	The innovation is advantageous compared to existing practices, and the costs of implementation are exceeded by the benefits	State and communicate its advantage Establish costs and assess cost-effectiveness
Ease of installation and understanding	The concept of innovation is easy to understand and implement The degree of change from existing norms, practices and level of resources along with potential conflicts are assessed	Simplify/streamline the innovation, but ensure that the essential components are maintained during scale up Anticipate and minimize potential conflict Identify where/how additional human and financial resources can be mobilized through existing channels Establish required channels for communication
Compatibility	The innovation should be compatible with the existing organizational values and norms as well as the current business environment The values of the innovation are maintained when the scaling up proceeds Some components require local modification to be relevant for changes in local context	Package the innovation in ways that enhance compatibility Build indicators into the monitoring system to assess maintenance of values and plan ahead to actions needed to maintain values Identify ways which minimize the changes that have to be made Identify needed local adaptations while ensuring the essence of the innovation remains intact

Testability	Small scale experimentation, e.g., in form of piloting, is possible in all business units before scaling up	Expand the innovation incrementally

Further assessments and suggestions of the scale-up are presented in Table 8. Even though the need for the innovation and the advocates exist, strengthening the need and especially motivation increases capacity to scale up. It can be concluded that the case company has implementation capacity in the relevant areas such as skills, training, leadership and human resources, but it does not mean that the capacity could, nor should, not be increased. All of the mentioned capacities should be increased. What comes to the timing and circumstances, it was perceived by the interviewees that impeding changes did exist during piloting, e.g., the integration process due to the company merger, which naturally restricted development of BIM implementation due to variety of changes that the merger entailed.

Table 8 Increasing capacity of the organization to scale up (ExpandNet and WHO 2010; modified by Tuomas Hykkönen)

Attribute	Description	Actions to increase capacity
Perceived need	There is a perceived need for the innovation There are individual advocates/champions of the innovation in the organization	Strengthen perceived need and motivation through advocacy using informal and formal channels
Implementation capacity	The organization has the capacity in the following areas: - Technical skills - Training - Leadership/coordination - Human resources - Monitoring/evaluation - Hardware, software and other tools - supervision - Values that support the innovation	Begin expansion in areas where capacity is stronger Identify opportunities for sharing resources within the organization Advocate for needed policy/legal change Identify other ways of building necessary capacities during expansion Test capacity strengthening before wide-scale expansion Decrease possible negative impact on other processes

	- Policy and legal framework necessary to introduce the innovation Different ways to strengthen capacity are tested in the pilot projects Scaling up can be done without negative impact on other processes	
Timing and circumstances	There are impeding changes within the organization that affect scaling up Potential changes provide opportunities or constraints	Adjust the scaling up strategy to maximize opportunities and minimize constraints arising from impeding changes

The suggestions for scaling up are concluded next. The most important learnings with some remarks are the following:

- Developing competencies should be continued and enhanced
  - Training should be focused for the purpose and arranged at the right time
  - Training should be focused to iTWO, Solibri Model Checker, and foremost to BIM in general (fundamentals, terminology, concepts etc.)
  - Mastering the basics and understanding the process is fundamental
- A harmonized overall BIM process should be developed in collaboration
- Internal participatory collaboration should be increased
  - Communication and sharing of knowledge should be enhanced by establishing new communication channels or increasing the utilization of existing ones
  - Monitoring and assessing the development of implementation
- Instruction and guidance materials, processes and practices should be developed in a way that everyone is able to understand and apply them
  - The level of design as well as design management vary
  - Ensuring that everyone has prerequisites to implement BIM
- Establish a ''Resource team'' to ensure that adequate technical, managerial and financial resources are available to support the scale-up
  - Include policy-makers, BIM specialists and technical experts
  - Motivated leaders with authority, credibility and longevity

    - In-depth understanding of the capacities and limitations of the company (how much can be invested in BIM)
    - Capacity to organize training and provide support for development

The suggestions for BIM implementation at project level are presented next. These are heavily based on the analysis of the case studies.

