Governing the implementation of BIM

A construction client perspective

Master of Science Thesis

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Preface

This Master of Science thesis is the final project of the postgraduate studies at the Department of Civil and Environmental Engineering at Chalmers University of Technology. The project has been carried out during the spring of 2013 in collaboration with the public housing company Bostads AB POSEIDON owned by the municipality of Gothenburg Sweden.

We would like to thank everyone who has been involved for their much appreciated help throughout the project. Special thanks go to our supervisor at Poseidon, Cathrine Gerle for all her guidance and support. It should be noted that this study could have never been conducted without her initiatives and her great interest in the subject area of Building Information Modeling.

Furthermore we would like to thank all the employees of the client company POSEIDON and the contractor company SKANSKA that have been involved in the BIM pilot project at Holländareplatsen. Their contribution has been significant since they have been very cooperative and willing to share their valuable knowledge during our interview meetings.

In addition we would like to specially thank our supervisors at Chalmers, Mattias Roupe and Petra Bosch for their significant help with academic issues and their valuable suggestions.

Last but not least we would like to thank all consultants that have been interviewed, professionals in the field of Building Information Modelling. All consultants are highly appreciated for their help and advices. Their contribution has been significant for our project.

Göteborg 2013

/ Georgios Karathodoros, Ólafur Rafn Brynjólfsson

Notations

Acronym → Description

AEC	Architecture, Engineering and Construction (Industry sector)
AIA	American Institute of Architects
BIM	Building Information Model or Building Information Modelling
BSAB	Swedish Construction Classification System
CAD	Computer Aided Design
COBie	Construction Operations Building Information Exchange
FM	Facility Management
IAI	International Alliance for Interoperability
IDM	Information Delivery Method
IDP	Information Delivery Process and Protocol
IPD	Integrated Project Delivery
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
LEED	Leadership in Energy & Environmental Design
LOD	Level of Detail
NBIMS	National Building Information Model Standard
ROI	Return on Investment
VDC	Virtual design construction
2D	Two dimensions: x and y
3D	Three dimensions: x, y and z
4D	A 3D model integrated with time plans
5D	A 3D model integrated with cost estimation

Abstract

Governing the implementation of Building Information Modeling (BIM)
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Building Information Modelling (BIM) is rapidly growing within the construction industry where its current utilization shows great effects on projects in terms of performance, time and cost. However, due to limited knowledge and lack of previous experience, many actors do not have a clear image of what BIM is, what it requires, its capabilities and challenges and therefore, they hesitate to implement these new methods in their practices. In response to this increasing demand of BIM in construction industry, it is significant for clients to focus on governing the BIM adoption in their organization. Clients should develop implementation strategy and deployment plan. A development of a standardized and easy-to-follow method of planning and controlling the BIM implementation is required to increase the effectiveness and efficiency of BIM application.

Based on literature review, this thesis gives rigorous definition of BIM and what it consists of. It provides a guidance of how BIM can be used effectively and defines which procedures should be followed through a project. Moreover, it examines all the significant aspects clients and project managers should focus on, concerning this new way of working. Furthermore, this thesis describes the BIM capabilities that clients can choose to utilize in a construction project and analyses the potential benefits that BIM can offer. Additionally, the thesis clarifies the challenges and risks that may appear. In this manner, all the project participants have the opportunity to understand all the difficulties that they may deal with.

Taking these into consideration, this report conducts a case study of a real BIM pilot project in Sweden. The client is a municipal housing company and their demand is to implement BIM methods and principles in the design, construction and operation of housing buildings. Besides, interviews were conducted with project managers and consultants, who are professional in BIM practices, towards getting a clear view of the current BIM practice in Sweden. They expressed their opinions and discussed about their experience concerning issues that were brought up in the theoretical part of this thesis.

The interview results compared to the academic knowledge provide a safe ground for the authors to base and articulate their ideas and develop a discussion about the critical issues of the subject area of BIM that clients should focus on. In the last part, the authors suggest how clients should design the implementation process and conclude with highlighting the most important aspects of implementing BIM in a project.

Key words: Building Information Modeling, BIM, governing, BIM implementation, BIM adoption, client perspective, strategy, benefits, risks and challenges.

Contents

1 INTRODUCTION

The first chapter is divided into seven parts. Firstly it introduces the background and secondly it defines the problem that is addressed in this thesis. Thirdly it states the purpose and aim of this study. Fourthly it describes the objectives of this research and fifthly it introduces the research questions. Sixthly it describes the limitation of this study and seventhly it briefly describes the context of each chapter in the thesis.

1.1 Background

The construction industry is a project-based industry. Despite the fact that there are several projects that look similar, each project is unique concerning time, location, environment, weather conditions, cost, demands of owners, users, stakeholders and society. These conditions make this branch really demanding and managers face several challenges. Due to this constantly changing environment and project uniqueness it is difficult to standardize the design and construction process, even for quite similar projects, which could subsequently increase efficiency and productivity.

Towards these goals of increasing the efficiency and productivity of construction projects, Building Information Modelling (BIM) is introducing new concepts, techniques and work practices. They are applied by innovative IT technologies and business structures that can significantly reduce the variable types of waste and defects and can enhance the current processes (planning, design, construction, operation) in the construction industry. It can be considered a tool to help actors within the construction industry to work better together and integrate their processes in order to get the most out of projects. (Eastman, et al., 2011)

BIM is defined by The National Building Information Model Standard (NBIMS) (National Institue of Building Sciences, 2013): "*A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward*"

1.2 Problem definition

BIM is rapidly growing within the construction industry where its current utilization shows great effects on projects in terms of performance, time and cost. However, many actors do not have a clear image of what BIM is and what it requires. They cannot yet recognise the potentials and benefits that BIM can offer. Therefore they hesitate to implement these new methods in their practices. In contrast they contend that implementing BIM is expensive, difficult and with insecure results (Arayici & Khosrowshahi, 2012). Thus BIM is not yet widely accepted and adopted in the construction industry.

Due to this limited knowledge and lack of previous experience in BIM projects, the main hesitation that clients have is that they are not aware of how to drive and control the implementation of BIM and they do not have the capability to define which function of BIM is useful and beneficial for their case.

It is important to realize that the level of BIM implementation might depend on project complexity and current needs of each organization. Implementing a function of BIM which is comparatively expensive for a simple project might not have the desired outcome. Additionally, clients are partially familiar with BIM practices and thus it is not clearly defined which steps they should follow. Consequently, they are unable to determine, not only which level of BIM implementation is appropriate for their organization, but also which functions they should use in order to maximize the benefits they can get.

Therefore, a clearly defined, standardized and easy-to-follow method of governing this process is required to help the client to implement BIM effectively and successfully. Clients should define specific goals, develop an implementation strategy and create a BIM execution plan.

1.3 Purpose and aim

The purpose of this master thesis is to help the construction client to implement successfully and efficiently BIM in both company's practices and new building projects.

The aim of this study is to provide a detailed guideline, a handbook for the construction client to govern, drive and control effectively the BIM implementation. Specifically, based on both current literature and interview research, this study attempts to develop a cohesive strategy and define certain steps for the implementation process.

It also aims to explore an on-going BIM pilot project and define the main aspects which the organization has to take into account while governing the BIM implementation.

1.4 Objectives

The objective is to provide primarily a comprehensive definition of the actions that client should take during the implementation process, as well as a rigorous definition of BIM concept and principles.

In addition, it is to provide a thorough analysis of the benefits that the organization might get by utilizing BIM and the challenges the organization may face during the implementation process.

The above definition and analysis should serve the organization to understand how to implement BIM, how BIM can be used effectively, what level of BIM they should aim for and what demands they should set for their next BIM project.

1.5 Research questions

The research questions that were formulated in the initial phase of this study and drove the further research are described as following:

- What main aspects should the construction client consider when governing the BIM implementation process?
- Which processes should the client follow in order to implement BIM effectively?
- What are the potential benefits that a client can get from BIM implementation?
- What are the possible challenges and risks that a construction client should consider while implementing BIM in a construction project?

1.6 Our scope and limitations

The main perspective of the authors concerning the term "governing" is how the construction client can plan, design, control and evaluate the process of applying BIM to the organization practices, projects and operation of new facilities. This study attempts to develop a certain approach in order to maximize the outcome of using BIM. It attempts to give answers to the question: *"How can BIM be used effectively?"*

By implementation we consider the proper and effective use of BIM, efficient utilization of BIM methods and techniques. In other words, construction client plan, design, build and operate a new building while using the functions that BIM can provide.

The major limitation is that the case study of this thesis is focusing on the real BIM project of Poseidon company which is considered pilot regarding the use of BIM practices. Thereby the majority of employees working in this company have limited knowledge and limited practical experience on BIM issues.

In addition, this specific project is about construction of an ordinary housing building which may not be considered as a project of high complexity. Thereby there is not strong necessity of utilizing many sophisticated capabilities that BIM may offer. By this means, issues that might have appeared in other larger or demanding projects i.e. hospital, industry plant, etc. are not recorded here, limiting the breath of this research.

Furthermore, this BIM pilot project is at the design phase during the conduction of this thesis, therefore significant issues that may occur during the rest project phases are not recorded in this study.

Last but not least, this study research is conducted in the context of a master thesis which is held at the last two semesters of MSc program entitled "Design and Construction Project Management". This limited time has constrained the amount of interviews that authors intended to conduct for their study and subsequently has limited the empirical data.

1.7 Disposition

The thesis is structured as follows: This first chapter provides an introduction to the research issue. It presents a general view of the background and describes briefly the main problem and what this report aims to achieve.

Chapter 2 – Theoretical Background

In the second chapter the theoretical framework necessary to carry out this research study is analysed. Authors elaborate the most important parts of related theory found in academic literature and electronic sources.

Chapter 3 – Method

Then, the research methodology followed in this research is introduced. The thesis describes the practical and technical aspects of conducting the research and materials (documents, charts, interviews) used for the study. The thesis continues with the limitations of the research approach.

Chapter 4 – Case Study

The fourth chapter refers to the case study, where the company's case, main activities and the BIM pilot project are described. Furthermore, the client's requirements concerning BIM implementation that are expressed in the BIM Guidelines are depicted in the second half of this chapter.

Chapter 5 – Results

Following, it presents and analyses the research results and findings, the empirical data which were collected through the interviews. These data are clustered in themes, following the frame of the theoretical framework.

Chapter 6 – Analysis and discussion

Based on the academic review and interview research, the next section develops a discussion where authors elaborate their ideas, articulate their opinions and sustain their proposals.

Chapter 7 – Conclusion

Authors conclude this study with summarizing the answers to the research questions of this thesis, emphasizing the most important factors, and outlining the pathway for BIM implementation.

2 THEORETICAL FRAMEWORK

This chapter constitutes the theoretical framework of this study where academic knowledge is used to provide a core and safe ground for this research to rely on. It consists of seven main sections where concepts, definitions and existing theories are used to help the reader to get a better understanding of the specific topic.

The first section 2.1 illustrates the concept of Building Information Modeling, which is the context that this study is related to. Different perspectives and definitions of BIM are addressed, its main features are described and principal aspects are clarified. The capabilities and functions of BIM are described in the section 2.2 where there is also analysis of the potential benefits that BIM can offer. In sections 2.3, 2.4 and 2.5 there is an analysis of implementation strategy and significant aspects that can contribute to successful BIM implementation and clients should consider. In the last two sections 2.6 and 2.7 there is a description of the major challenges and risks that may occur through the BIM implementation.

2.1 Building Information Modelling BIM

In the construction industry, techniques have been developed in order to increase efficiency and productivity, enhance quality and reduce project cost and delivery time. BIM is a rapidly developing technique that offers the potential to attain these objectives (Azhar, et al., 2008).

More and more BIM projects are taking place and subsequently the awareness of BIM is pleasingly increasing among actors in the construction industry (Jongeling, 2008). However, many actors are still not aware of BIM and its capabilities due to lack of previous experience. They do not have a clear image of what it is required to implement BIM and therefore they hesitate to implement these new methods in their practices (Azhar, et al., 2008).

Based on literature review, this thesis cites a rigorous definition of BIM, and provides a reliable identification of what BIM involves and what it aims to serve.

2.1.1 The BIM concept and definition

"*It is not only a tool, it is not only software, it is a method*". (Interviewee)

The awareness of BIM is pleasingly increasing among actors in the construction industry. Nevertheless the concept of BIM is often misinterpreted and architects, engineers and contractors continue to use traditional modelling methods instead of adopting the innovative BIM methods (Jongeling, 2008). Different definitions are being assigned to BIM, misleading people about its actual mission. Some of the interpretations are the following:

Jongeling (2008) points out that BIM models have significant differences with regular 3D-models which have traditionally been used to visualize building designs. Furthermore he points out that the traditional 3D-models are not even built on the same principles as BIM models (Jongeling, 2008). Napier (2009) however states that the main difference between BIM and a traditional 3D-models is that BIM is not just a digital representation of building information and objects, but it is also a building modeling process (Napier, et al., 2009).

Zhyzhneuski (2011) supported that the idea of BIM was first introduced by Chuck Eastman in the 1970s, who predicted a new method where: "*Any changes of arrangement would have to be made only once for all future drawings to be updated. All drawings derived from the same arrangement of the elements would automatically be consistent*" (Zhyzhneuski, 2011).

A thorough and precise definition has been expressed by BuildingSMART (2012), the International Alliance for Interoperability which specifies that BIM comprises three correlated functions (BuildingSMART, 2012):

> *"Building Information Model: is the digital representation of physical and functional characteristics of a facility as such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its lifecycle from inception onwards.*
>
> *Building Information Modelling: is a business process for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.*
>
> *Building Information Management: is the organization & control of the business process by utilizing the information in the digital prototype to effect the sharing of information over the entire lifecycle of an asset. The benefits include centralised and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as-built documentation, etc. – effectively developing an asset lifecycle process and model from conception to final retirement."*

BuildingSMART formulated this definition of BIM taking into consideration the three separate functions of BIM but at the same time highlighting that these functions are linked to each other (BuildingSMART, 2012).

2.1.2 BIM categories

Following the same perspective with the previous definition, National Building Information Model Standard (NBIMS) clustered BIM into three different categories (Eastman, et al., 2011):

- BIM as a product
- BIM as an IT-enabled, open standards–based deliverable and collaborative process
- BIM as a facility lifecycle management requirement.

BIM as a product is referring to Building Information Model. The model itself is considered an intelligent data-rich digital representation of a facility where the model has to contain information or properties beyond graphical presentation. This can be considered one of the most important factors that can promote great benefits for the industry (Eastman, et al., 2011).

BIM as an IT-enabled, open standards-based deliverable and collaborative process is referring to Building information Modelling. In this category BIM is considered a process where the model is developed and used to increase the project efficiency. This process intends also to enhance collaboration and coordination among disciplines and other activities (Eastman, et al., 2011).

BIM as a facility lifecycle management requirement is referring to Building Information Management. In this category BIM is considered a method which is developed to manage all the required information and focuses mainly on sustaining and sharing information. It intends also to enhance information exchange flow procedures thought the building lifecycle among phases and participants (Eastman, et al., 2011).

2.1.3 The importance of information sharing

"BIM facilitates exchange and interoperability of information in digital format." (Autodesk Inc, 2002).

In a conventional way of design and construction, AECOM professionals (2012) point out that the communication is document based. Despite the fact that information is distributed and stored in digital formats and digital forms of drawings and reports, information is held in several forms and locations that are not formally structured and coordinated and thus are deficient in consistency. For instance, information for building components is dispersed in drawings, specifications, bills of quantity, descriptions. Under those circumstances there is not only probability for data conflicts and redundancy but also risks of data inconsistency and incoherence (AECOM PCC business development team, 2012).

Conversely, according to Autodesk Inc. (2002) BIM creates, manages and operates information on digital databases making them available for sharing, and facilitating the participants to cooperate more efficiently and integrate their processes. Additionally, BIM ensures the consistency of information by correlating the information of the databases. Due to this, every change is automatically updated and harmonized in all other parts. Moreover, BIM captures and retains information available for further access by any other industry-specific and purpose-specific applications (Autodesk Inc, 2002).

Furthermore, BIM solutions have an approach of creating, processing and storing necessary information about a facility and then display the information in traditional drawings or any other desirable way (Autodesk Inc, 2002). In addition, BIM is called to provide a digital system which serves as a central source of project information. All design disciplines can derive, share and update information from this central source, a fact that can create great possibilities for improvement in the design and efficient integration of processes (AECOM PCC business development team, 2012).

In current practice, AECOM professionals (2012) argue that one single project digital model has not yet been realized. BIM digital information is still held in particular project models, each one serving different purpose – architectural, structural, cost, etc. However, the key feature of BIM practice is the existence of shared digital database. The project models are co-ordinated and derive information from the shared database, ensuring compliance and consistency (AECOM PCC business development team, 2012).

Concerning this shared digital information database, Autodesk professionals (2002) describe that the BIM model can catch the project information by the first moment that it is created. Afterwards the BIM model can control, reprocess and store the information in this shared database and make it accessible for further use and change during all project phases. The BIM model can produce drawings in order to depict the building itself at any specific time (Autodesk Inc, 2002).

In this manner, generating, exchanging, storing and reusing project information are done in better ways that can enhance significantly the communication among design and construction disciplines through the building lifecycle (AECOM PCC business development team, 2012). In other words, BIM supports the process of generating, sharing, integrating and managing project information among project phases and among disciplines. They conclude that BIM can be considered as an information bridge between different disciplines. (AECOM PCC business development team, 2012)

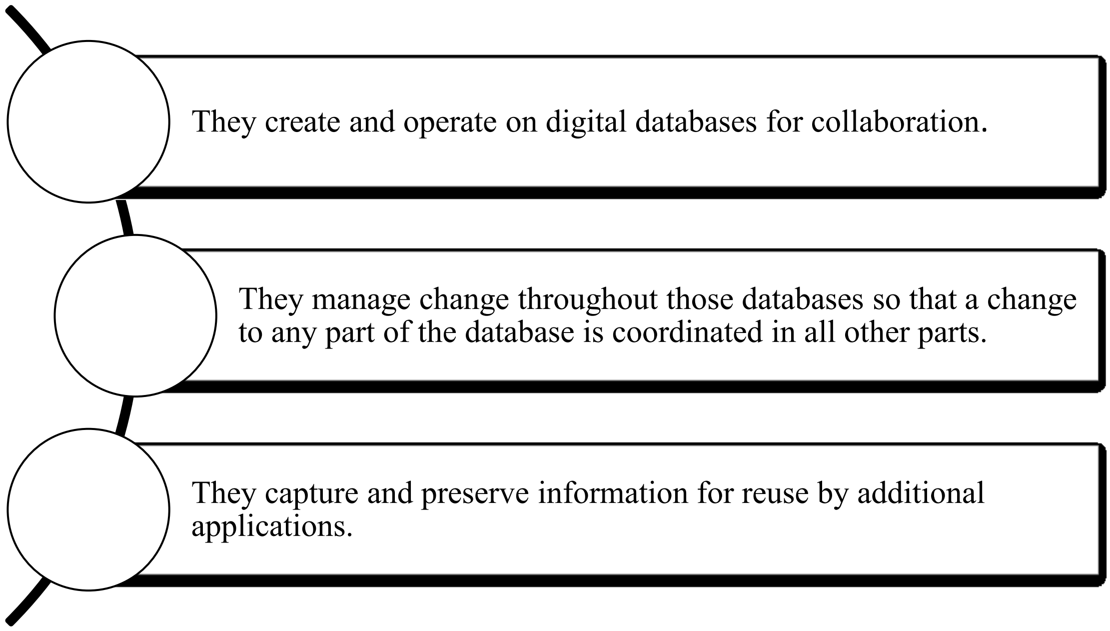

Figure 1: The three main characteristics of BIM **(Autodesk Inc, 2002)**

2.1.4 Difference between CAD and BIM design

The traditional CAD drawings and the architect 3D models have been evolved to the new BIM models which are rich with information (Solibri, n.d.). In this chapter it is intended to conduct a comparison between the "new" BIM approach and the conventional CAD approach.