- BIM should be implemented in terms of the actual needs and requirements of the project
    - Lower the rate of implementation if necessary, and increase the rate of implementation from project to project
    - At first, the focus could be on the model creation process and utilizing the model for design coordination
    - Secondly, the models could be utilized for cost estimation too – define the scope
    - The units with more experience should focus on new elements of the implementation, e.g., BIM-based scheduling, and increasing the rate of implementation within the current BIM Uses, e.g., exploiting the spatial model for preliminary cost estimation
- Realistic and clear BIM Uses and objectives should be defined in detail
    - Monitor and control fulfillment
- Assess and select competent designers/modelers
    - Have them show/demonstrate a couple of their BIM projects
- Get the design and modeling process on the right tracks from the beginning by engaging internal and external personnel in decision-making
    - Close collaboration at the beginning at least with those implementing BIM
- Go over the BIM execution plan and instructional materials together with the designers
    - Ensured that the materials are understood and read in the first place
- External BIM coordinator should be supervised
- The information of the models cannot be trusted with eyes closed
    - Demand and use Model Description Document

Lastly, some key questions regarding model data content and information for development of BIM processes are presented:

1. What information is needed and why?
2. Who needs the information?
3. In what format and how the information should be produced and represented?
4. What information or supporting material is required for producing the information?
5. When the information is needed?

5 Discussion

The purpose of this study was to gather and analyze experiences of BIM implementation in housing pilot projects for scaling up the implementation. The first objective of this thesis was to establish an in-depth understanding of BIM implementation from a holistic perspective through the literature review. Based on that, the current situation of BIM implementation in the units of the case company was described, and the most important elements and their dependencies were identified. Based on the analysis of the research data and literature review, a framework for guiding the development of BIM implementation in housing projects of the case company was developed.

The collected research data can be considered valid as it was collected from typical developer contracting housing projects, in which BIM was implemented. Considering data from other type of projects as a supplementary part of data collection does not invalidate the results. Instead, it can be seen that for a qualitative study, identifying differences between the studied area and other areas contribute to developing an in-depth understanding on the studied subject.

One limitation of the case study methodology is the relatively low number of the interviewees, considering the size of the company. However, the interviewees represent the personnel engaging in BIM pilot projects, and therefore the target group can be considered valid. Furthermore, the constructive discussions with the BIM manager of the business segment significantly supported developing the understanding of BIM implementation in the pilot projects. The discussions considered some specific as well as some larger issues related to concepts, processes, practices, technology, competencies and knowledge.

Integrating BIM ecosystem into the business ecosystem is an intricate process. The business ecosystem has been evolved for decades, and the new ecosystem, which itself is still in the early phase of its evolution, demands changes to the business ecosystem. The systems integrators must have a lot of knowledge about both systems to be able to properly consider the integrated subsystems and their elements. The ecosystem perspective suggests that technology, processes and people should coevolve, or the system integration might lead into disconnect between system components (Gu et al. 2014). It was concluded in chapter 4.2 that an imbalance of the evolution of technology, processes and people, was evident, and the most critical element hindering the development was people, especially their competencies. However, BIM implementation, in the big picture, was seen beneficial instead of a hindrance. The integration of ecosystems was functioning. Thus, it can be concluded that partial adoption had taken place.

Correct information was emphasized in the processes of creating and utilizing BIMs. Many things were highlighted in the study, but they all seemed to culminate in knowledge, skills and competencies. Managing the fundamentals, i.e., terminology and concepts, is in a way in the core of mastering knowledge, skills and competences. Understanding interdependencies is often more challenging than understanding terms, but without a sufficient foundation, it is even more challenging. It all seems to revolve around correct and accurate information, knowledge, skills and competencies.

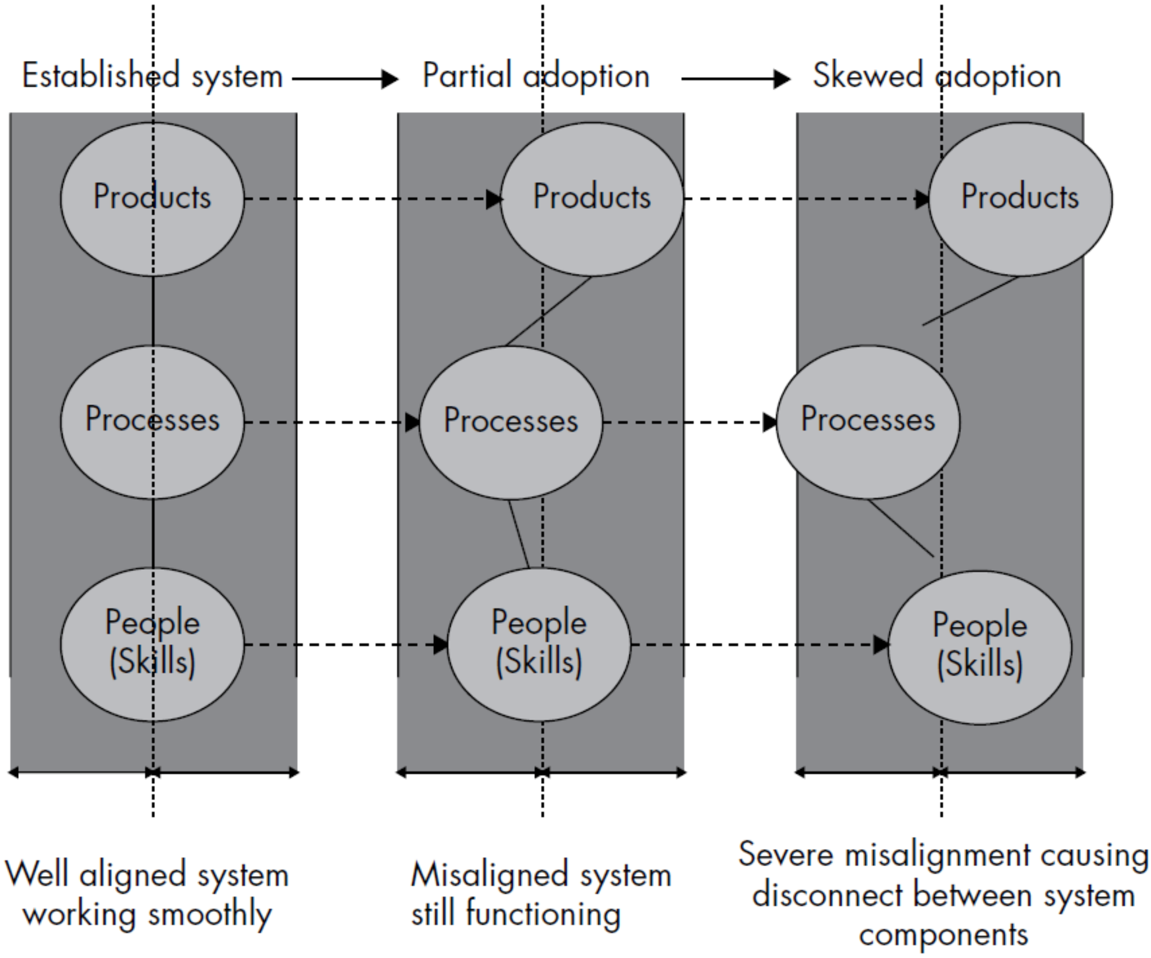

Figure 28 Coevolution of products, processes and people in a system (Gu et al. 2014)

Future research could focus on any of the elements of BIM implementation defined in this study: technology, processes, standards, roles, collaboration, competencies and utilization of the models. One interesting research possibility would be the project management software of the case company, iTWO, it's utilization and potential. Another research area could be related to information flow in a housing BIM project. What would be the optimal flow of information in a typical housing project regarding the accuracy and correctness of information and data. Another one would be to study the significances of roles to the success of BIM implementation. For example, a project manager could have an important role in the implementation as a possible enabler or restrictor of success due to their responsibility of the design, and position to demand BIM more from internal as well as external project participants. What role could have the most impact on the success of the implementation and what would it depend on? Would it be project manager, designer, senior manager, BIM coordinator or BIM manager?