Consistency

The first principal difference to highlight between BIM and conventional CAD is that BIM creates, processes and uses computable information about a facility which can be automatically coordinated, harmonized and internally uniform (Solibri, n.d.), whereas the conventional CAD describes a building by independent 3D views such as plans, sections and elevations (Azhar, et al., 2008).

In a CAD workflow, editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation (Azhar, et al., 2008). In a BIM-based workflow, the team creates a 3D parametric model and uses this model to automatically generate drawings, elevations, sections and layouts necessary for documentation (Azhar, et al., 2008).

Object-oriented design

Azhar, et al. (2008) demonstrated another significant difference. CAD drawings are only graphical entities, such as dots, lines, arcs and circles, in contrast to the intelligent contextual meaning of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns (Azhar, et al., 2008).

Accordingly, the building components are objectified. Thus, the real life building components are described and represented by coded digital objects. For instance, a wall is represented by a wall object that understands the physical and functional properties of walls and acts as one. A wall object does not anymore depict a wall in 2D with lines. In contrast, it has properties that describe geometrical dimensions (length, width and height) but also include information about materials, finishes, specifications, manufacturer and price. Every single building component can be represented by digital objects in a similar way (Ibrahim, et al., 2004).

Data-rich parametric model

Azhar, et al. (2008) pointed out that BIM models contain data rich objects. A BIM model is not only a computer model made of lines, points and geometrical objects but it consists of "smart objects". These objects carry all the information related to the building and can be used and modified during the building lifecycle. They include its physical and functional characteristics and project lifecycle information, from the initial concept design, through the construction and ultimately through facility operations and maintenance. In this manner, a BIM model can be used to demonstrate the entire building life cycle. For instance, a ventilation unit should also contain data about its manufacturer, supplier, operation and maintenance procedures, flow rates and clearance requirements (Azhar, et al., 2008).

Additionally, these data-rich objects contain information concerning how they relate to other objects which is so called "parametric information". This information type is not only about dimensional relationships, but for instance it may relate objects to thermal performance, carbon emissions, cost, repair and replacement cycles, etc. (AECOM PCC business development team, 2012).

Thus, a BIM Model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule (Azhar, et al., 2008).

As a result, Azar et al. (2008) demonstrated that there is nowadays the possibility to extract easily quantities and shared properties of materials. The construction documents such as the drawings, procurement details, submittal processes and other specifications can be easily updated simultaneously, interrelated and consistent (Azhar, et al., 2008).

2.1.5 BIM's mission

BIM is a collaborative approach of designing that involves and facilitates integration of the various disciplines to build a structure in a virtual environment. The BIM process facilitates the design team to work efficiently, and empowers them to identify potential problems before they arise during construction (Castagna, 2008).

Furthermore, BIM process develops and makes use of digital generated n-dimensional models for simulating the planning, design, construction and operation of a facility. Architects, engineers, contractors and managers are able to visualize the structure in virtual environment and to identify potential design, construction or operational problems (Castagna, 2008).

Hartmann and Fischer (2009) had a different perspective for BIM and its mission, indicating that Construction IT solutions in general are created and managed focusing more on the strategic long term benefits for an AEC project, an AEC company, or the AEC industry as a whole. They described the future vision of digital models in the construction industry as:

- All systems in construction share common platform, network and protocols, with secure external connectivity via the internet enabling local, remote and mobile monitoring, diagnostics, reporting and operation.
- These systems provide optimized control and intelligent services to users and operators.
- The life cycle of construction products is supported by applications using semantically rich models that contain all relevant information without need for human interpretation.
- Digital models are accessible anywhere and anytime.
- Future digital models provide easy access.

2.1.6 BIM and Integrated project delivery IPD

Traditional project delivery

In a traditional project delivery, the workflow does not have a constant pace and the collaboration among the project participants is not so strong. The way of working can be described as an exchange of drawings with consecutive and sequential activities like a relay race, where each actor completes his tasks and then he hands his part over to the next in the line (The American Institute of Architects, 2007).

A new project delivery which can optimize efficiency

A new project delivery, called Integrated Project Delivery (IPD), is a workflow which utilizes new technologies such as BIM. It defines business structures and processes which empower the project participants to contribute with their knowledge and expertise earlier than traditionally. This early integration gives all team members the opportunity to realize better their highest potentials, to employ their talents and insights in a collaborative way in the design process and to expand the value which they can provide throughout the project lifecycle (The American Institute of Architects, 2007).

In order to achieve the benefits that IPD promises, all project participants must adopt the following IPD principles (The American Institute of Architects, 2007):

- **Implementation of Appropriate Technology**

  At the project initiation, the very first phase of a project, clients in collaboration with project participants should define which technologies (i.e. software platforms) are appropriate to be utilized in order to maximize functionality and interoperability (The American Institute of Architects, 2007).

- **Utilization of BIM**

  Even though IPD can be achieved without BIM, incorporating BIM methods into IPD process can bring about more efficient collaboration (AECOM PCC business development team, 2012). Utilization of BIM technological capabilities and support can enable and strengthen integration of all design disciplines. (Azhar, et al., 2008).

- **Open Communication and Transparent Processes**

  Information exchanges must be carried out following disciplined and transparent data structures (i.e. ifc file formats and ifd library) in order to achieve interoperable and open communication. This type of data structures is necessary to enable efficient communication among all participants. Therefore, appropriate technology which can comply to open standards must be preferred in order to support IPD (The American Institute of Architects, 2007).

- **Early Involvement of Key Participants and Early Goal Definition**

  The integrated project processes rely on early contribution of individual knowledge and expertise. At the earliest possible time, project teams should involve all the key participants representing multiple disciplines and interests, and should continue collaboration throughout the whole facility lifecycle. During the early project stages the integration of their knowledge is most powerful and informed decisions have the greatest effect. Therefore, as early as possible, the integrated teams should define and develop project goals. IPD approach has developed a culture that keeps project goals at the core which everyone should adhere to but also respects individual participant objectives and values (The American Institute of Architects, 2007).

- **Collaborative Process**

  In order to achieve successful IPD they should form integrated teams which follow collaborative processes and work together effectively. They should follow a structured and trust-based collaboration which is committed to serve project goals rather than individual objectives (The American Institute of Architects, 2007).

- **Intensified Planning**

  The IPD approach is aiming to greatly improve the design results prior to construction, attempting to avert the production phase challenges. Integrated teams should exert greater effort in order to improve planning and design, which will subsequently increase the efficiency of execution and reduce the high cost of construction effort (The American Institute of Architects, 2007).

- **Contracts and contractual requirements**

  IPD approach can be applied to a variety of contractual arrangements. For higher efficiency they are preferred contract types which encourage involvement of all project participants and contractors early in the project. The integrated teams should in any case consist of client, architect/engineers and contractor who will be fundamentally responsible for the project, from conceptualization phase through project delivery (The American Institute of Architects, 2007).

Differences between traditional project delivery and IPD

An IPD project with the early involvement of project participants, the early goal definition and the intensified planning presents significant advantages in comparison to the traditional methods. At an earlier phase integrated teams make bigger design efforts and produce greater effects. In this way, they have the ability to affect more the final cost and functional capabilities of the facility and simultaneously they have the possibility to make changes with low cost (The American Institute of Architects, 2007).

The “Macleamy curve” or “Effort curve” illustrates the concept of making design decisions earlier in the project when ability to influence positively the outcomes is greater and the cost of changes is lower. This curve demonstrates clearly the differences between the integrated and the traditional project delivery (The American Institute of Architects, 2007).

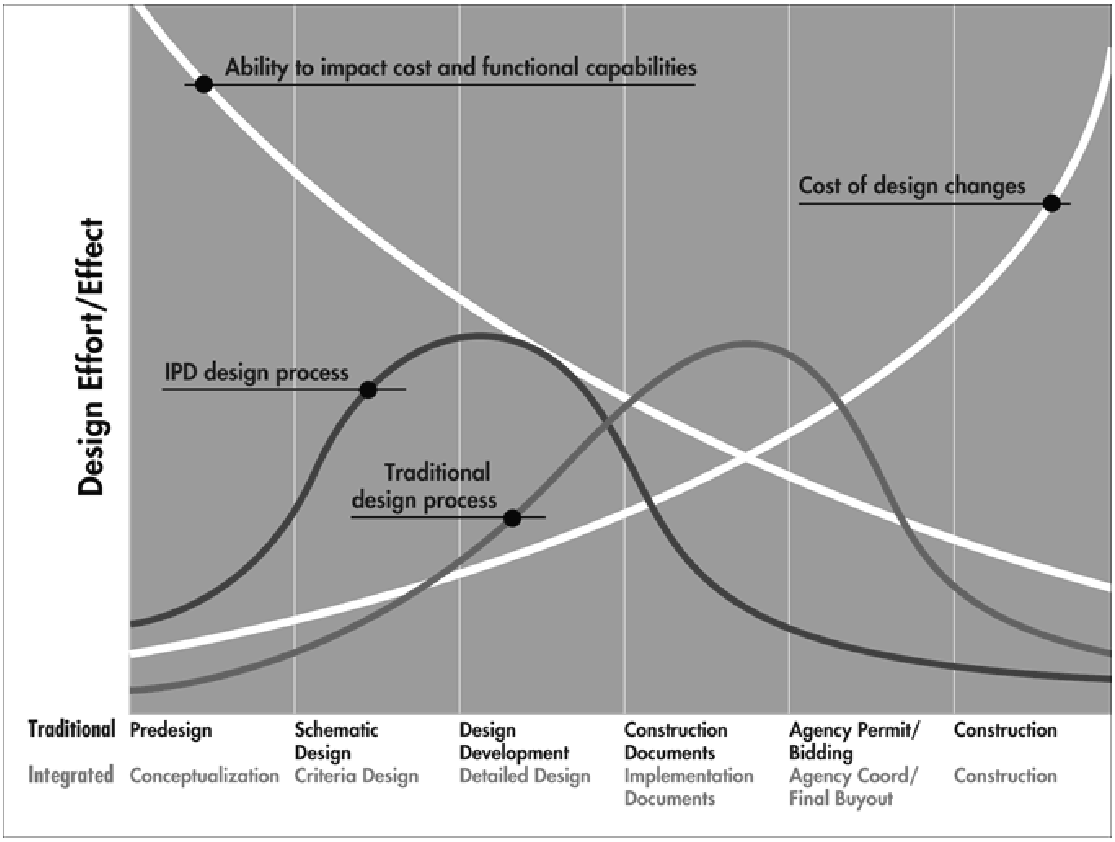

Figure 2: "The effort curve" by Patrick Macleamy **(The American Institute of Architects, 2007)**

2.2 BIM Uses and benefits

This chapter describes the BIM Uses that clients may choose to utilize in a construction project according to their needs (chapter 2.2.1) and analyses the potential benefits that BIM can offer (chapter 2.2.2).

2.2.1 BIM Uses and Capabilities

According to Messner, et al. (2012), a BIM Use is defined as a method of applying the BIM approach in order to improve a specific process during the design, construction and operation of a facility (Messner, et al., 2012).

Each BIM Use is specifically applicable to particular purposes and demands for the facility owners and is most beneficial for certain needs concerning implementation cost, commercial gain and project complexity. Therefore, at the initiation phase, the BIM manager helps the client to choose which BIM Uses (functions) should be utilized regarding the specific demands of the project. By selecting the most appropriate function of BIM, they can maximize the commercial gain of implementing BIM (Messner, et al., 2012).

Visualization

The most common BIM Use, visualization is a tool that creates the possibility for building owners, contractors and tenants to evaluate possible solutions and identify potential problems of the final product before the construction starts. Visualization creates renders of a building both from the outside and inside to explore possible design solutions. The level of detail in the renders can be chosen by the client and can differ between stages of the design phase. Furthermore the most important part about visualization is communication, since visualization can enhance the communication between participants and thus everyone can understand what the client is asking for in order to create the right renderings. In addition, it can facilitate and encourage the communication between different stakeholders (Krygiel, et al., 2010).

Analysis

Various analyses can be conducted with a BIM model all the way from the design until the facility management stage. These analyses can help with assessing and defining the most feasible or beneficial design alternative regarding energy, light and acoustic efficiency and therefore these analyses can contribute to make the design more sustainable and reduce the final cost (Krygiel, et al., 2010). One of the most valuable advantages of BIM models is that they can understand geometry and structure of digital data, and consequently assist and achieve interoperability between software applications. Therefore, this point makes it possible to do a bigger range of different analyses through the BIM model (Krygiel, et al., 2010).

n-Dimensions modeling

Fu et al. (2006) argued that n-Dimensions model is an extension of the BIM Model which is created to unite and cluster various issues of design information that are needed during a building project lifecycle, for instance these information can concern issues of design sustainability, energy saving, cost and facility management (Fu, et al., 2006). The n-Dimensions model makes it possible to realize and simulate the whole lifecycle of a project and therefore can help with decision making and reduce uncertainties (Kamardeen, 2010).

BIM has been developed to the way that BIM extensions can be considered 4D, 5D, 6D and 7D. The 4D (3D+time) is formulated when each activity of the time schedule planning process is linked accordingly with the 3D model. In this manner, it can be conducted a real time simulation of how the construction is taking place over time. Consequently, it supports project participants to develop the planning process and empowers them to do analyses and identify problems that may occur because of inadequate time scheduling of the construction processes (Kamardeen, 2010).

The 5D (3D+time+cost) is formulated when cost estimation is aligned to the model in such a way that gives the possibility to examine the distribution of the financial budget of the project over time. As a result it can improve the efficiency of quantity take-off process and can increase the precision of the cost estimation (Kamardeen, 2010).

The 6D can serve the facility management by providing a valuable descriptive image of all components of a building. In combination with the fact that the model can understand and store geometry relations and property information, the model can be used to assist a facility management database (Kamardeen, 2010).

The 7D makes it possible for designers to check if the design can comply with the requirements for carbon emissions and to develop design alternatives accordingly, for example choosing building materials with respect to carbon footprints (Kamardeen, 2010).

The n-Dimension models motivate project participants to get involved early on the project since they can now perform simulations and analyses for the project at early stages, assess adequately their design alternatives and take better decisions while reducing the required cost (Kamardeen, 2010).

Dimension	Use	Models
3D	Visualization	Existing conditions models Safety & Logistics models Animations, rendering, walkthroughs BIM driven prefabrication Laser accurate BIM driven field layout
4D	Scheduling	Project phasing simulations Lean Scheduling Simulation
5D	Estimating	Real time conceptual modelling and cost planning Quantity take-off Cost estimation
6D	Facility management applications	BIM as-built Lifecycle strategies Maintenance plans and technical support
7D	Sustainability	Conceptual energy analysis Detailed energy analysis LEED tracking

Table 1: n-Dimensions modeling **(Kamardeen, 2010)**

BIM is characterised by its ability to adapt to the requirements of each project and to add new functions. Therefore it can increase the number of dimensions that it can handle. BIM has exceeded the capabilities of the traditional modelling tools which could manage up to two or three dimensions (Jongeling, 2008).

Clash detection

During the clash detection, the appropriate software identifies conflicts between different disciplines and different models. The purpose is to mitigate collisions between building systems before the construction phase. Another ability of clash detection is to visualize construction processes, sequences and logistics. Due to the previous reasons, clash detection can consequently reduce the required construction time, increase productivity on site and decrease cost. Furthermore it can provide more accurate as-built drawings (Bloomberg, et al., 2012).

Sustainability LEED evaluation

This is a process where a project is evaluated based on Leadership in Energy & Environmental Design (LEED) or other sustainable criteria. The evaluation concerns building materials, building energy performance, construction or operational processes of the building. This evaluation can be applied throughout the whole lifecycle of a facility. However it is most effective if it is conducted during the planning and design phase. In order to increase the probability of getting the desired LEED certification, the designers should analyse and evaluate each design alternative concerning sustainability issues (Bloomberg, et al., 2012).

Cost estimation

BIM can improve the efficiency of cost estimation and assist professionals to perform cost estimation early on in the design phase. Since it can provide better visual representation of the building and the required construction elements, it can also support professionals to produce more accurate bills of quantities. Furthermore they can now estimate more adequately the potential cost impact of further additions and modifications that might occur later on in a project and generate quick revisions when needed. Consequently the cost estimation supported by BIM can save money, reduce time and prevent budget overruns. (Bloomberg, et al., 2012).

2.2.2 Benefits

This chapter describes some of the benefits that an organization can gain with BIM implementation.

Organization can gain many things by implementing BIM. These benefits can be technical, managerial and economic benefits or combination of all three. The need for each benefit can differ between projects.

The Cooperative Research Centre for construction innovation (2007) states that the major benefit is that BIM can integrate precise digital representations of building elements with information databases. Furthermore the CRC stated more benefits that an organization can gain by using BIM (Cooperative Research Centre for Construction Innovation, 2007):

- BIM delivers faster and more effective processes where information can be more easily shared and reused, adding value to the project.
- BIM offers better design by enabling careful assessment of building proposals, facilitating simulations and performance benchmarks, and empowering improved and innovative solutions.
- Implementing BIM can support more effective assessment of the design alternatives, more accurate estimation of the environmental performance of the facility and therefore better understanding and competent control of lifecycle costs and environmental issues.
- BIM can enhance the production quality and increase the productivity by improving the documentation, upgrading construction drawings, and motivating automation and prefabrication.
- BIM enables automation assembly by facilitating digital product data to be transferred in downstream processes and enabling it to be used in manufacturing like prefabrication.
- It is possible with BIM to provide better customer service with accurate visualization that makes it easier for the costumer to understand better different proposals and realize clearly how the final product will be.
- BIM can provide lifecycle data where information from the initial requirements from the client, the design phase and the construction phase can be used for later facility management purposes.

Building owner are getting more aware of the potential benefits that BIM has to offer, and with increased understanding of the possible benefits they are focusing more on how BIM can help them post-construction to decrease maintenance and operation cost since that cost can be up to 80% of the total cost of buildings (Faloon, 2012). This fact motivates the owners to put more focus on requirements through all stages of the building, since the owners are extremely focused on knowing the final cost and how they can reduce that cost as much as possible. Furthermore the owners want to be able to use the model to help them make better informed early decision that can help with better performance throughout the building life cycle (Faloon, 2012).

Azhar, et al. (2008) argued that the experience on Return on Investment (ROI) in BIM projects can be considered high. Even though the initial cost of using BIM can be high, the potential saving outweighs that cost compared to a non-BIM project. Furthermore Azhar,et al. (2008) stated the fact that clash detection alone can save up to 10% of the contract value by preventing possible problems that in a non-BIM project would have to be fixed on construction site and not always by using the best solutions. This can cause delays that might cause some extra cost for a project (Azhar, et al., 2008).

BIM benefits linked to the building life cycle are many, when considering life cycle approaches the entire life cycle of the building is considered, including when all the information about the building for each phase is taken into account, the aspects of each phase are thought of in the project life cycle; planning, designing, production and operation. This fact integrates BIM tools in order to define and simulate the building, both the delivery and operation. This fact enhances the fact that BIM contributes to implement sustainable design principles from the beginning to the end of a building life (Castagna, 2008).

2.3 Governing the BIM implementation

The following chapters 2.3, 2.4, and 2.5 provide a guidance of how to govern the BIM implementation, how BIM can be used effectively and defines the roles and which procedures should be followed through a project. Moreover, the chapter 2.5 examines all the significant aspects clients and project managers should consider concerning this new way of working.

- Which is the process of implementing BIM?
- Which certain steps should they follow?
- Which requirements should they set to drive the use of BIM?
- Which BIM capabilities should they choose to utilize in each project?

This chapter 2.3 is divided into four parts, which describe the roles of different sectors and different actors that all can influence the implementation process.

Definition of governing

This master thesis is entitled “Governing the implementation of Building Information Modeling (BIM) - A construction client perspective". In order to clarify the thesis scope, it is necessary to explain what is meant by using the terms "governing" and "implementation".

"Governing" is the act of controlling a process and the actions related to this process, exercising a determining influence over the process. In other words, governing a process is driving and steering this process towards to a specific goals (Oxford University Press, 2013).

In the context of BIM implementation, the term "governing" is the process of controlling the BIM implementation. Specifically, the study attempts to develop a standard approach for construction clients to plan and execute more effectively the integration of BIM throughout the organization, the projects and the lifecycle of a facility. The aim is to maximize the value of BIM implementation.

The term “implementation” represents the act of putting (a decision, plan, agreement, etc.) into effect (Oxford University Press, 2013). In BIM related academic resources, common terms used for this purpose are: utilization, employment, use, application. In this case, it is the process of applying the BIM methods and principles in the organization and in the project delivery, from inception and throughout the whole facility lifecycle.

2.3.1 The role of the public and private sector in developing BIM

The role of the public sector

Wong, et al. (2009) argue that the public sector support in every country can work as a driving force for higher BIM implementation in the construction industry of each country by requiring BIM implementation in public projects and setting requirements and developing regulations and standards. This regulatory context can create a uniform environment and lead to a wide acceptance in the industry and help to create a common base for construction actors to stand on. In addition, this support of the central government towards BIM can also provide an official approval of their BIM utilization and provide incentives for research and development in BIM (Wong, et al., 2009).

The importance of public sector involvement can be observed in Finland, Denmark, and Norway where this involvement has led to a wider and stronger adaption of BIM (Wong, et al., 2009). It is furthermore concluded by Wong, et al. (2009) that inside a country the level of support provided from both the public and private sector for BIM implementation can present significant advantages.

In addition, Wong, et al. (2009) emphasized that in general a strong public sector support in BIM implementation can provide a more uniform, homogenous and better coordinated mechanism of BIM development established across the country. It is also contended that a strong public sector support should be still required even in the case of the great interest of the private sector to implement BIM across the country (Wong, et al., 2009).

The role of the private sector

The strong interest of the private sector of a country in BIM development and implementation can create new business activities and collaborations and trigger commercial incentives for BIM development, even though these efforts may not spread across the country. Central government support towards BIM is needed to increase the effects nationwide and drive smoothly the changes (Wong, et al., 2009).

On the other hand, a weak private sector support towards BIM would not give incentives to the companies for inter-organizational collaboration. In this case, companies show more interest in developing their internal business processes, causing problems of incompatibility with other companies and increasing the fragmentation of construction industry, hindering the public sector to get the necessary feedback to push nationally the BIM development. This can also have effects in the hardware and software BIM development. This situation is often prevalent in countries where the

BIM implementation is at the initial stage or is non-existent for both public and private sector (Wong, et al., 2009).

The adoption of BIM has different extend in each country. The public sector in Sweden is not involved in great extent in the development of BIM. It is the private sector and industry that has taken more initiatives, and the Swedish leading contractors have an active role influencing the use of BIM and leading the development (Kiviniemi, et al., 2008).

Open BIM organization

Specifically, in Sweden one of the prime organizations for increasing the awareness of BIM and its benefits in the construction sector is OpenBIM. It performs a development program that started in 2009 by fifteen companies/organizations which are active in the construction industry. The program is operated and financed by industry stakeholders who are actively involved in construction projects (OpenBIM, 2013).

The OpenBIM organization arranges a number of workshops, seminars and meetings in order to increase the awareness of BIM and its benefits. Based on their vision, the most efficient way of implementing BIM methods is believed to be achieved through a strong awareness of BIM concepts and its benefits, a mutual understanding between the different actors involved in the construction industry and through the utilization of BIM which can increase the efficiency and effectiveness of the working processes (OpenBIM, 2013).

The OpenBIM organization formulated a common idea that the effective ways to influence the processes of construction projects are through (OpenBIM, 2013):

- Increased participation of users, actors and stakeholders by involving several participants more often and earlier in projects
- Increased number of alternative solutions analysed with BIM
- Consistent use of BIM for visualization, integration and automation of processes

2.3.2 The role of the construction client

The construction client has a significant role in the sustainable development of the construction industry and therefore in the efficient implementation of new methods, such as Building Information Modeling (Bergdahl, et al., 2006).

Firstly, the construction client is responsible to develop a construction project from concept to commissioning, ensuring that the needs of the owners, customers, industry and the community are met (Bergdahl, et al., 2006).

Client as an Owner and Financier

The construction client as owner and financier determines the long-term quality offered to customers and end users and also the way in which the demands of customers and the community will be met, while maximising the use of resources (Bergdahl, et al., 2006).

Client as a Purchaser

The construction client, as purchaser of the construction sector's products and services, is the one who steers the process from concept to implementation, and thereby also creates the conditions for the use and technical management of buildings or structures (Bergdahl, et al., 2006).

Client as an Employer

The construction client, through its choice of partners, determines the type of skills and expertise that will be involved in the process, shaping skills development in this sector. He governs the procurement of services or products which aim to encourage competition and further development of processes and products (Bergdahl, et al., 2006).

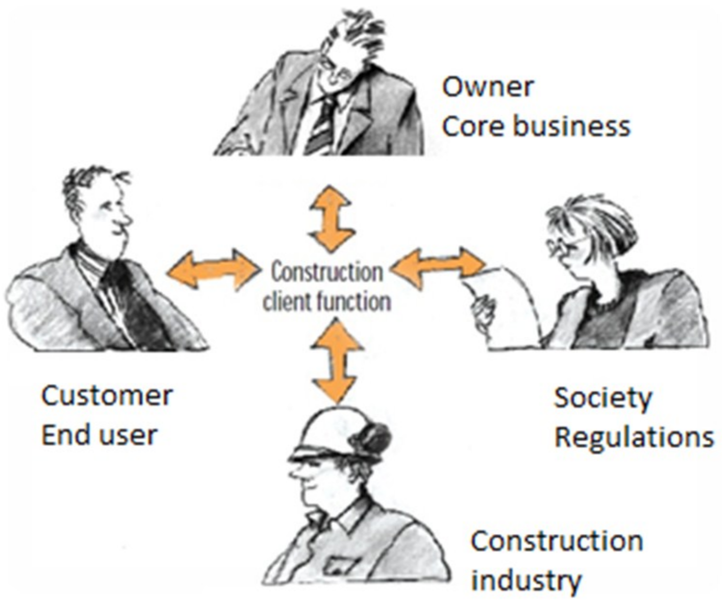

Figure 3: The role of the construction client **(Bergdahl, et al., 2006)**

Secondly, acting according to the building lifecycle demands, the construction client is responsible for the holistic approach that governs the creation of every building or structure. This holistic approach creates the appropriate conditions for project participants to design, construct and operate the building or facility (Bergdahl, et al., 2006).

Thirdly, acting in a regulatory context, the construction client is responsible for ensuring that all the project participants do their work following the requirements and directives that are set through contracts and building provisions (Bergdahl, et al., 2006).

2.3.3 The role of the BIM Manager

The project management team should assign an individual to the role of BIM manager at the initial stage of each BIM project. The BIM manager should be sufficiently competent individual to manage the development of the BIM plans at early phases and the coordination of several design disciplines (Consulting Oy, et al., 2012). The BIM manager has the main responsibility of driving the implementation of BIM principles and demands in a project. In addition the BIM manager has the main responsibility of integrating the design teams and facilitating communication (Bloomberg, et al., 2012).

Competencies

The individual shall have sufficient experience and expertise in both BIM principles and project management for the size and complexity of the project (Bloomberg, et al., 2012). Furthermore, his tasks are related to technical issues which requires relevant proficiency in the use of BIM authoring and coordination software as well as experience in the overall BIM processes (Bloomberg, et al., 2012).

The BIM manager can be either the design manager, or someone chosen by the design manager or project manager. His role is overlapping both with the design manager and construction manager, and in many cases the coordinator supports both parties in their core activities (Consulting Oy, et al., 2012).

Tasks and responsibilities

Based on literature, the BIM manager has the overall responsibility for the appropriate implementation of BIM during design and construction phase (Consulting Oy, et al., 2012). The BIM manager responsibilities should include the following (Bloomberg, et al., 2012):

- Develop, monitor and control BIM guidelines, BIM deliverables and milestones, and BIM project execution plan, and define roles and assign responsibilities to each party concerned.
- Support and report to the client and project management team, cooperate with the principal designer and design manager, coordinate and manage BIM meetings with key project participants.
- Assure project development and compliance with the client demands, BIM principles and BIM guidelines, and BIM project execution plan.
- Coordinate, facilitate and control the creation of correct models, the information exchanges, data extraction and integration of BIM models of different disciplines.
- Provide and control the necessary infrastructure for the design teams (network systems, software platforms).

2.3.4 The role of the Discipline BIM Coordinator

After the design initiation, BIM modelling tasks are assigned to the individuals responsible for each design discipline. This role can be assigned to BIM professionals or designers responsible for each design discipline (Consulting Oy, et al., 2012).

The individual shall be the main responsible for the specific design team concerning BIM issues, and therefore should have the appropriate competencies for efficient utilization of BIM within their discipline. (Bloomberg, et al., 2012).

Tasks and responsibilities

The Discipline BIM coordinator shall cooperate with the BIM manager, participate in the updating of the BIM execution plan and coordinate all technical discipline-specific BIM activity (tools, content, standards, and requirements). The BIM coordinator tasks shall include the coordination of BIM tasks assigned to the specific design discipline with the rest of their discipline team (Consulting Oy, et al., 2012). Other tasks of the discipline BIM coordinator are (Bloomberg, et al., 2012):

- Formulate BIM reports and data management, develop guidelines and control the design process for his own team as it was agreed in the project
- Coordinate BIM users within the discipline, coordinate BIM training as required, and support team concerning the use of BIM tools, the creation of discipline specific BIM content and other BIM modeling matters
- Check and assure the quality of his design discipline models and the functionality of merged models in his own discipline

- Participate in BIM meetings and communicate effectively with other design disciplines in connection with interfaces and data transfers
- Coordinate collision control and detection within the design team, extract the model in proper form in order to support the integration with other disciplines

2.4 BIM Implementation plan

A guide of how to implement

In this chapter an implementation plan is elaborated. It constitutes a structured methodology for clients to develop effective plans for BIM adoption into the organization processes and BIM utilization during the lifecycle of a facility. The purpose is to develop structured standardized planning procedures. This systematic BIM plan is necessary for the clients to maximize the value of BIM implementation (Messner, et al., 2012).

Four levels implementation plan

Messner et al. (2012) have developed a structured guide for the implementation of BIM, which is divided in four planning levels. At each planning process, managers shall analyse the necessary elements from several scopes and viewpoints (Messner, et al., 2012).

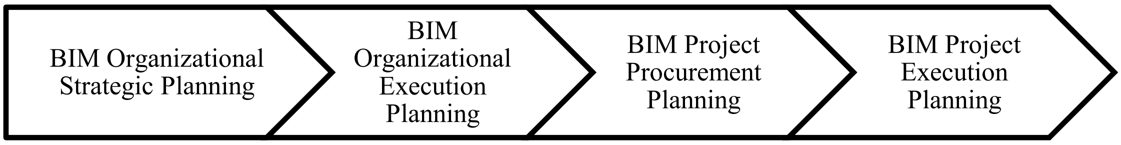

Figure 4: Implementation plan **(Messner, et al., 2012)**

Firstly, the guide determines a process of developing strategic and execution plans, focusing on an organizational level of BIM planning. These two develop a cohesive strategy for the BIM implementation in order to support and complement the BIM Project Procurement and Execution Plan. The last plan, BIM Project Execution Plan, defines an approach for increasing to the greatest possible degree the value of implementing BIM into a project.

The four BIM planning procedures address common BIM Planning Elements which are classified into six categories. Client should consider these six elements while he develops the four BIM planning procedures:

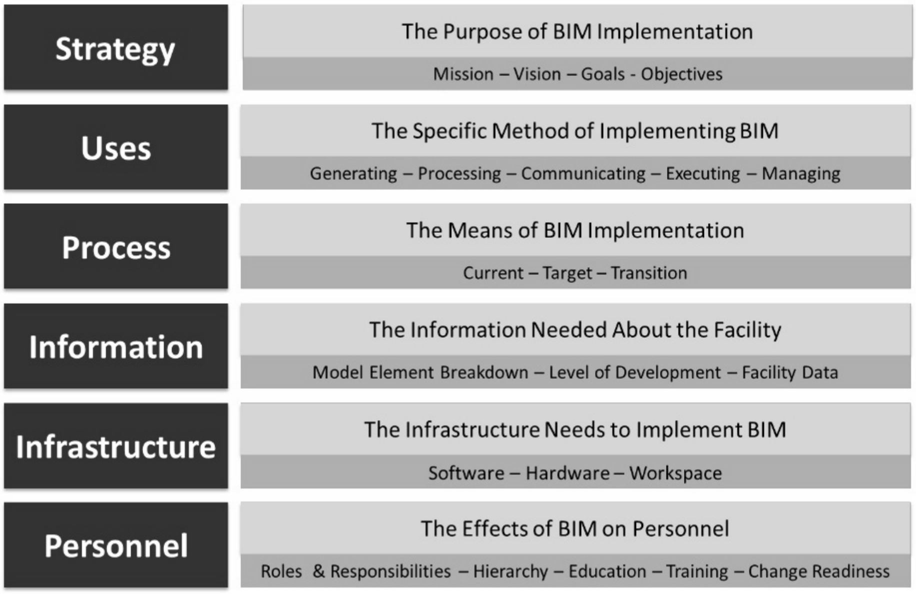

Figure 5: BIM planning elements **(Messner, et al., 2012)**

2.4.1 BIM Organizational Strategic Planning

The first planning procedure has a strategic perspective and is focusing on an organizational level of BIM implementation for clients. The procedure is designed with the support of the management group of the organization and helps to ensure the organization is ready for the implementation of this new BIM process with planned resources.

It aims to assess existing organizational conditions, define the purpose of BIM implementation, adjust and coordinate BIM goals, objectives, mission and vision, and create a transformation plan to adopt and utilize BIM (Messner, et al., 2012).

Three consecutive steps

The Strategic Planning procedure comprises three steps and it is created to direct the management team in a standardized way (Messner, et al., 2012).

1. Assess existing organizational conditions

The client shall conduct an organizational assessment. The assessment is focused both internally to evaluate their status and externally to appraise their performance in comparison to the current BIM adoption by the rest actors of the industry. The aim of this step is to recognise potential areas of adoption and implementation of BIM processes.

This assessment is necessary to examine the several organizational aspects that require adjustment or replacement in order to facilitate the transition. In this mean, the management team can evaluate which aspects of the organization are performing appropriately, and determine those that require enhancement (Messner, et al., 2012).

2. Establish Desired Level of Implementation

The planning team defines the purposes of BIM implementation and align BIM goals and vision with organization mission. They decide which desired BIM level of implementation (or maturity) they aim to achieve. In order to make this decision, they have to consider the organization capabilities, experience, knowledge, and readiness for change. In addition, they define next prospective BIM Objectives and BIM Uses for their company (Messner, et al., 2012).

3. Develop Advancement Strategy; a transition plan to implement BIM

The planning team develops an effective advancement and implementation strategy. BIM Organizational Strategic Planning does not only aim to determine short-term goals and long-term visions. The management and planning team shall also develop and document a transformation action plan to implement BIM. The careful and advanced planning gives the possibility to the planning team to establish a structured approach in which they can define precisely all the barriers in order to mitigate the risk of escalating costs and wasting time and resources.

The careful and advanced planning is crucial because the implementation process can differ among organizations and is contingent on the goals and objectives; the company size; time and financial investment; experience with BIM and the available resources (Messner, et al., 2012).

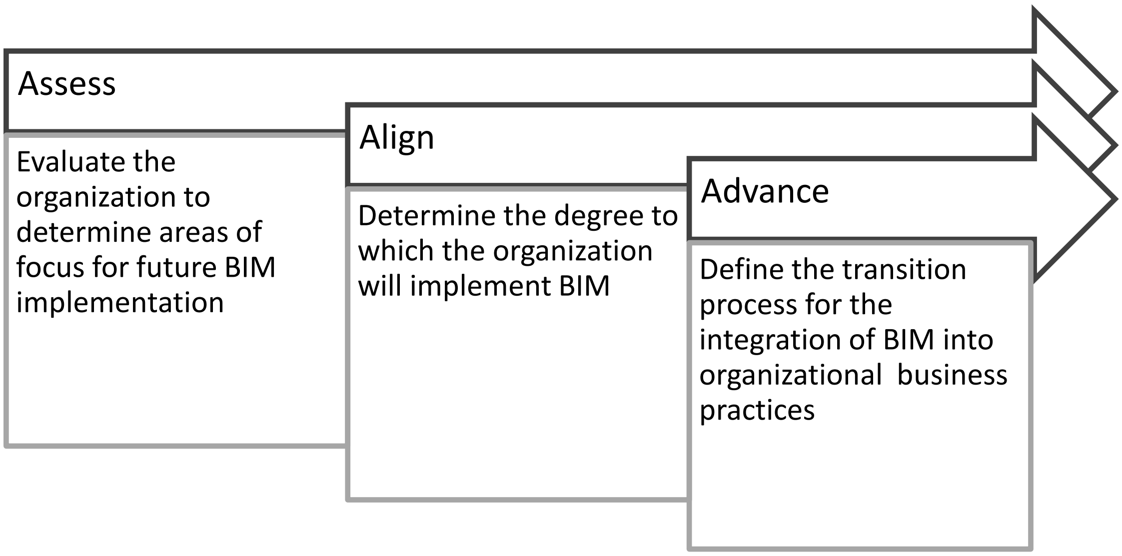

Figure 6: BIM organizational strategic planning **(Messner, et al., 2012)**

2.4.2 BIM Organizational Execution Planning

Since the management team has previously developed and set up a strategic plan for the integration of BIM within the organization processes, consequently the first phase of implementation requires that they shall determine precisely how to accomplish this integration of BIM within the organizational processes (Messner, et al., 2012).

In this planning procedure, the goals of the strategic plan are interpreted into daily regular projects and assignments to enable integration of BIM within the organization processes (Messner, et al., 2012).

As potential obstacles, the strategic planning can be successful only if the management team achieve to develop comprehensive planning of specific steps required to attain the strategic objectives. Strategic plans can also be effective only when there is constant and regular communication of the plan. Accordingly, this second planning procedure of organizational execution can complement the strategic plan and support the management team to cope effectively with these difficulties (Messner, et al., 2012).