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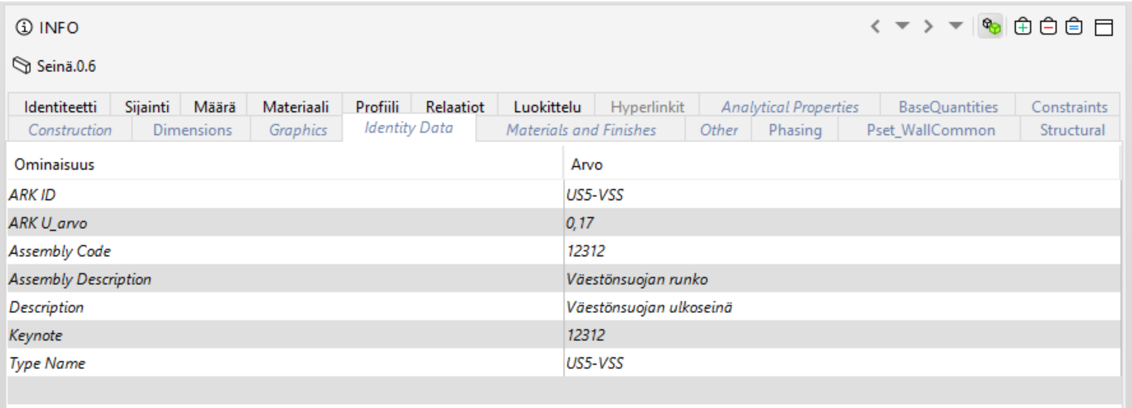
Appendix 1. The interview questions

Background

- Background of the interviewees and previous experience with BIM
    - Have you participated in BIM projects previously? Which roles/tasks did you have?
- Have you had any training on BIM in general or on specific software such as Solibri Model Checker/Viewer or Quintet?
- What is BIM to you and what elements there are?
- Why is YIT shifting towards BIM-based project execution, what are the goals? What challenges and risks there are for the business?

Experiences from the pilot – generation and utilization of BIMs

- What models the designers have produced? Have you had to do modeling work yourselves? Why?
- Have information contents and level of detail been purposeful? If not, what kind of shortcomings or flaws has emerged?
    - Has the information been assigned to the right attributes? (Figure)



- How and by whom have the models been utilized? E.g., in the following processes:
    - Design coordination
    - Assessment of design options in the beginning of the project
    - Profitability assessment
    - Quantity take-off and cost estimation
    - Procurement
    - Production planning
    - Marketing
    - On site (visualization of design, quantity take-off, cost control, procurement, work planning)

Experiences from the pilot – changes in the processes

- How has BIM implementation changed the typical processes of a project?
    - Design and design management: what kind of a process is the generation of models?

- What benefits have been noticed or measured in different processes? (e.g., less design errors, easier or faster processes?)
- Has BIM execution plan been done for the pilot project? What does it contain?
    - Definition of goals and utilization of models
    - Roles and responsibilities

Collaboration

- How has collaboration been between the project participants?
- Has managing designers been successful? Especially defining the required information content
- Has there been changes regarding information management and communication?

Guidance

- Have BIM guidance and available materials been adequate? (e.g., BIM execution plan template, naming conventions, information content charts)
- How could the guidance and support be developed?

Training

- How has training occurred, e.g., considering the use of BIM software? (internal/external training, peer to peer)
- What are the most important learnings from the pilot considering following projects?
- How have BIM and the changes been received? What is the general consensus?

Scaling BIM implementation

- Do you think the business unit has the prerequisites to execute all projects using BIM?
    - Is there adequately knowledge and skill to use BIM software and other tools (e.g. information content charts, BIM execution plan), and to manage the processes (design management, cost estimation and control)?
- Is the unit prepared to utilize the models to other purposes than in the pilot?

Appendix 2. The BIM process of the case company depicted by BIM manager