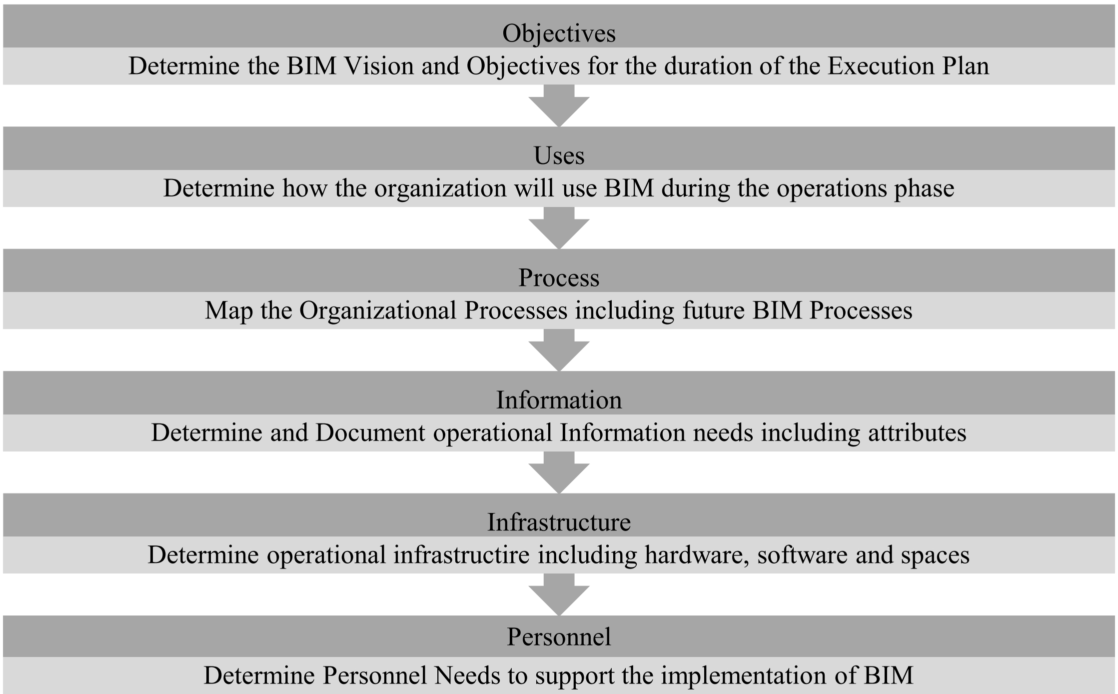

Figure 7: BIM organizational execution planning **(Messner, et al., 2012)**

1. Determine BIM Vision and Objectives

The planning team has determined broad corporate mission and goals, and BIM vision and objectives in the first planning procedure of organizational strategy. Now they evaluate the corporate goals and formulate clear BIM objectives. In this way they can decide whether the BIM objectives are feasible within the timespan of the plan (Messner, et al., 2012).

2. Evaluate Internal BIM Uses

They determine how to use BIM in order to improve their internal processes. Their focus is internal because they aim to integrate BIM within the internal organisation processes and subsequently attain particular objectives. Additionally, they record and document the BIM level of maturity they obtained after the completion of the execution plan of previous projects (Messner, et al., 2012).

3. Design BIM enabled Process

It is essential to understand and document the overall organizational structure and all the processes in order to advance them. Therefore, the management team shall firstly record and map the existing organizational processes which will incorporate BIM in their present state. Then, they shall develop a detailed transition plan for each BIM use where the new BIM processes are mapped and afterwards the future process for each operational activity is documented. The management team shall be aware of the fact that the operations of a facility may comprise repetitive processes (Messner, et al., 2012).

4. Document Internal Model and Facility Data Information Needs

In this step they define and document information needs. In this way they can summarize all the information requirements and control if they can comply with organizational information requirements. Information needs include the Geometric Model and Facility Data Needs. The Geometric Model is a digital virtual representation of building elements with assigned features and correlated characteristics. Facility Data is information communicated by plain text that can be saved as assigned data to the digital objects and can determine aspects such as manufacturing characteristics, materials, and project identification codes. It is necessary to include both types of information when documenting information needs (Messner, et al., 2012).

5. Determine Infrastructure Needs

An organization should consider the infrastructure needs including software, hardware, and physical spaces. Additionally, it is important to regard BIM uses, BIM processes and information requirements as infrastructure requirements (Messner, et al., 2012).

6. Determine Personnel Needs

The appropriate human resources can significantly affect the success of implementing and integrating BIM. Considering personnel needs, the management team shall consider knowledge and skills, appropriate experience and necessary training, roles and duties, organizational structure and change management in order to adapt to the new way of working (Messner, et al., 2012).

2.4.3 BIM Project Procurement Planning

The client shall develop a definite procurement strategy involving BIM contract documentation when the client plans for procuring BIM services on a project. In a typical case, the client develops early the contract documentation for the upcoming project. Key contractual issues should be addressed in this type of documents, which regulate the project requirements and consequently govern the direction of the project ahead of the time that design or construction begins (Messner, et al., 2012).

Furthermore, the management team shall assure that the project will comply with the client's demands and the project participants will have a common understanding of the scope and the details of the project obligations and specifications to which they are signing. Therefore, it is critical to establish the appropriate procurement language. In addition, it is vital to conclude and form the BIM needs for the upcoming project. Documenting the BIM needs, demands and specifications in advance of the project initiation gives the possibility to the project participants to start the BIM processes earlier and increase their effectiveness (Messner, et al., 2012).

Concerning contract types and BIM implementation, the client shall choose an appropriate contract type that better incorporates key project participants' involvement through a BIM-driven process. Adopting the principles of the IPD approach can facilitate BIM implementation, since IPD approach empowers this early involvement of key project participants. They can influence the design by incorporating their valuable technical and practical knowledge over different disciplines earlier in the process. In this way, project teams will face fewer difficulties to implement BIM. (Eastman, et al., 2011).

This increased emphasis on early collaboration means that efforts made by team members and the benefits they produce may change. Hence new contracts are required that encourage close collaboration, sharing of information, sharing profits, sharing risks and setting fees (Eastman, et al., 2011).

It is important for the client to give emphasis to the three following aspects when developing BIM procurement documentation.

1.Team selection

The client shall use a reliable tool to determine the BIM experience and skills of potential project team members. This tool can be named "Request For Qualifications" (RFQ) and comprise analytical, methodic, structured documents.

Secondly, the client shall get a clear answer regarding the cost and description of the suggested BIM Uses. For this purpose it is critical to develop appropriate documents, entitled "Request for Proposal" RFP. Thus the client can have a trustworthy estimation of the expenses necessary for the effective performance of BIM Uses (Messner, et al., 2012).

2.Contract procurement

The BIM contract is conducted to determine and document the regular client prerequisites concerning BIM. The BIM contract is concerning standard project goals and also BIM organizational objectives. Later on, the BIM Project Execution Plan is considering the particular BIM requirements for each project (Messner, et al., 2012).

3.Execution requirements

The management team shall develop a typical BIM Project Execution Plan Template which shall serve as a structured basis for the BIM Project Execution Plan and shall comprise and determine the major information needs and requirements that the client has designated, such as data requirements for facility management systems (Messner, et al., 2012).

The project execution plan should be developed based on this template and all project participants shall contribute to this plan development at the same time as they get involved in the project. Since the BIM Project Execution Plan is completed, the client shall decide the formal approval and attach it to the contract as appendix (Messner, et al., 2012).

The typical BIM project execution plan template can furthermore help the client with the procurement strategy and make it easier for him to see if the actors are capable of performing the objectives of the BIM project execution plan (Messner, et al., 2012).

2.4.4 BIM Project Execution Planning

Several companies and authorities collaborate in a project specific environment, form a temporary organization and develop information and results that they need to share for use by other participants later in the project. All participants in this temporary organization shall know the exact content and the proper time of each information exchange in order to improve the efficiency of communication and collaboration in the project. (BuildingSMART, 2011)

The BIM Project Execution Planning Procedure is a structured method for the project team to design the execution strategy for BIM on a project. Particularly, BIM Project Execution Plan is a detailed plan that describes how a project will be executed, supervised and organized concerning BIM processes. In addition, the BIM Project Execution Plan is supposed to develop further and be able to offer a data management and an information plan (Bloomberg, et al., 2012).

The BIM Project Execution Plan should assign responsibilities and roles to all project participants for the creation and process of the models. It should also contain the specific project requirements set by the client. It should then be developed further with a joint approach that involves all stakeholders (Bloomberg, et al., 2012).

Specifically, a planning team should be formed in the early stages of a project to develop further the BIM Project Execution Plan. Representatives from all the primary project team members should participate including the client, designers, contractors, engineers, major subcontractors and facility manager (Messner, et al., 2012).

BIM Project Execution Plan puts emphasis on team skills. It also aims to follow up the latest improvements in technology and to help the design team to realize the BIM current capabilities of the construction industry. With a cooperative process, the team can agree on how, when and to which extent BIM can be used to support the project outcome and goals (Bloomberg, et al., 2012).

The BIM project execution plan consists of four steps. It is intended to guide effectively client, managers, and project participants by providing a methodical organised series of actions to develop comprehensive, consistent project plans (Messner, et al., 2012).

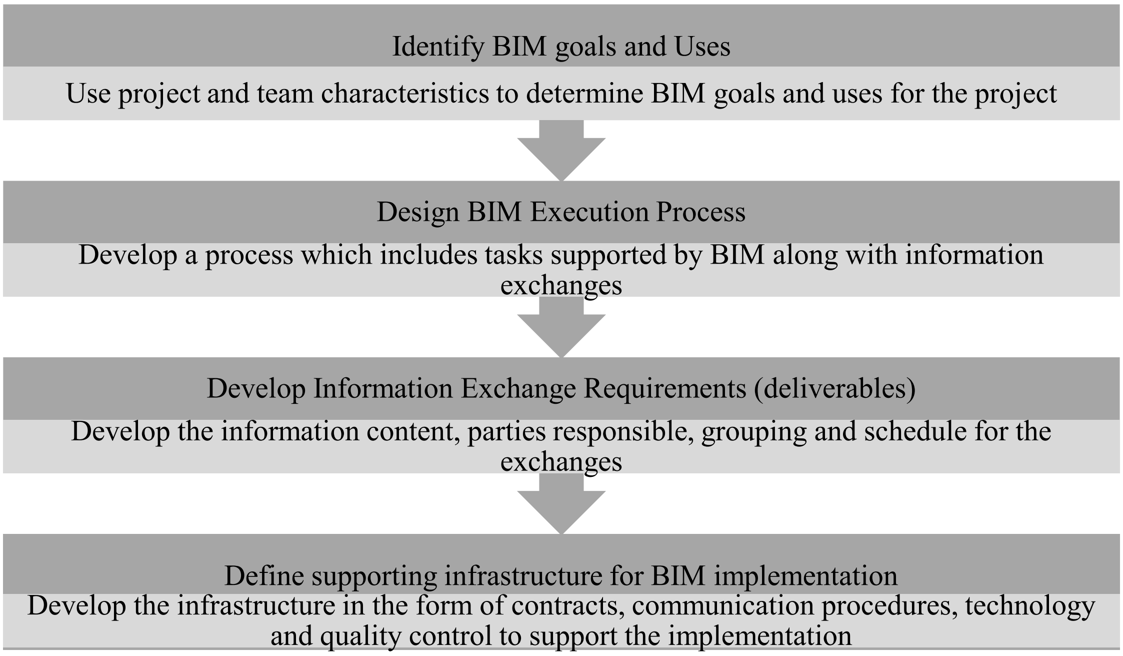

Figure 8: BIM Project Execution Planning **(Messner, et al., 2012)**

1. Identify high value BIM goals and uses for a project

At the early project planning phase, the first step is to identify the most appropriate BIM Uses. This decision is based on the project characteristics, participants' goals and capabilities, and the desired risk allocations. Therefore, it is critical to clearly define the overall goals of BIM implementation. These goals mostly concern project performance such as increasing efficiency or productivity of the processes, shortening the project length, enhancing quality of product or services, decreasing cost impact of changes, or producing valuable operational data for facility management (Messner, et al., 2012).

2. Design the BIM project execution process

After identifying each BIM Use, it is necessary to understand and design a process map for the implementation of each BIM Use and of the project as a whole. This high level process map shows the sequencing and interaction between the primary BIM Uses on the project. It allows the team to clearly understand how their work processes interact with the processes performed by other team members and helps them to perform effectively their tasks. It helps them to get a better understanding of the entire BIM implementation, comprehend the content and scope of each information exchange that will be held between project teams, and specify and determine the processes necessary to be performed for each particular BIM Use (Messner, et al., 2012).

3. Develop Information Deliverables and Exchange Requirements

Once the appropriate process maps have been developed, the information deliverables and exchanges should be clearly identified. Defining information exchanges between project processes is critical for successful BIM implementation because it is important for the team members, particularly for the author and receiver, to clearly understand the information content for each information exchange transaction. In addition, the team needs to understand what information is necessary to deliver each BIM Use. An Information Exchange Worksheet is designed for these reasons which should be completed in the early stages of a project after designing and mapping the BIM process (Messner, et al., 2012).

In order to define the content of model information deliverables and the level of detail needed at a particular stage of a BIM project, and specify clearly the exact content and the proper time of each information needed to carry out a BIM process, Hooper and Ekholm developed a participant-friendly method of articulating BIM content entitled BIM Info Delivery Protocol (Hooper & Ekholm, 2011).

The BIM-Info Delivery Protocol (IDP) is presented in **Figure 9** and on **Figure 10** as a sequence of pedagogical steps. (Hooper & Ekholm, 2011).

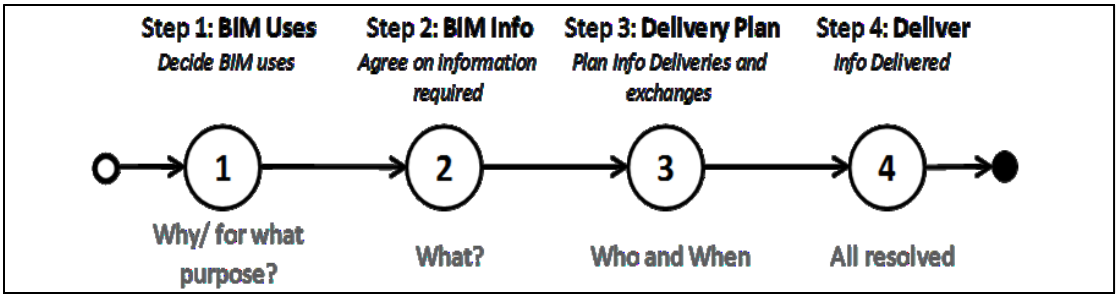

Figure 9: Strategic BIM Info Delivery Process **(Hooper & Ekholm, 2011)**

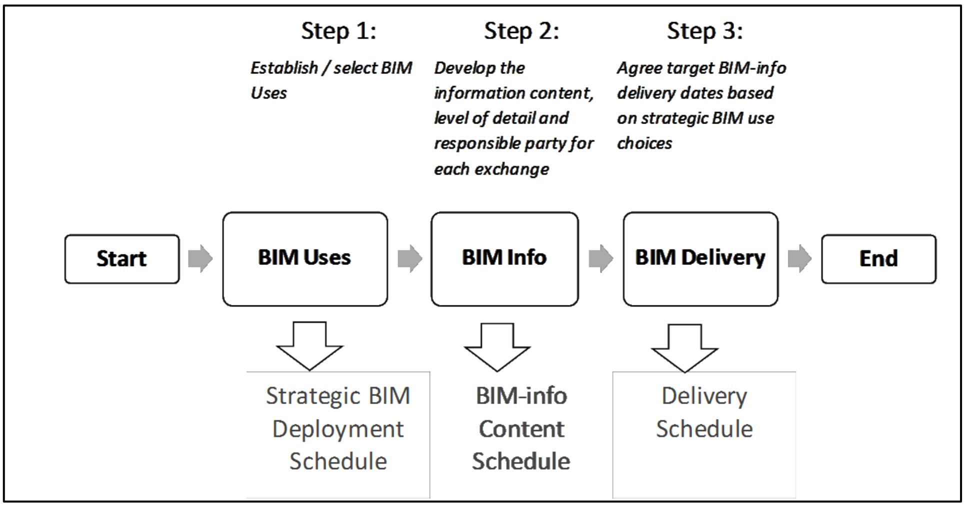

Figure 10: BIM Info Delivery Protocol IDP **(Hooper & Ekholm, 2011)**

By creating a process map and defining the exact information necessary to accomplish tasks successfully, project participants can increase productivity and enhance the quality of design output (Hooper & Ekholm, 2011).

BuildingSMART organization has developed a standard methodology called Information Delivery Manual (IDM). This standard methodology defines how to capture, document and determine processes and information stream between parties during the lifecycle of a facility. It describes how and when the BIM based information is utilized by different project disciplines. The Information Delivery Manual is principally intended to ensure that the suited data have the proper form and are transmitted in an appropriate way that they can be interpreted by the receiving software. Thus, it is important IDM to be fully supported by the software in order to become operational. (BuildingSMART, 2011)

4. Define supporting infrastructure for BIM implementation

The team must develop the infrastructure needed to support the BIM process during the project. This will include the definition of the delivery structure, contracts and contract language, the communication procedures, and the technology infrastructure. It will also include the identification of quality control procedures to ensure high quality information models (Messner, et al., 2012).

2.5 BIM framework and technical aspects

This chapter analyses thoroughly the features that were mentioned in the four previous planning procedures and have significant role in the governance of BIM implementation.

2.5.1 Levels of maturity and stages of implementation

According to Messner, et al. (2012) the third step of the BIM organizational strategic planning is that the client should develop an effective advancement and implementation strategy. This careful and advanced planning gives the possibility to the planning team to define which level of BIM implementation is proper to choose depending on the organization’s goals, size, financial investment, BIM experience and available resources (Messner, et al., 2012). The term “level of implementation” is described at the following paragraphs.

Levels of sophistication or maturity

BIM means different things to different people. On the one hand, using 2D CAD, supported by simple spreadsheets to communicate project information is a basic form of BIM. On the other hand, using a fully integrated collaborative project model covering all key design disciplines and based on IFC data exchange standards and protocols is also a form of BIM, but at a much higher level of sophistication and usefulness. To get a better understanding of what BIM adoption means – and how to get the most out of it – it is helpful to have a simple model that captures different levels of sophistication or 'maturity' in the use of BIM (AECOM PCC business development team, 2012).

Stages of implementation

These levels of sophistication or maturity start from level 0 where a project has not implemented any BIM principles. Therefore it is described as the pre-BIM status. The following levels implement more BIM principles and present an accumulative progress. Thus, they are also considered as stages and therefore the term "BIM implementation maturity stages" is also commonly used in literature (Arayici & Khosrowshahi, 2012).

Level 0 (the pre-BIM status)

Unmanaged CAD design which is usually performed in 2D and it is using paper or electronic paper such as pdf as the main data exchange mechanism (Arayici & Khosrowshahi, 2012).

Level 1 (object-based modeling)

Managed CAD design performed in 2D or 3D. This first level or stage is the migration from 2D to 3D and it is object-based modeling which contains documentation. The BIM model is made of real architectural elements that are represented correctly in all views. It uses a collaboration software or network which accommodates a shared data environment and employs regular data structures and formats. The BIM model is still single-disciplinary and the deliverables are mostly CAD-like documents. The stage one requires new software to be applied therefore this stage is considered to involve high technology change (Arayici & Khosrowshahi, 2012).

Level 2 (model-based collaboration)

Managed 3D environment is held in separate discipline 'BIM' models and it has tools with attached data. It progresses from modeling to collaboration and interoperability. In the level 2, two design disciplines can work together and this cooperation can take place during the same project phase or between two different phases. The information exchanges can occur for instance between architectural, structural models, steel models, and facility maintenance models. This data exchange is mainly on the basis of proprietary exchange formats. Designing and managing a building is a highly complex process that requires smooth communication and collaboration among all members of the project team. It requires integrated data communication and data sharing between the stakeholders to support this collaborative approach .This approach support the digital models in order to perform 4D (assigning processes with detailed time or schedule related information) or even 5D (linking processes with cost estimations). Processes and working methods require medium changes in this level (Arayici & Khosrowshahi, 2012).

Level 3 (network-based integration)

This level has progressed from collaboration to integration and it reflects the real underlying BIM philosophy. This third stage is the ultimate level of BIM sophistication or maturity and likely the last goal for BIM implementation. Fully-open process consists of a single project model and its data integration and exchange are using IFC standards. This level can be considered the actual "network- based integration" where the single project model can integrate all project processes. The process is managed by a collaborative model server. Players interact in real time to generate real benefits from increasingly virtual workflows and stakeholders can maximize their benefits. This level needs complete organizational transformation regarding practices, tactics, knowledge, infrastructure, and culture can be altered significantly (Arayici & Khosrowshahi, 2012).

Level of maturity depends on the project complexity

The dimensions and the levels of BIM that are needed to be utilised in each project are depending on the project complexity and the exact requirements set by the client. For example a complicated project where there will be a lot of problems during the construction phase because of lack of working space and great number of different subcontractors working simultaneously in the construction site necessitates the utilization of 4-D and the construction area management plans, well known as ADP plans (Arayici & Khosrowshahi, 2012).

2.5.2 BIM Efficiency: Level of Detail

A BIM model requires for its creation more time and effort in the early design phases than a common CAD drawing. The BIM process does not only consist of the geometry design and the shaping of construction elements as in traditional CAD design. The elements of the BIM model are being assigned with information about colour, weight, cost, manufacturing and other functional properties. This extra information needs require that designers determine the level of detail that should be included in the models at each design phase, in order to balance the invested time and the produced outcomes (Khanzode, et al., 2008).

Many companies dealing with a BIM project do not have a definite image of what is required to be included in the model at each phase during the design and documentation process. The CAD users now have access to capable 3D tools and have the opportunity to create accurate and rich data models with high detail, much more than it is necessary to get the goals of construction documentation complete (Webster, 2013). Thus it is necessary for either the project manager or BIM manager to understand how to define the model level of detail and direct the design team properly in order to avoid project budget and schedule surplus (Webster, 2013).

The Level of Detail (LOD) specifications define with high detail and clarity the content and the amount of physical and functional attributes which the model objects should contain and the minimum model requirements at various stages (Bloomberg, et al., 2012). They can be considered the model minimum requirements at each phase. Model designers utilizing these specifications know what they have to deliver and what their produced models should serve in each phase. These specifications give also the possibility to the users to understand the purpose and limitations of each model that is being delivered (BIM forum, 2013).

The American Institute of Architect AIA established a framework which determines guidelines and principles for any building model delivery. It is intended to resolve the following issues throughout the whole project lifecycle (Bloomberg, et al., 2012):

- How accurately shall the model be designed?
- Who has the responsibility of modeling a specific object?
- What type of information shall be incorporated in the model?

The level of development is accumulative and should progress from LOD 100 at conceptual design through LOD500 at completion of construction and start of facility operation (Bloomberg, et al., 2012).

Design phase	BIM models
Pre- Schematic (LOD 100)	Existing condition model Site Analysis Space program Design authoring – Volumetric Model Zoning and Orientation
Schematic (LOD 200)	Design Authoring- Preliminary model Sustainability (LEED) evaluation Programing Phase Planning Preliminary Cost Estimate Design Review Preliminary 3D coordination
Design Development (LOD 300)	Design Authoring model Sustainability (LEED) analysis Detailed Energy analysis System cost estimates 3D coordination reporting Program Validation
Construction Documents (LOD 400)	Design Authoring – final model 3D coordination validation Cost estimation Sustainability (LEED) reporting
Services during Construction (LOD 500)	Construction System design Phase planning Digital fabrication Record Modeling Asset management

Table 2: LOD, deliverables and design phases **(Bloomberg, et al., 2012)**

LOD 100: Conceptual design

The model consists of the conceptual geometry, depicts the generic masses of the building and contains information about spaces, volume, orientation and so on. This generic model gives the possibility to perform solar and early energy analysis (Bloomberg, et al., 2012).

LOD 200: Design development

The model consists of the approximate geometry. Building elements are designed with approximate size, location, orientation and amount. The model gives the possibility to perform general performance analysis and early calculations (Bloomberg, et al., 2012).

LOD 300: General construction documents

The model consists of the precise geometry. Building components are precisely designed with accurate size and position. This model is applicable for creating general assembly and construction drawings. It gives the possibility to perform accurate analyses and simulations on each object and system. In addition it is appropriate for coordination and clash detection (Bloomberg, et al., 2012)

LOD 400: Fabrication information

This level gives the construction models. Every object is designed for fabrication purpose. The model is appropriate for detailed construction and fabrication drawings which depict accurate size, shape, material, and how units will be installed. It also gives the possibility to create schedules for production and construction (Bloomberg, et al., 2012).

LOD 500: As-Built model

It delivers the "As-Maintained model". This BIM model is equivalent of As-Built traditional drawings. In this model, elements integrate rich technical information necessary for operations, maintenance and procurement (Bloomberg, et al., 2012).

These Levels of Development are suggestive and BIM Manager is unrestricted to describe model deliverables more thoroughly. These levels suggest a framework for developing a precise BIM Implementation Plan which specifies the responsibilities of each project participant in the development of the model (Bloomberg, et al., 2012).

2.5.3 Interoperability, OpenBIM and IFC

Interoperability is a term that was initially used to define the ability of information technology platforms or systems engineering services to allow information exchange. In AEC industry, interoperability is now defined as the capability of managing and interexchanging product and project digital information between software process platforms. The process systems concern design, procurement, construction, maintenance, and business that are performed between collaborating firms and within individual companies. In other words, Interoperability is the ability of diverse systems and organizations to work together "inter-operate" (Cerovsek, 2011).

In the context of Building Information Modeling, interoperability can be described as the ability to manage and interexchange product and project digital information, between different actors within a project that are all working at a collaborating firms (BIM Steering Committee, 2012).

Interoperability issue

Each BIM software platform has its own language to describe a building model. This language is not necessarily understood by other BIM software platform because software developers have developed different ways of modeling in order to create, manipulate, and store digital models in native file formats (Cerovsek, 2011).

This communication problem between platforms may concern the process of one digital model. In addition, the same building is usually represented by several categories of BIM models because there are more than one design disciplines involved. Thus there are several digital models (architectural, structural, mechanical, etc) which may be constructed by different tools and, therefore, may have inappropriate format for another designer (Cerovsek, 2011).

Open BIM approach

Open BIM is a worldwide approach supporting interoperability and collaboration in the design, construction, delivery and facility management of buildings. It is developed by BuildingSMART (2011) and based on open standards and workflows. This technical certification system supports AEC software developers to advance, assess and validate their digital information exchanges so that their software platform can communicate efficiently with rest Open BIM platforms (Building SMART, 2011).

Open BIM principles

Open BIM is following certain principles that promote interoperability. It is committed to the utilization of open standards such as Industry Foundation Classes (IFC) and it engages all vendors of the current market who have similar strategy to participate even if they develop competing products. Moreover, Open BIM attracts users of BIM solutions to join the Open BIM workflow without suggesting them to give up their production tool (Drajko, 2012).

IFC- Industry Foundation Classes

Industry Foundation Class (IFC) is a vendor free and used for data exchange specification. BuildingSMART (2013) has developed an object oriented file format which complies with this IFC specification and is intended to assist the progress of interoperability in the AEC industry. Specifically, it is an open format that specifies building elements in a consistent manner in order to establish a universal language for data sharing in the construction and facility management industries (Building SMART, 2013).

This format is a common data schema for BIM that provides a foundation for the exchange and sharing of information directly between software applications of a shared building project model. Thus the software application is not expected to support various native file formats. Due to the fact that IFC is intended to constitute an open format, it is not owned by a particular software developer. It is intended to be neutral and independent of a certain software developer's strategy and influence (Building SMART, 2013).

The data schema has a life cycle approach because it contains information concerning the several disciplines that are getting involved in the facility lifecycle phases, conception, design, construction, operation, maintenance and demolition (Building SMART, 2013). Nowadays, the version IFC 4 has been published and it has been standardised as the ISO 16739 standard (buildingSMART, 2013)

BIM cloud and BIM Server

BIM cloud is a digital communication and information storage that is established through a web portal to a project server. This enabled logging of all communications and a database for all current and live information. The primary advantage of this approach is the possibility to inquire, coordinate and merge the BIM-model, and produce IFC files right away. Due to the fact that BIM cloud can support numerous users at the same time, it is possible for many actors to work simultaneously on their own part of the model and the model will be updated right away. It is furthermore possible for different actors to get notifications when the model or the part that is important to them is updated or changed by others (Open source Building Information Modelserve, 2013).

2.5.4 Classification systems

Ekholm and Häggström (2011) elaborated that the aim of building a classification system for the construction industry is to provide the industry with common agreed standardized terminology and semantics. These standards should contain for example a system for calculating cost, technical specification and exchange of information. In a BIM context there is a growing need to use a classification system both for use in international construction projects and national project. Furthermore there is a need for common ground in classification system where translation between the national system and the international system needs to be developed to a common system so all actors in a project are speaking the same language (Ekholm & Häggström, 2011).

National classification systems BSAB Sweden

The aim of the BSAB Swedish national classification system is to provide the construction industry in Sweden with a common language to make it possible for different actors to talk to each other with the same language and possible save money by preventing errors that otherwise might have occur due to misunderstanding. The BSAB can help with different activities in a construction project some of these tools will be counted (Svensk Byggtjänst, 2013):

- Mutual classification tables that promote efficient exchange of information between production and management.
- Technical descriptions.
- Numbering plan that is provided by the BSAB building component table.
- Item information.
- Quantity indexes that can be used for quantity calculations.

International classification system

The purpose of the International classification System (ISO 12006-2) building classification standard is to be a foundation for a framework that will be used for developing a building classification system by organization on a national or regional level. The standard has been developed towards the goal of harmonizing diverse classification systems from different national and regional building classification systems. The ISO 12006-2 recognizes the main classes that are interesting to the construction industry to be used in different CAD information systems. The main vision of the standard is to complete life cycle of construction works within the construction industry. It furthermore provides list of recommended tables according to particular views or principles of specialization (Ekholm & Häggström, 2011).

International Framework for Dictionaries

The International Framework for Dictionaries IFD is a core component of the BuildingSMART data standards programme and supports the interoperability between software applications and product databases (2013). It is a reference library with terminologies which creates a catalogue of what objects can be named. Its aim is to ensure that the attributes which are attached to objects by a designer can be understood by other engineers (BuildingSMART, 2013).

IFD Library is a dictionary of construction terms defining the use of each name (type, properties, etc) in a concrete manner for everyone and for every purpose. It specifies each term with unique serial number (Global Unique ID) and each term definition is described by being associated with other terms. The IFD Library relies on the corresponding ISO standard. Hence, the rules about the use and type of each term, and how it relates to other terms conform to the same standards.

Accordingly, software can use these unique serial numbers to perform precise information exchanges based on the use and content of the terms and not on the names assigned to them. Additionally, if a user refines an object by adding or adjusting further values, attributes and descriptions, all those new values can be instantly translated into other software languages (BuildingSMART IFD, 2009).

2.5.5 The Information needs for Facility Management

Information exchange

The client has different requirements for information than the contractor and the designer since the client is more interested in facility management and data that can be used for operation, maintenance and renovation work. Thus it is important for the client to define clearly the information needs and exchange requirements in the project documents. The information exchange requirements mainly consist of two things, the facility data and the model element level of development This documentation is necessary to be developed at the beginning of the project and defines both the facility data and the model level of development that are needed to be properly stored. (Messner, et al., 2012).

Modelling requirements for FM

One item that the Level of Detail (LOD) does not determine is the digital information of each object required for facility management. All building elements shall integrate facility management attributes and properties which shall be precisely defined. The properties vary in level of detail and can constitute a foundation for the facility management information requirements of an organization. In order to make an effective selection of required attributes and facility management information, COBie format shall be preferred since it structures information in an operational manner (Messner, et al., 2012).

Construction Operations Building Information Exchange (COBie)

Construction Operations Building Information Exchange COBie is defined as an industry standard format for delivering facility digital information (Messner, et al., 2012). Specifically, COBie is a structured universal manner of managing information stored on a BIM model which is intended to support the facility management of a building (Complete Digital Integration, 2007)

Its purpose is to exchange information that is gathered during construction and to be passed on to a building's facility management system. It has a specific file structure that facilitates the authors of the digital information during design, construction, and commissioning phase to populate a spread sheet with the necessary information required for the facility management, such as equipment name, type, location, physical and functional characteristics, etc. Facility management systems can export valuable information from this COBie spread sheet and populate their data system.

COBie has a certain predefined way of structuring information, but it is not intended to determine what properties shall be tracked and populated by an organization. The latter is dependent on each organization's needs. The COBie approach of delivering information is established by the National BIM Standards USA and many clients have included COBie in their project demands (Messner, et al., 2012).

In addition East and Chris (2013) point out that one of the most obvious applications with COBie is to replace the traditional paper-based construction handover documents (East & Chris, 2013).

Interoperability between IFC and COBie

A fundamental principle of buildingSMART projects is that the Industry Foundation Class (IFC) model can facilitate the necessary information exchanges. Thus, BuildingSMART has developed a design process that can ensure that the COBie spreadsheet format is compatible, transposable and correspondent with the IFC Model. In addition, in order to enhance this interoperability, a software program has been developed to convert IFC to COBie spreadsheet and vice versa. (Nisbet & East, 2012).

fi2 file format

The fi2 is a standard that can be used for managing different types of information that are related to facility management. The fi2 is the common language that makes it possible for different system within the facility management sector to communicate and makes it possible for them to interact. Due to the fast development in the IT sector the facility management sector needed to have a format the allows the flow of facility management information and the possibility to increase the set of original requirements from the facility management sector to be better coordinated into the construction. The standard is managed by association, *fi2 Management information*. The members of the association are the leading facility management companies and vendors that work in the industry (Föreningen för Förvaltningsinformation, 2006).

2.5.6 Documentation

BIM Guidelines

The purpose of a BIM Guidelines is to provide guidance on how to execute a BIM project. The guide is supposed to form unity in the use of BIM in all projects. It is supposed to support an organization building operation and maintenance protocols. It is furthermore supposed to be tailored to the organization requirements and standards for every project to control enhanced capabilities that is provided by BIM for each project. In addition the BIM guidelines manual should be reviewed and updated to be able to take advances of new technology and methodology that is used in the construction industry (Bloomberg, et al., 2012).

2.6 Barriers and challenges

This chapter clarifies the challenges and risks that may appear when clients implement BIM. In this manner, all the project participants have the opportunity to understand all the difficulties that they probably face.

There are many challenges and barriers that an organization faces while implementing BIM. The extent of challenges and barriers differs between the level of BIM and what benefits the organization is trying to get from the implementation.

Arayici and Khosrowshahi (2012) count various barriers that an organization in the construction industry could face and challenges related to these barriers. Some of these barriers and challenges it faces will be counted (Arayici & Khosrowshahi, 2012).

- The firms are not familiar enough with BIM, the challenge is that they need to train the staff on new processes and workflows.
- The reluctance to initiate new workflows or train staff, the challenge is to make sure that the organization is willing to make changes.
- Benefits from the BIM implementation do not outweigh the cost to implement BIM, the challenge is to make sure that the new processes and workflow are implemented effectively to be able to outweigh the cost.
- Possible benefits are not tangible enough to justify the investment and they do not offer enough financial gain, the challenge is to make the organization understand BIM better and the possible benefits it has to offer.
- The organization lacks the capital to invest in new hardware and software, the challenge is to make the organization understand the value from a financial perspective.
- Resistance to make cultural change and the believe that there is no demand for BIM use and therefore no need to implement BIM, the challenge is to make changes in the industry so a cultural change can actually count.

In addition Hooper and Ekholm (2011) state that one of the biggest challenges is that even though many consultants show great interest in BIM, construction industry presents a lack of practical knowledge in applying current technology and leveraging the much advertised benefits of BIM (Hooper & Ekholm, 2011).

Azhar, et al. (2008) focus more on the managerial challenges around the BIM implementation, what challenges it might face in the future and in current practice in the construction industry. They point out that there is no formal agreement on how to implement or use BIM within an organization and not many documents that provides information about how to do that. Furthermore they state that the progress of creating contractual documents around the BIM model is developing too slowly. Another issue that is addressed is what actor should continue with the development of the BIM models and how the cost for that should be divided between stakeholders. The emphasis in the industry should be to develop the processes and promote further BIM use to be able to govern the issue about ownership and risks. The future of BIM modeling should allow stakeholders like facility managers to be able to enter the project at much early stages. The future challenges for the owner will be to get all the stakeholders involved at the right time to be able to get all the important information at the right time this could be a crucial success factor for a project (Azhar, et al., 2008).

Another challenge addressed is that in BIM projects more resources are needed during the design phase. Therefore more cost is needed for design changes or iterations for specialist that are part of the design team. In addition to this a cost that comes from purchasing new software can be considered a barrier for smaller firms (Hooper & Ekholm, 2011).

2.6.1 User resistance to change

The concept of user resistance is largely a one-sided concept that describes resistance to be a dysfunctional psychological problem of individual users and therefore can be considered a huge barrier for the implementation of Construction IT (Hartmann & Fischer, 2009).

Direct accounts of change recipients indicates that an individual resistance to use a technology and the success of a same technology implementation on a project do not often happen within the construction industry (Hartmann & Fischer, 2009).

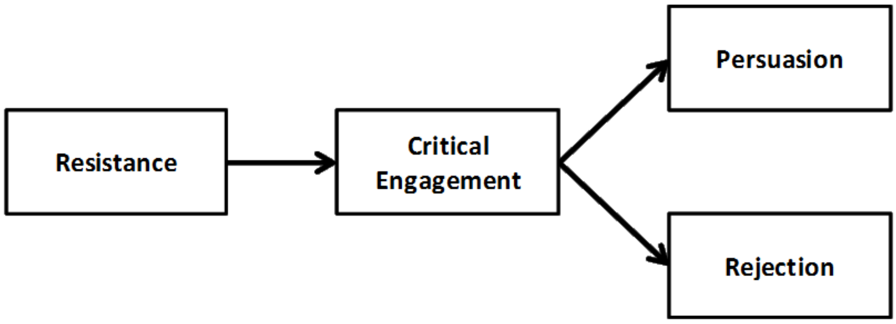

Figure 11: Casual relationships between the phenomena **(Hartmann & Fischer, 2009)**

Hartmann and Fischer (2009) argue that user resistance is an important concept that causes professionals working on a project to critically engage themselves with the Construction IT. This way makes it easier for the professionals to identify the shortcomings and the benefits of this technology which lead to persuasion of the professionals or to resistance to use parts of the technology, see ***Figure 11*** (Hartmann & Fischer, 2009).

The identification of benefits and shortcomings seems to enable the professionals to successfully implement the Construction IT on the construction projects. Additionally, this identification of shortcomings enables the professionals to actively search for solutions of how to prevent the shortcomings and to improve the implementation more than the initial intentions of the change agents (Hartmann & Fischer, 2009).

Furthermore, the resistance of the professionals towards part of the technology helps to ensure that project teams use the coordination IT tools meaningfully within the local project context. In addition Hartmann and Fischer (2009) state that resistance is an important factor that makes the implementation of the Construction IT more successful within a project.

2.7 Risks of BIM implementation

This chapter is divided into three different parts, firstly it addresses the issue of the legal ownership of BIM models, secondly it describes the legal responsibilities for models and sharing the risks and thirdly it brings out the problem of technical risks.

The project participants will face many risks that can create problems to their work and reduce their incentives to increase their performance and productivity. Therefore it is important to think that the main goal is to avoid inhibitions or disincentives that discourage participants from fully realizing the model's potential (Azhar, et al., 2008).

Azhar, et al. (2008) argue that BIM risks can be put in to two broad categories, legal risks related to contracts and technical risks. The following paragraphs will discuss briefly each key risk in every category.

2.7.1 Legal ownership of models and copyright

The first risk mentioned is the lack of deciding the ownership of the BIM data and the need to protect it with copyright laws and other legal channels. One example could be that the owner that is paying for the design might feel that he owns the BIM data. However, if other actors of the project team are providing vital information that is used in the project, that information needs to be protected as well. Therefore that is no simple solution to the matter of who is the actual owner of the data. Each projects needs a costume design approach where needs of each team member is meet and the aim is to get people to understand the actual potential of the model (Thomson & Miner, 2006). One possible way to avoid this dis-agreement about copyrights could be to state clearly in the project contractual documents the ownerships responsibilities and rights (Azhar, et al., 2008).

When a participant of the project team, other than the architect, the engineer or the owner adds data to the BIM model, issues about rights can come up. Example about this could be when vendors offer special design with their products, while hoping for the design manager to specify their products in the model. This can create legal issues since the additional designer from the vendor was maybe not licensed to practice in the location of the project (Thomson & Miner, 2006).

2.7.2 Legal responsibilities for models

Another contractual matter to address is who is responsible for the models accuracies and that all information that is added to the model is correct. This matter is a very complicated and involves a great deal of risk. Furthermore it needs to be thought about before entering a BIM project and should be issued in the contractual documents. Therefore before using BIM technology all the risk related to it must be analyzed. This fact requires more time spent in reviewing BIM data and might be considered new expenses for the project team during the design and planning phases (Thomson & Miner, 2006).

The concept of BIM is not defined clear enough for the BIM process, so each actor is not certain enough about his responsibilities and that can cause increased risks. For example if the owner of the BIM data wants to sue the designers for an error in the design, it can be difficult to prove who is responsible for the error (Azhar, et al., 2008).

2.7.3 Technical risks

Technological problems can occur when the actors in the BIM process use different software's that do not communicate well enough with each other's. This can create problems with the integration of the BIM processes. Example about this could be when the general contractor uses different software than the sub-contractor and other actors in the project to create for instance time schedule and cost breakdown for the project. If they do not use the same program a lot of unnecessary manual work has to be done. However, a BIM-guideline could address these issues early in the process where the interoperability and file formats are solved that would mitigate the risk of this happening (Thomson & Miner, 2006).

Azhar, et al. (2008) furthermore state that one of the most efficient ways to mitigate the risks while doing a BIM project is to have collaborative and integrated project delivery contracts, where the risks and possible rewards are share between project participants (Azhar, et al., 2008).

3 METHOD

Aiming to get a clear view of the actual way of working with BIM, interviews were conducted, where project managers and consultants who are professional in BIM practices presented their opinions and discussed about their experience concerning issues that were brought up in the theoretical part of this thesis.

This chapter describes the research methods that authors followed and the practical and technical aspects of conducting this research.

3.1 Research methodology

The study can be divided into two different categories, theoretical part based on literature review and interview based part where semi structured interviews were conducted. For the literature part material was searched through different databases like Scopus and Google Scholar with combination of search words like; *BIM, implementation, benefits, construction industry, challenges and risk*. The study was conducted using qualitative method. The questions for the interviews were created to try to get the information needed to answers the research questions:

- What main aspects should the construction client consider when governing the BIM implementation process?
- Which processes should the client follow in order to implement BIM effectively?
- What are the potential benefits that a client can get from BIM implementation?
- What are the possible challenges and risks that a construction client should consider while implementing BIM in a construction project?

3.2 Qualitative method

Holme and Solvang (1997) describe the main purpose with a qualitative study is to identify and to explore an insufficiently known properties. They furthermore state that the main idea is to try to discover angles on a certain subject that is difficult to establish in advance and a deeper understanding of the subject is needed. In addition they state that in a qualitative study a large amount of information about the subject is gathered from a relatively small sample size (Holme & Solvang, 1997). Considering these facts and the purpose and aim of this study a qualitative method was selected to conduct this study.

3.3 Semi structured interviews

In total, there were conducted 12 semi-structured interviews involving 16 people. All persons that were interviewed were chosen either because of their connection to the BIM pilot project or because of their expertise in BIM. The interview participants that had connection with this BIM project were employees working for Poseidon, the architect and the contractor. Other persons interviewed were consultants that were not directly connected to this project but their profession is specially focused on BIM implementation processes. The interviews were held between the 25 of February until the 19 of April 2013. The length of each interview varied from 60 minutes to 240 minutes. This variation of each interview length depended partly on the knowledge of BIM and the previous experience from similar project while using BIM.

At Poseidon, interviews were conducted with three different persons. These persons were the project manager of this BIM pilot project, the person responsible for the facility management system of this firm and the person responsible for handling and storing all CAD drawings, digital drawings and documents that are used in Poseidon projects. Four interviews were conducted at the contractor office in Gothenburg where the persons interviewed were the design manager, the person responsible for the visualization analysis and the BIM coordinator of this BIM pilot project. In addition a BIM strategy developer a member of the BIM development department of the contractor was interviewed. One interview was conducted at the architectural firm that is involved in this project. The persons involved were two architects and one BIM coordinator.

In order to broaden the research sample and benefit from the valuable knowledge of BIM professionals, interviews were conducted with persons not directly involved with this project but with expertise in BIM issues. At a consultancy firm in Gothenburg one interview was conducted where two persons were interviewed, a software developer and a BIM manager. Two interviews were held in Malmö at two consultancy firms. In one of these interviews the person interviewed was a BIM Manager and CEO of the company. In the second firm, the persons interviewed were a BIM coordinator and a BIM strategy developer. In Stockholm one interview was conducted in a consultancy company with a BIM manager.

The questions were not given prior the interview. The interviewers followed this practice because the authors did not want the interviewees to give prepared answers. The data collected should be based on their personal experience and real work practice and not on theories and articles. Furthermore interviews did not have a strict style but they had a form of discussion with follow up questions when it was suitable.

4 CASE STUDY

In the second part, this report conducts a case study of a BIM pilot project in Goteborg, Sweden. The client is a municipal housing company and their demand is to implement BIM methods and principles in the design, construction and operation of a housing building.

4.1 Case Company

This chapter will describe the housing company Poseidon. It will further more show the structure for a BIM pilot project that the company is executing in collaboration with a contractor using a partnering contract.

Studied Company

Residential housing AB Poseidon is a municipality owned housing company. It is a daughter company of Framtiden AB which is owned by the city of Gothenburg. Poseidon owns and manages over 26.000 apartments in Gothenburg with over 40.000 tenants. It has 228 employees. The company is divided into headquarters and 8 different districts, where each district represents a part of the city. Poseidon’s vision is to create a sustainable society for the future. Their Policy is to provide people with affordable and attractive housing opportunities in different parts of the city. The company furthermore has an obligation to develop and strengthen different parts of Gothenburg and create safe and comfortable environment to live in. Poseidon is constantly building more houses and renovating existing buildings. The annual turnover of Poseidon for the year 2012 was approximately 1 844 112 MSEK (Bostads AB Poseidon, 2013).

4.2 The BIM Pilot project

Poseidon in collaboration with a contractor has made a partnering contract to execute a BIM pilot project at Holländareplatsen in Gothenburg. This project contains a building of a 53 apartments, five stored residential building. To be able to follow the difference in this BIM pilot project and a normal project, the contractor was asked to put all cost that can directly be traced to the usage of BIM aside, to make it easier for Poseidon to compare the total cost with cost of previous traditional projects when the project is finished.

The main aim of this BIM pilot project for Poseidon was to get some organizational knowledge about BIM, and getting people inside the organization to understand the potential benefits of using BIM and what capabilities it can deliver.

It was of great importance for Poseidon while choosing the contractor to execute the project, that the contractor was capable of using BIM. The contractor had to go through a narrow process before being chosen, where the contractor was evaluated and had to prove the capability with experience from previous projects, and come with a plan about how it was going to execute the project.

The organizational structure for the project is a combination of representatives from Poseidon, the contractor and some outside consults that are not part of the actual project. The structure for the project can be seen in the following ***Figure 12***. The project manager for the project comes from Poseidon and is the key person in all communication within the project.

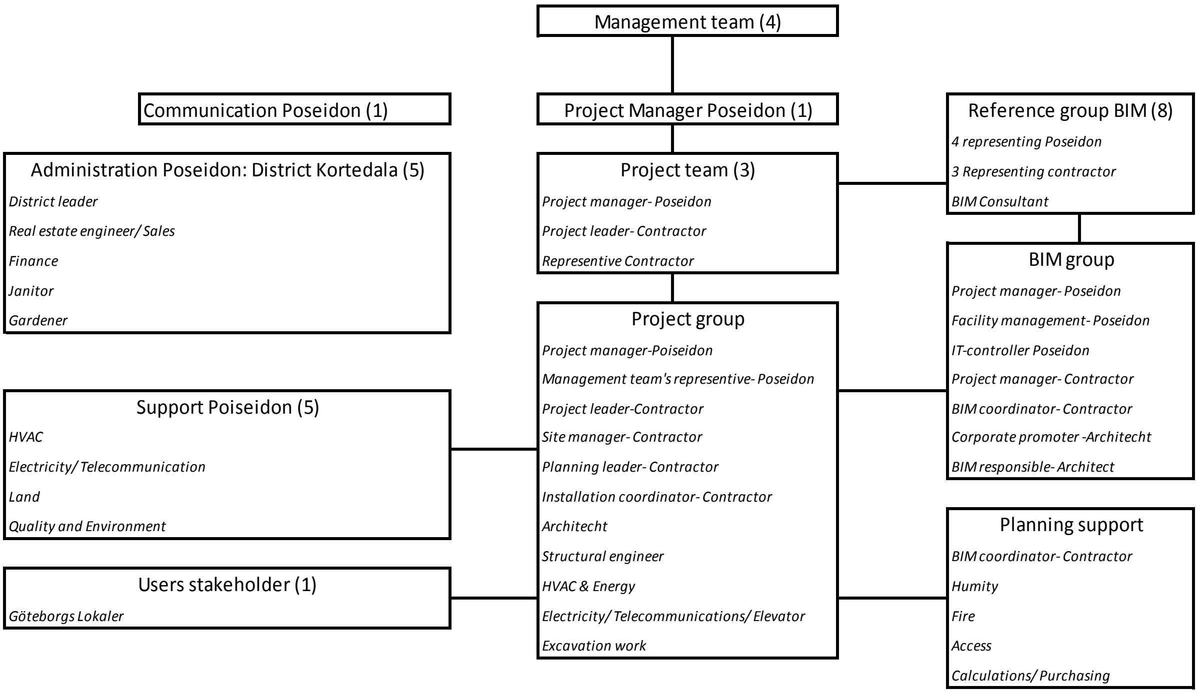

Figure 12: The project organization structure for the BIM pilot project at Holländerplatsen

4.3 BIM guidelines and project requirements

For this BIM pilot project, a BIM Guidelines was created by the contractor in collaboration with Poseidon. In this document the project demands and specific BIM requirements, which all project participants should meet, were defined. The main demands of this BIM pilot project defined in this BIM Guidelines are the following:

- All drawings produced from BIM in digital representation
- Collision clash detection
- Quantities take off
- Use of digital models on construction site
- Specific requirements for facility management

After the completion of this project, the client will evaluate this BIM Guidelines, develop it further and integrate it within the main Project Manual in order to be used in future BIM projects.

Designers and subcontractors in this project are chosen by the contractor except the architect that was chosen by Poseidon. All designers were involved during the early stages except the designer of ventilation, pipes, electricity and the prefabrication designers. The reason was that these parts will be done by sub-contractors and the main contractor was going to use his connection to get offers from different sub-contractors that fulfil the requirements that are written in the BIM guidelines.

The limitations of this pilot project can be considered time, cost of implementing BIM and limited experience of working with BIM from the contractor and Poseidon and maybe not knowing what to expect with the final product.

5 RESULTS

This chapter elaborates the information collected during the twelve (12) interviews that were conducted. The sixteen (16) interviewees were asked to describe their perceptive of BIM concept and issues related to governing BIM projects. They were furthermore asked to describe the BIM uses and the potential benefits that BIM can provide. People that had relevant experience described the main difficulties, risks and challenges they faced while using BIM in previous BIM projects.

5.1 Building Information modelling BIM

5.1.1 The BIM concept and different perspectives

A new way of working

Many actors have different interpretation and understanding about what BIM actually is and consists of. There is not actually a strong common BIM definition among participants within AEC industry. An engineer dealing with visualization analysis gave his definition of BIM as a new way of working and design integration:

"So BIM is not a tool, it is not a system. It is not specific computer software. But it is more about a method and a new way of working. (...) It is a big change in every day work. (...) People have to start thinking about better collaboration and integrate all the disciplines in order to get the most out of BIM."

The shared source of information

He declared that BIM modeling is not design which is based only on one single digital model. His perception is in contrast to the concept of what many software promises:

"There is not only one BIM model in total but there is one model for every discipline, such as original geometry, visualization, energy analysis, etc. (...) You can assign information to each object, so each object contains a lot of details and features like fire resistance, sound isolation. You have to work with each model in the most appropriate software. It is not possible to make all the simulations with one software platform. (...) The different models are based on the same information, the one source of truth, and therefore we can combine them. So the picture with the single house model in the center and actors around is misleading."

A collaborative process

Two consultants, professionals in BIM field, gave the following answer when they were asked if BIM consists only of IT solutions and digital visual representation of a facility. They perceived BIM as a way of working which comprises designers, IT solutions and information content:

"It is important to know that BIM is related to information management, however BIM is not only information management. (...) You have software system, you have information and you have people, and you have to work together in a new process."

The importance of information sharing

Having another perspective, a BIM consultant focused more on the information content that BIM models can comprise and he considered also BIM as an IT solution that helps the communication between design disciplines and it is necessary to consider a lot of issues associated with information management:

"It is not a 3D CAD, it is not about modeling. BIM is more about Information management. It is a new way where everything is depicted by an object which contains information about its own characteristics and properties. (...) The link between different disciplines must be better integrated and BIM is aiming to that direction. (...). It is better to talk about BM and IM. BM stands for graphical views and 3d cad view. IM represents the information view, the ability to store information inside the objects."

Object-oriented parametric modeling

Having this in mind, he continued that BIM originates from CAD technique and the modeling process now consists of object oriented modeling which uses solids and parametric modeling:

"BIM is derived from CAD technique. Later they advanced the object-oriented modeling and now the 3d solid modeling, where they use solid objects. (...) Furthermore there is the technique of parametric modeling. Since the geometry has been defined for each object, then parameters, attributes and id are assigned to each object. Ready objects are saved in a library and are accessible for new drawings. There is no need to draw objects again. You only change the parametric features and dimensions and then the object is stretched. This is the main principle of the BIM tools."

5.1.2 BIM and Integrated project delivery IPD

Several BIM professionals highlighted the importance of involvement of key project participants in early project phase who will work in a more collaborative environment in order to maximize the value of BIM implementation and can facilitate the biggest outcome of the capabilities of BIM with following the principles of Integrated Project Delivery.

Early integration and decision making

A consultant with experience as BIM manager commented that it is better to make early decisions and involve the right people from the beginning rather than adjust the project BIM demands afterwards:

"It is important that we get many parties involved from the beginning. (...) there is a wrong idea that since it is BIM it will be quite simple to change things later. Actually you can always remodel but it could be more time consuming if you have not decided something in the beginning, you have not involved the proper people from the beginning and try to perform an additional task afterwards. (...) People think that since they have already made a model, it would be easy to make a quantity take off afterwards. But then they have to put a lot of additional information on the objects and make further adjustments. This is a typical misunderstanding of BIM. (...) It is important to model it like that from the beginning and involve the people with the appropriate knowledge in the proper time."

Longer design phase and better design solutions

IPD requires more time and more design efforts at the early phases. It takes time and project participants shall be involved very early in the design phase and spend more time for design. The engineer who usually has the tasks of visualization analysis and collision coordination explained why this longer design phase has significant effect on project performance:

"The design phase may take slightly longer. But then you will cut an enormous time at the end totally. (...) You make an investment by spending a little bit more time in the design phase, and you will reduce the construction cost and the maintenance and operation cost. (...) The duration of operation phase in a building life cycle is much bigger than the design and construction phase. So reducing the facility management cost can have much bigger advantages in comparison to the initial investment cost."

The design duration depends on the information needs

Professionals working for a consultancy company with expertise in BIM implementation (BIM manager and Software developer) had the same perspective about the design efforts and their actual benefits. They analysed the process of developing a digital model in order to explain clearly why and when it is required more time for BIM implementation.

"Comparing to a traditional project, the design process of BIM projects takes longer time. You need to use more time and do more work in early stages to put the model together than previously in traditional projects. (...) The time duration of design phase depends on what level of BIM you want to have in your project and how much information you want to put into the objects. If the client demands a BIM project and 3d is only required, you can actually make it much faster. (...) But if you have to put all the physical and functional attributes into the objects, for example fire resistance and other classifications, then you will need more time. More information means longer time."

5.2 BIM Uses and benefits

5.2.1 BIM Uses and Capabilities

Each project has unique demands and requirements and therefore one project may not need the same BIM Uses and functions as another project. A BIM coordinator pointed out that after the completion of each project the client has to evaluate what it has gained. By utilizing each BIM Use and evaluating which BIM Use had higher costs than gains and may not be suitable for the next project. Another BIM consultant, being asked which capabilities he would advise the client to focus on, answered:

"You have to think carefully which BIM capabilities you want to use in your project since each project is unique. You might not need the same capabilities when you are building apartment flats compared to what you need when you are building a hospital"

Visualization and digital representation

The visualization capability of BIM can serve as a marketing tool for the client in order to attract potential buyers and future users. It can also serve as a tool that can facilitate the design evaluation and help the client to select the best design alternatives. Furthermore, visualization can be a valuable tool throughout the design phase that empowers communication between project participants. BIM consultants elaborated these ideas:

"Visualization is not only a marketing tool for the customer. It can serve as a communication tool between project participants and resolve conflicts and other issues. The client and contractor can benefit by using this tool. They can evaluate the design alternatives based not only on their own cost and profit, but also the end user

interests and satisfaction. Then they can come up to firm decisions and define clearly the requirements, eliminating ambiguities and preventing possible conflicts."

n-Dimensions modelling

There is a general misunderstanding concerning the functions of BIM. Specifically, there is not established a common idea about the dimensions of BIM uses. A BIM coordinator, with technical background argued:

"We do not like to talk about 4d, 5d, 6d and 7d. It makes people confused. In civil projects you design a road, a layer of asphalt, a layer of gravel etc. which can be described with two dimensions design, but it is still BIM. You don't need to draw it in 3d, but you can still use it to connect to time plan and so one. Does that make it 4d or 3d? When you connect the model with the quantity take-off analysis, cost or time simulation? We use the proper description instead of using terms of 4d, 5d or 6d."

4D time scheduling

Another consultant described his personal expectations about the future BIM capabilities, such as scheduling 4D and the relevant info accuracy:

"In order to be able to do detailed and accurate scheduling, you have to put in the right input first. Most project have the same structure and a computer can do a preliminary time schedule but in more complex projects a computer can do up to 80% of the schedule but then we have to fill up the rest of the schedule ourselves. The information input accuracy depends on the person responsible who must have relevant experience, for example of how to build a wall and how long it takes."

The software developer with high qualifications in integration of BIM models and clash control was asked about the capability that BIM promises to perform 4D models and he identified the factors for successful implementation of 4D modelling:

***"**We don't have experience of many projects with proper 4d models. (…)In order to perform a 4D modelling, we need to spend a lot of time to define in high detail the time schedule, how to build the elements, the proper time when each building element should be built and the necessary duration of each task. You must get a special person who will be responsible for the time planning and management, not the BIM manager (…) There are standards for this procedure, what type of information should everyone provide for the responsible person. There is specific place to put information about the timing for each object. In this way, we can perform detailed 4d modelling."*

Energy analysis and LEED evaluation

BIM tools can perform Energy analysis and LEED evaluation. The software developer with high qualifications in integration of BIM models and clash control described the common method of performing these analyses:

"There are two types of energy analysis. The first one is the early stage energy analysis which makes approximate estimations. The generic tool is integrated into some software. It gives the possibility to perform very early stage analyses to evaluate and compare design alternatives. You can adjust different parameters and compare the resulting carbon footprints. You do not specify materials in great detail, just specify the type of walls. (…) The second type is the heavy duty energy analysis. There are software like Ecotect where you can import the Revit model and perform very sophisticated analyses such as solar analysis, thermal diffusion, heat transmission, cold draft, etc. It requires a lot of information for each building element such as

materials with the accurate synthesis of material layers, etc. Since architects do not input so much detail into the model at the early stages, they cannot perform this second detailed analysis early."

Quantity take-off and cost estimation

BIM can be used to generate an accurate quantity take-off and cost estimation, this can be conducted early on in the design phase and can provide cost effects of additions and modification that might occur later on in a project. A BIM consultant analysed this ability to perform accurate quantity take-offs with using BIM tools:

"If we know the volume of each building object, we define the density of each material in order to calculate accurately the weight. This is the basic principle of quantity take-off. The main problem of quantity take-off is that BIM and CAD software systems do not follow the legal Swedish measurement rules such as AMA. The CAD systems are extremely accurate and they measure the length, height and thickness according to how you draw an object. However, every country follows their national rules about how to measure the dimensions of a room, a column, a wall, etc. These legal rules are not so precise and somehow simplified because they were formed according to the manual drawing methods before computers were widely used, when it was time consuming to calculate the quantities by hand."

5.2.2 Benefits

It was not only the academic research that has shown that BIM implementation has many potential benefits for an organization. Interviewees also stated that BIM can significantly improve both the quality and efficiency of the construction and management processes in many manners, and also result in better and more sustainable end products.

Better quality in the design

Utilizing BIM and performing clash control can reduce significantly the design errors and improve the design decisions. The models are characterised by high accuracy and high level of detail. The BIM coordinator commended that visualization is a tool that helps the designer to realize better what is being designed and understand how it will look like in reality with high precision.

Better communication

The visual representation of the objects can help the communication of the design among the project participants. It can also facilitate communication in the construction phase and can be considered a useful tool for a site manager.

"In history there have been different representations and symbols of the elements, which required special knowledge to read the signs and caused misunderstandings. With the visual representation it is easier to understand what is depicted."

Mitigating construction problems

A BIM developer supported that one of the biggest benefits that you gain with the better design is that you can mitigate the risk of solving problems on site. He further stated that solving problems on site is not desirable, it is often costly and the solutions are not always ideal. Furthermore, he highlighted that this is exactly the issues that they want to get rid of through BIM implementation.

Consistency

Consistency is another great benefit of utilizing BIM. Making changes in a model has direct effects on all the related objects and drawings and thereby everything is updated and consistent. BIM model is one single source of truth and all documents and drawings are only representing different views of the same truth. All the information can be stored inside the digital objects of the BIM model and designer can automatically produce every type of drawing. Accordingly, a BIM manager stated:

"BIM provides a significant ability. When the designer makes changes, he makes a change in one place and it automatically changes everywhere. The designer does not have to make the same change to all the drawings. The change has direct effect to all the drawings, sections, documents, which subsequently increases significantly the design quality and eliminates the risk of defects in the construction. In the traditional design method, designer should make the same change one by one in all the drawings."

BIM can improve the end product

The highly sophisticated analyses that BIM tools can perform, the early evaluation of the design alternatives and several design parameters, the integration of all design disciplines in combination with the high accuracy and consistency of the design can contribute to significant improvement of the final product, satisfying the client.

"Another also aspect of BIM is the analysis phase. There are so many tools that we can utilize today to drive the improvement of quality and energy efficiency of the buildings. We can use the BIM model to do several analyses and actually make changes that improve the product in the end. You can utilize BIM and gain many things in a life cycle perspective."

Realizing the benefits

A BIM coordinator highlighted that it might not always be easy to realize the benefits right away. The benefits might be observed later on through the building lifecycle. He also expressed his concerns about value of BIM implementation and highlighted the difficulties people face to understand the value of BIM utilization in comparison with the value of traditional methods.

"An owner with internal maintenance and operations staff may value lifecycle Uses of BIM more than an owner who does not have any life cycle benefits."

Being asked to define what can be achieved through implementation of BIM in future projects, their answers demonstrated that they do not have a clear image about the potentials of BIM use and the benefits BIM can deliver. Accordingly, this was depicted in the case of an experienced design manager when he was asked if the 3D model can make his job easier:

"It will take much more time, it may be positive and it may help us during the construction phase to have better view of what we are going to build".

The Design manager was not opposed to the BIM implementation but he was not willing to be the person who leads the change. He stated that the model can possibly reduce the cost but on the other hand creating the 3D model requires time and resources. He further claimed that all the possible defects of the drawings can be effectively fixed in the construction site by experienced workers, reducing the necessity of using BIM:

"Yes maybe, but it depends on how skilled the people working on site are. If they know how to do things it is cheaper".

5.3 Governing the BIM implementation

5.3.1 The role of the construction client

The construction client acting in a regulatory context should set clear project demands, develop and establish procedures of implementing BIM and document these requirements and guidelines in manuals and contracts. Interviewees supported that the client and the management team should constantly control and drive these procedures and ensure that all the project participants perform their tasks according to these requirements. In order to highlight the importance of the role of the client, they often stated that:

"They should be aware of the high-value returns of BIM for their business and understand and communicate the necessity of BIM implementation. In order to implement BIM effectively, the clients should take more initiatives, set the proper demands and control the process."

The client is responsible to develop and drive a construction project from concept to commissioning, ensuring that the needs of the company, the customers, the industry and the community are met. BIM managers supported this idea which called "client driven process":

"The client should be the responsible to drive the BIM implementation. It is called client driven process. We aim to strengthen the client and his ability to require things. They must be more aware of their own requirements and their needs. In Sweden, clients are quite poor in defining the products and they usually hire architects and other people to define their requirements. For instance, a hotel owner should know the requirements for his own facility such as temperature of the rooms, typical wall colours, sound level inside rooms, etc. These requirements are critical for the success and profitability of the company."

Client as an employer, through its choice of partners, determines the type of skills and expertise that will be involved in the process, shaping skills development in this sector. He governs the procurement of services or products which aim to encourage competition and further development of processes and products. The engineer dealing with visualization and clash detection described that the client should demand from all the key participants to be involved and participate actively in the design phase:

"The client should demand the involvement of key participants from the beginning in order to use efficiently their knowledge and should also demand that they should become familiar with BIM in order to be able to follow the new processes."

Consultants valued the importance of motivation and engagement of client and project participants in implementing BIM:

"This BIM pilot project will be better than average. The partnering contract in combination with the great interest and demand from both Poseidon and Skanska increases the possibilities of success. Both are motivated and engaged with their goals and responsibilities. There are good reasons for each side and they will be successful."

5.3.2 The role of the BIM manager

Interviewees highlighted the importance of a BIM manager. The BIM manager should work directly for the project client and serve the client's interest and goals. The BIM manager should collaborate closely with the client in order to define the project and develop the planning procedures, as it was described in the theoretical part of this report.

The contractor is involved later on in the construction project after the procurement which has already been developed by the client and BIM manager. In addition the contractor has more project lifecycle approach rather than the building lifecycle approach which BIM implementation requires.

"The BIM manager should work directly for the client and not for the contractor. Contractor is not involved in the early phase of design and in the late phase of facility management. The design and construction is one year, but the building life is 100 years. The project is only a disturbance. Why should we put so much effort for this one year project? It is the building life cycle project that has great interest. The BIM manager should get this facility management perspectives and he should check the follow-up, transmission of information."

The BIM consultant emphasized that the BIM manager should be independent. He should have a separate role in order to avoid wrong strategy and methods:

“BIM manager should be independent. If an architect works in a wrong way concerning BIM, all the others will follow the wrong way of utilizing BIM. In big projects, architects have their own BIM coordinator in the project. In NKS hospital project, there is a BIM coordinator dedicated to support the architects. He ensures that they implement BIM things properly.”

Furthermore, interviewees pointed out the importance of getting involved in the earliest phase of a project where he can assist the client and the project manager to set the project demands and requirements and conduct the project manual:

“Managers are called in the initial project phase to define the project requirements. They have to specify which capabilities of BIM are necessary to be used for the design and execution of this certain project. Therefore, manager together with the client, they conduct the project and BIM Guidelines in order to set the demands and also to define the technical specifications.”

In addition, BIM Guidelines and technical specifications are not enough to implement BIM. BIM manager should ensure that all the project participants follow the client demands and work according to the manual:

“You need to drive things and push in every project. You cannot expect that you get what you are asking for if people just have to follow only a BIM Guidelines. It is very complicated so it needs this speciality competence to be able to force these things to happen. BIM managers are educating people in each project and then control and check if they deliver what the BIM Guidelines requires. They are checking if their deliveries are the right kind of deliveries.”

Later on during a project he is responsible to coordinate the design team and control the project delivery according to the demands:

"The BIM manager coordinates the design team and defines procedures; how they work with the models and what information they should add in each object. He

manages BIM issues such as level of details, deciding the object families and defining objects in the BIM system. The right way of working and the right detail at the right time can save a lot of time and subsequently a lot of money. Additionally, his role is to define how to communicate and exchange files. And he gets files from all the designers and integrates the models together and performs model-checking and clash detection."

5.4 BIM Implementation plan

5.4.1 BIM Organizational Strategic Planning

Need for an effective implementation strategy

In order to implement BIM effectively significant changes are required in the way construction business works, at almost every level within a building process. Most interviewees highlighted that BIM implementation does not only require learning new software applications, but also requires learning how to reinvent the workflow, how to train staff and assign responsibilities, and changing the way of modeling the construction. It appears that all organizations could benefit from a clear set of guidelines and possibly a roadmap outlining an effective strategy and methodology of implementing BIM.

"BIM manager has also the responsibility to inform the client about the capabilities and all the important factors of implementing BIM. They develop together the new ways of working, a new strategy which will obviously affect them. They make decisions together about the level of implementation and which BIM functions they should utilize. BIM managers are together with the client all the way. Client can make use of the experience of the BIM manager."

5.4.2 BIM Organizational Execution Planning

Possible Organizational Changes for BIM Implementation

The effective use of BIM requires that changes should be made to several aspects of an organization. Actually, BIM requires several changes, change of the way of working process, of staffing needs, of project organization, and of how a firm uses information.

"The facility management team should have the expertise and the necessary skills to specify clearly what kind of information they need in their processes of facility management. They should both define and document these facility data information needs and requirements at the contracts and project manuals at the early beginning of a project. Defining a precise way of expressing information is required in order to successful implement BIM inside organizational processes."

5.4.3 BIM Project Procurement Planning

Selection of competent project participants

Many of the interviewees pointed out the importance of choosing the right participant with the right expertise in a project. This can be a great factor on whether the project will be successful or not. However they pointed out that in many cases the cheapest participant is chosen even though that can cause various problems in a project. When a BIM coordinator was asked if it could be better to have a tender process where the participants should be evaluated based more on their qualifications rather than on the cheapest offer, his answer was the following:

"That is how it should be done, but even in the case of the big contractors they only think about the price, they have a budget that they have to follow and they have to hire the one who is cheaper even though they know that it can cause problems later on".

The BIM coordinator highlighted the importance of careful selection of project participants who should be competent in order to make things right and maximize the benefits of BIM.

"The most important things of BIM will be visualization, 3d collision control and cost calculations. Concerning quantity take off, the production drawings must be 100% correct. We can reduce waste but we must be sure that the design drawings are done by competent people. However, we sometimes involve consultant engineers who do not have the necessary experience. We must assign the responsibilities to the right person with necessary qualifications and experience. (...) Prices can change, details can change. This is why we prefer to hire companies as a total contractor. After careful selection we collaborate with the company with the right persons to make the drawings and we work usually together with them. Only then, the quantity calculation can be more accurate and correct. The client must do the same."

A BIM manager was asked if there is any way to avoid hiring an incapable participant in a project:

"In order to ensure the right choice, we must be more specific. We must define clearly specific requirements concerning competences, relevant experience and duties of each person. The more specific you are in your demands and requirements, the easier to make them understand early their responsibilities. And also you need to have a detailed and careful evaluation to get the quality you need. Never go for the lowest cost because the worst consultants and the worst sub-contractors are always the ones who are prepared to dump the prices."

Partnering contracts

BIM implementation can be facilitated by project delivery methods and contracts that encourage collaboration of project participants and integration of different disciplines. IPD is the project delivery method that encourages the integration of all disciplines in early stages in order to maximize the benefit of better design decisions. Furthermore, partnering is the contract type that encourages collaboration and active involvement, and realizes sharing of profits and risks among participants. Some individuals highlighted the importance of partnering contracts which facilitates the active involvement of the contractor in the design phase and the integration of his technical knowledge.

Concerning the potential benefits of the partnering contract, an engineer who works for the contractor and has the role of the design manager identified factors that can affect the design and the total project cost. According to his perspective, the active involvement of the contractor and the site manager can employ their technical knowledge concerning construction processes, reduce the cost and increase the efficiency of the construction:

"If the site manager has not been involved in the design and the construction phase has started, the models are completed and the design solutions may be inefficient and expensive and not comply with the contractor's usual way of working. This happens because designers do not consider the fact that contractors have a certain way of

building. (...) New type of projects requires that site manager should be more involved during the design phase than they are today and have a more active role. (…) *Clients prefer to collaborate closely with the contractor in order to integrate their experience and knowledge about construction and prices etc.*

In the case of partnering contract, the contractor being represented by the design manager and the construction manager work closely with the client's project manager. They form a team who drives the project. It is a rather innovative way of working, a partnering approach with benefits and demands:

"We have a partnering contract with the owner of the project and we start the project together from the very beginning. The contractor shall be involved very early in the design phase and helps the client to do the design. The contractor may be involved 6 months earlier than in a non-partnering project. The design manager, the construction manager and the client work together and make decisions as a team. We both gain time and money by having a better tendering procedure. The client prefers to involve the right people. The reason that client has chosen this contract type is to get much better product and hopefully the cost of maintenance and facility management will be less at the end. It requires a lot of work and time, it may not be easy but hopefully it may be the best for both the owner and the contractor. The first partnering project may cost more than the next one."

5.4.4 BIM Project Execution Planning

Determine BIM goals and Uses suitable for the project

An interviewee highlighted the importance of detailed project execution plan and careful selection of level of BIM implementation and BIM goals:

"Every project is unique. Each project has its own demands and there is no need to spend money for full implementation of BIM. In other words, different project types and owners derive different value from BIM. Therefore when managers are called in the initial project phase to define the project requirements, they have to specify which capabilities of BIM are necessary to be used for the design and execution of this certain project."

Assign new responsibilities

At this planning procedure responsibilities and roles are defined. There are new roles and different responsibilities in a BIM project. Some interviews acknowledged these differences:

"Before BIM, in the project team it was the design manager responsible for the coordination of all the design. He takes all this kind of decisions. It was not a BIM issue at all. Now with BIM we have a new tool to help us to view these issues in 3d. There are new tasks. And with collision control, you can identify more easily overlaps and other clashes. But the responsibilities may still belong to the design manager. In the BIM model, it can be described who is responsible for each object. Information can be added to define who is responsible and who owns the object."

Early integration of key participants

An engineer who usually has the tasks of analysing visualization and collision coordination and is getting involved at the conceptualization phase of BIM projects recognized the significance of key participants' integration at the early design phase:

"I would demand to have all the disciplines involved in the design phase and in the collision coordination such as architectural, structural, mechanical, electrical, plumbing, ductwork, building services. I would also like to involve prefabricated elements in the model. Today the prefabricated models are not so involved in the design phase, because they require a lot of information and thereby they prefer to come in later in the design phase. This is important in my opinion since the usual problems in the construction site occur due to problems with the prefabricated objects. (...) So if I was in client's position, I would set clearly this demand in order to make sure that every discipline is inside the model."

BIM info delivery plan and project execution

It was pointed out by a BIM manager that it is important to have a BIM info delivery plan. This plan should state who has to deliver what in the model and when it has to be delivered. Working according to an info delivery plan should increase collaboration between different designers with better efficiency.

Define supporting infrastructure

The engineer underlined the impact of supporting infrastructure in the success of the implementation. Responsibilities should be assigned to BIM manager or coordinator to assure that the project execution complies with the client demands, the BIM project execution plan and BIM principles. BIM manager shall also define quality control procedures to ensure high quality information models:

"Once all the requirements are specified, people are hired, contracts have been written and responsibilities and tasks are defined, you must have a process with checkpoints, milestones, effective measurements and controlling checks. However this controlling process may cost very much in terms of working hours, resources and personnel. In order to avoid delays and extra cost in controlling, we must have a precise BIM project execution plan."

5.5 BIM framework and technical aspects

5.5.1 Levels of maturity and stages of implementation

In the case of this BIM pilot project, many interviewees clarified that the very important thing to get from BIM was that they want to implement the use of the 3D BIM model and the visualizations on the construction site. In addition they stated that there is also huge demand of more efficient quantity take-off and cost estimation in the construction industry and BIM can help in this direction.

"It is very important to get the model out on the building site so that the construction workers can see the 3D model. This is an internal demand that we have and *always consider in the design phase in our company. This is significant improvement because the 2D drawings are not easy to understand and people cannot get the whole truth, especially when there are complicated structures or pipes (...) Materials take-off is also very important because everybody needs to get accurate estimation of quantities. BIM can help us with a smarter way to make estimations instead of using measure sticks, rulers and estimations by hand."*

A BIM manager supported that an easy way to start with BIM is the clash control which 3D model can provide. It is a good start because it requires the involvement of many disciplines and is simple and easy to accomplish. It also helps the people to understand better the project since they can have a detailed visual representation of the future building.

An employee of the involved contractor stated that the firm has established a general rule. This rule dictates that if they work as general contractor and the project budget is over certain amount, they have to use BIM and specifically a base BIM package which consists of visualisation, 3D modelling, coordination, collision control or clash detection and the involvement of their firm's BIM coordinator.

At a second level of implementation, a BIM manager supported, it is very important to establish a project file server which enables project participants to exchange information in real time and share the latest updated models. Furthermore they should establish a routine of delivering and integrating models

"This helps everybody to keep up with the current design phase. It also creates better order within the project and enhances the communication. You shall also set up a procedure of deliveries, such as everybody must deliver models on Fridays and everybody can see the changes that have been made. If the BIM manager controls this procedure regularly, then the designers start talking each other. This is the first step for actual communication."

5.5.2 BIM Efficiency: Level of Detail

A BIM manager supported that the right level of detail at the right time can have great significance in the efficient implementation of BIM and these responsibilities shall be assigned to the right person

"Right level of detail in the right time is critical to avoid waste of time and effort. It is crucial for the project budget and the final outcome of BIM utilization. The project execution plan shall define when we need certain level of detail, who shall be responsible for adding this detail and if we have the right person that can use this information. The architects are usually able to form the correct layers but BIM manager cannot demand that they know how to put details in the material properties even if the properties are available in the software and someone can easily set them. This role concerning level of detail should be assigned to a person with experience in these issues."

5.5.3 Interoperability

Software companies have developed programs that are compatible with ifc format file enhancing the interoperability among different programs and disciplines. A BIM consultant described the practice of integrating different software platforms:

"Software platforms can easily communicate and perform information exchanges. Navisworks is a software program where BIM manager can integrate files that were previously exported from different software programs. BIM manager can demand from all the project participants to export their own updated file and share it in Dropbox or other web server. In this way, there is the ability to integrate different models from different disciplines and have the updated model every day or every hour. It is easy if it has been required in the BIM Guidelines"

A BIM consultant supported that there is not any significant technical issues with software compatibility and interoperability nowadays, however not all interviewees agreed on that. This BIM consultant in addition stated that there are no big problems to work with different software programs. The biggest challenge is the human factor.

It is difficult to get people to learn what BIM is about, stop working in a certain traditional way and learn how to collaborate with others utilizing BIM.

"Sometimes we have an architect that says that they have worked with BIM a lot of years and they are really good and when we start working with them we realize that they are not used to work with others, they just know to work with each other inside the company. So when they start to collaborate with others, they don't really know how to do it. For example they should use the 3d model from the electrician, take it into their model and see it. In contrast they reply that they have never done that before. It is more about how we work with the 3d and the information."

Concerning the challenges of ifc files, a software developer supported "

"There are always small problems with each software system, because ifc format is supposed to cover everything. So there are a lot of grey areas within it. So there are issues, but there were many more issues just few months ago. So it is improving vastly. If you are a BIM coordinator, it does not really matter which software someone uses to create the model now. You will be able to make good clash detections, integration of models and coordination no matter which software you use."

5.5.4 Classification systems and IFD

Classification system and the way of naming and identifying objects have significant impact on the facility management. Software technician suggested that it will be very useful for the client to have a detailed list of features and building elements, for instance the type of wall, the type of doors, in order to facilitate the integration of the final model of the building to the facility management system. Therefore if they use a commonly accepted classification system, they can eliminate problems in the final integration and reduce the manual input of information into the facility management software.

Utilizing the international library for object terminology such as IFD does not require extra time and cost for the design phase. The software developer supported that defining the proper way of using IFD at the beginning can save time.

"But if they require BIM details it does not necessarily mean that the project will take longer. It depends. You can provide all this information for the actual objects from the beginning in your object library and then the necessary information continue following the models. Then you just pick an object from the library and you put it on the model of the building to represent a building element. You need more time to prepare an object for the object library but you do not need more time to put the object on the model. But some information that you need to put it into the model during the early phase of course it will take more time."

5.5.5 Information needs for Facility Management

Utilizing BIM clients should consider issues that affect their firm and the facility management and they should focus mainly on their specific needs and profit. Therefore they should pay attention and clearly define their information needs concerning their facility management software system.

"When you start working with BIM as a facility manager, you really need to be specific what info you need, how BIM info are actually going to be handled. As a first step, you require from the consultants to deliver rooms. You need to make them

calculate the areas according to how you define the contracts for the flats. For example, concerning maintenance, if you are going to make changes of floor materials, it will be based on the rooms and their net area. So you need to collaborate with both the facility management personnel and the economic department and specify these information needs."

A BIM manager who works greatly with facility management mentioned that there are two different models that shall be delivered. One is the archiving that clients need to save in its initial form from the project. The second should be alive, interact with the facility management system, accept changes and receive new information, so it shall be kept constantly updated. Therefore these demands shall be clearly defines from the first day of the project, in order to be achieved successfully.

5.5.6 Documentation

Standardizing the process of BIM with BIM guidelines

When asked if it could be wise to standardize the process of BIM with guidelines the answers were not coherent. One interviewee stated that it could be wise but it had to be a strict follow up to make sure that everybody is working according to the processes and the BIM guidelines. Another interviewee said that it could be difficult since the construction industry is so project based and not all projects need the same capabilities. BIM manager stated the following "*Projects are unique and have different complexity and therefore they need different capabilities*." In addition it was pointed out that it would be possible to have some sort of standardized process as a foundation and adjust it to each project.

A BIM manager supported this opinion and declared that BIM guidelines are essential to solve everyday issues. In order to reach the goals that client has set, the BIM guidelines should be in great order and define several issues such as level of detail, information exchanges and deliverables, responsibilities, etc. The BIM manager continued that during the project execution problems occur and they need to adjust and update the guidelines. In order to reach certain level of BIM, BIM manager shall define clear directions.

A BIM consultant declared that the weakness of BIM guidelines is that the guidelines has not any legal force and it is considered more as a guide for the design team. Therefore there is great need to define also the responsibilities and other significant issues in the contracts.

5.6 Barriers and Challenges

During this study, interviewees expressed their concerns about BIM implementation and highlighted the difficulties they face to understand the value of BIM utilization and the potential benefits of BIM in comparison with the value of traditional methods.

According to the opinion of several interviewees the main challenge of BIM implementation was the resistance to change the way of working and adapt to a new workflow. It can be seen in the theoretical framework that BIM technology implementation not only requires learning new software applications, but also requires learning how to reinvent the workflow, how to train staff and assign responsibilities, and the way of modelling the construction.

It was often observed that the persons with longest experience in the construction industry were more conservative, were narrow minded and showed the biggest resistance to adapt to the new disciplines of BIM. Thus they hesitate to take initiatives in this new era and they expect to follow only the traditional procedures. An experienced site manager said when asked about BIM and challenges:

"Well it is new for me but I have been working for 30 years, so I always do the same as I always do, if you are old you cannot change."

The same person was not completely against the BIM implementation but he was not willing to be the person who leads the change. He pointed out that the model can possibly reduce the cost, but making the 3D model can cause a lot of expenses too. In addition, he claimed that possible defects of the drawings can be effectively fixed on the construction site by experienced workers, reducing the necessity of using BIM:

"It depends on how skilled the people working on site are. If they know how to do things it is cheaper".

5.7 Risks of BIM implementation

Legal and technical issues

Another main issue that was discussed with the interviewees was the legal issues of contracts and responsibilities that must be assigned to the designers of BIM models. It was mentioned that contracts have not been developed so much and a lot of time is needed to reach a common ground.

"The current contract does not allow the 3d models to be master. The contracts are all based on paper and drawings. That are many issues about the status of the objects inside the model, who owns what, who has the right to change what. All these things are a big grey area. And there are things being investigated within the building industry to improve this, but it takes a lot of time."

When asked about technical issues, the main topic addressed was about software incompatibility and the difficulties that could occur when different designers use different software's. A BIM developer stated that everyone could export in ifc format and in that sense the software is compatible. Another BIM manager stated that he had witnessed too many times in his profession where import and export with ifc had not worked properly and people are wasting valuable time on this. In addition he pointed out that this could be avoided if all designers in the project could agree on common software to use.

6 ANALYSIS AND DISCUSSION

The interview results together with the academic knowledge gained through the literature review provide a safe ground for the authors to base and articulate their ideas and develop a discussion about the significant issues of the subject area of BIM that clients should focus on.

6.1 Building Information Modeling BIM

6.1.1 The BIM concept and different perspectives

The conduction of interviews confirmed the existence of different perspectives about the meaning of BIM and its mission among professionals and experienced actors. Persons with greater experience perceive BIM as a broad concept meanwhile persons dealing with design perceive more as creation of 3D models.

The conduction of interviews also demonstrated the need of a common definition in order to help the project participants to have a better sight of the new work process and understand their new responsibilities. The client shall ensure that all actors in a project are working with the same understanding of BIM towards the same common goal.

The thorough and precise definition which has been expressed by BuildingSMART (2012) and used in the theoretical framework of this report can support the project participants to form a solid idea about BIM and its definition.

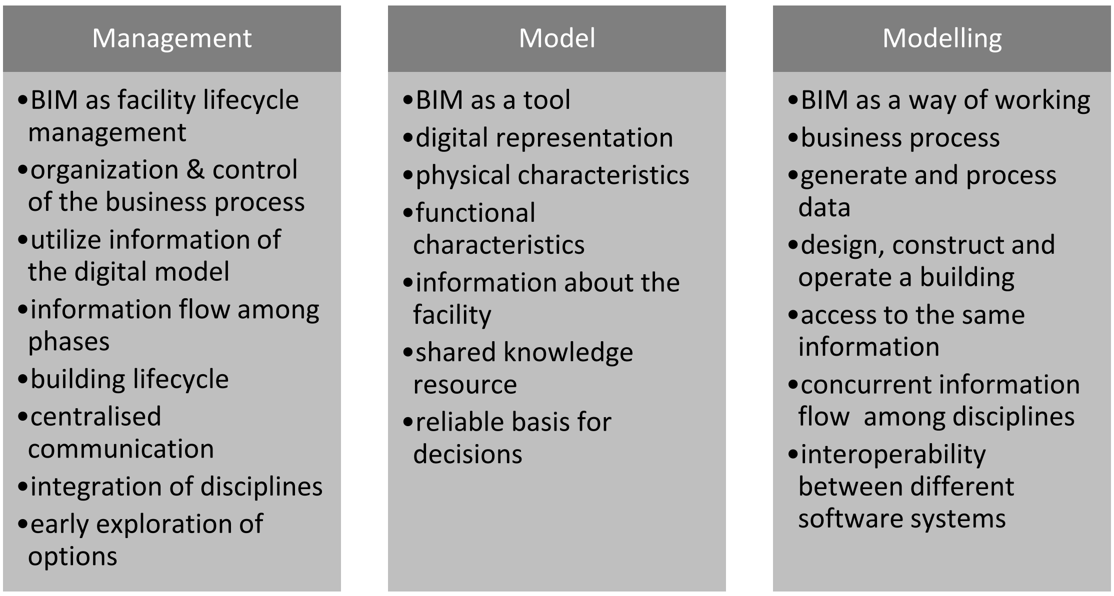

Figure 13: Definition of BIM **(BuildingSMART, 2012)**

6.1.2 BIM and Integrated Project Delivery IPD

Several interviewees highlighted the importance of early involvement of key project participants who will work in a more collaborative environment in order to maximize the value of BIM implementation. The interviewees supported that following the principles of IPD can optimize efficiency of the project delivery and BIM implementation.

Many of the interviewees agreed on that designers should make early decisions and key participants should be involved from the beginning. In addition the design phase may take longer time but most of them were aware of the significant effects and benefits on project performance.

The results from the interviewees are supported by the American Institute of Architects (2007) where Integrated Project Delivery (IPD) is described as a workflow which utilizes new technologies such as BIM and can optimize efficiency. It empowers the project participants to contribute with their knowledge and expertise earlier in the design process than traditionally (The American Institute of Architects, 2007).

The American Institute of Architects (2007) furthermore declared that in order to achieve the IPD benefits, project participants should adopt the IPD principles which were elaborated in the theoretical framework (The American Institute of Architects, 2007):

- Implementation of Appropriate Technology
- Utilization of BIM
- Open Communication and Transparent Processes
- Early Involvement of Key Participants and Early Goal Definition
- Collaborative Process
- Intensified Planning
- Contracts encouraging involvement of key project participants

6.2 BIM Uses and benefits

6.2.1 BIM Uses and Capabilities

There were not many capabilities that were directly mentioned in the interviews. However the emphasis was more on the process of carefully choosing what capabilities should be used for the project and that it should be directly connected to the complexity of the project. Some of the Capabilities that are described in *Chapter 2, Section 2.2.1* were mentioned during the interviews like visualization, clash detection, cost estimation and various analyses, however none of the interviewees was prepared to say or prioritize what capability should be used in all projects. The main reason for that was claimed to be the environment of the construction industry where each project is unique. The interviewees furthermore stated that it is important for the client to choose the right capabilities and use small steps to continue learning from each project and do evaluation after each project. Comparatively big steps shall not be taken at a time because that can cause a failure and loss of money for the client.

6.2.2 Benefits

The possible benefits that an organization can gain by implementing BIM are many. However as the results from the interviews stated all of them do not appear right away and will be seen later on in a building lifecycle. Some of the key benefits mentioned in the interviews are in accordance to the theory elaborated in *Chapter 2.2, Section 2.2.2.* The most discussed benefits were visualization at different stages of a project lifecycle. It was considered as one of the most important benefit since it helps different actors at different stages to communicate and understand better the project. It furthermore helps the client to sell the product and makes it easier to communicate the construction to different stakeholders (Cooperative Research Centre for Construction

Innovation, 2007). Better design with less error was as well mentioned and that can help all actors to save money and time in a project. Another benefit that was considered important was clash control that helps to mitigate the risk of solving problems on side that can be expensive and not always the best solution. However it must be considered that capabilities and benefits go hand in hand so while considering what benefits you want to get from BIM the right capabilities must be present to get those benefits.

6.3 Governing the BIM implementation

6.3.1 The role of the construction client

The role of the construction client is one of the most important roles in a construction project as the client is responsible for the success of the project and ensures that the right actors are chosen for the delivery of the project.

The majority of the interviewed individuals recognized the importance of the role of the clients in the successful implementation of BIM. Clients have a key role to play in adopting BIM on construction projects. By following the principles identified in this report, clients can provide the necessary conditions for BIM to be highly effective and for the considerable potential benefits to be realized.

The interviewees demonstrated that the client should establish standard working procedures towards BIM implementation in order to maximize the value of BIM implementation. The authors' opinion is that the three directives developed by Bergdahl, et al. (2006) shall be considered while developing these necessary standard work procedures.

According to Bergdahl, et al. (2006) the main roles and responsibilities of the construction client are structured in three areas:

- The construction client shall be responsible for developing a construction project from concept to commissioning.
- The client shall act according to the building lifecycle demands and follow a holistic approach of governing the creation of every building or structure
- the client shall act in a regulatory context

Interviewees suggested that the client shall understand what BIM can provide and ensure that the management team shall choose the BIM level of implementation which is feasible and suitable for each project. Concerning the uniqueness of each project, Bloomberg et al (2012) underlined that it is important for the client to realize that every project requires specific BIM implementation and professional assistance by a BIM manager offers great potentials for a successful project.

Interviewees furthermore highlighted that the most important decision clients shall take is the selection and appointment of the design and construction team. Finding the right team of people with a positive approach to using BIM, to sharing information and above all to learning from the experience is critical.

In this regard, clients should expect all their consultants, contractors and specialists to be familiar with BIM and its requirements; to be positively engaged in its adoption and to be actively developing ways in which processes can become more effective and efficient. In addition, clients should take initiatives and set proper and clear demands in a BIM project in order to create stronger incentives for the rest actors to follow the development.

6.3.2 The role of the BIM manager

The importance of the BIM manager was emphasized by the interviewees. The latter stated that the BIM manager could be considered a key person to achieve a successful implementation of BIM, which is in accordance with the view of Bloomberg, et al. (2012). The interviewees supported that the BIM manager works as the contact person between the client and other project participants and ensures that the client can understand what BIM capabilities are needed and feasible for the project. Furthermore the BIM manager is responsible to coordinate BIM meetings and ensure that BIM tasks comply with schedule and BIM project execution plan. Therefore it could be wise for the client to involve the BIM manager as early as possible in a project to get the most from his professional experience and knowledge.

BIM is currently providing benefits as a better and more efficient tool for design and construction. However some interviewees stated that building owners and clients are still unaware of BIM methods and business benefits it can provide to their firm. Thus, it appears to be a need for providing professional guidance to clients.

An interviewee stated that a BIM manager having the knowledge and experience in BIM issues can serve as a professional guide that will support the client to implement BIM. This is in accordance to what Bloomberg, et al (2012) argues where it is stated that the BIM manager shall have the overall responsibility for the appropriate implementation of BIM. Furthermore the BIM manager shall support the client and project management team to drive the necessary changes, to create the contracts and the BIM guidelines, and to assure that the project will comply with both the client demands and BIM principles (Consulting Oy, et al., 2012).

6.4 BIM implementation plan

The interview findings give a better view of the BIM issues concerning real practice. Secondly, the theoretical framework of this thesis provides the fundamental knowledge that the client should have about BIM and its implementation. Having a better knowledge and understanding of all these BIM issues, the client can then have a better perspective of this approach of BIM implementation elaborated in this thesis.

Most of the interviewees elaborated ideas that were in agreement with the directives of implementing BIM that were brought out through the literature review of this thesis and were described in the theoretical framework. In addition, BIM Managers analysed and suggested actions that relatively comply with the concept of the four planning procedures which were reviewed in the theoretical part of the thesis.

This thorough and concrete approach of implementing BIM through four planning procedures developed by Messner, et al. (2012) can provide a comprehensive action plan defining all the actions necessary for successful BIM implementation.

This detailed list of needed actions for successful BIM implementation can be used by the client as a checklist that facilitates the implementation process (see appendix *Chapter 9*). It can be considered an effective and easy to follow guide for the client to implement BIM.

Four levels implementation plan

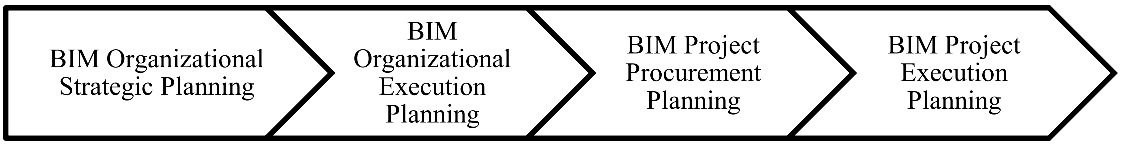

Figure 14: Implementation plan **(Messner, et al., 2012)**

6.4.1 BIM Organizational Strategic Planning

The interview findings highlighted the importance of the fact that the client shall primarily focus on the organizational issues and the first aim shall be to form an effective strategy for implementing BIM into organizational processes. The project management team of the organization shall be responsible for the design of this procedure and direct changes in order to ensure that the organization is ready for the BIM implementation, taking into account the available and the planned resources. They further stated that the management team should define the organizational goals and BIM implementation strategy. These directives mainly correspond to the objectives of the first planning procedure developed by Messner, et al. (2012).

Interviewees also supported that organization may choose to engage external BIM professionals or develop strategic partnerships with specialist consultants. In this phase the project management team needs the support of consultants with expertise and relevant experience in BIM projects. Interviewees highlighted that the client can benefit from BIM manager’s knowledge and increase his awareness on BIM capabilities and important factors of BIM implementation. Furthermore, they suggested that the client shall direct and organize the project in close collaboration with the BIM manager, a person who shall work directly for the client. A BIM manager is necessary to facilitate all the BIM processes and assist the client to form a strategy. He can also help the management team to identify areas that need to be improved and aspects they would like to develop in the future.

The following sections are categorized into three consecutive steps which are connected to the Organizational Strategic Planning mentioned in *chapter 2.4.1.*

1. Assess existing organizational conditions

One of the most important objectives of this phase that was highlighted by the interviewees is to assess existing organizational conditions, which is in consistency with the approach described at the theoretical framework. Interviewees underlined that client shall evaluate the organization processes in order to identify areas that need change and assist the progress of BIM implementation. Interviewees also pointed out that the effective BIM implementation requires changes in the way AEC organizations work, concerning several levels within the design, construction and operation process.

2. Establish Desired Level of Implementation

Concerning the second objective of the guide of Messner, et al. (2012), which specifies that the client shall establish desired Level of Implementation and determine the degree to which the organization will implement BIM, interviewees suggested also that the client shall be in close collaboration with the BIM manager and make decisions together about the desired level of BIM implementation and which BIM functions they should utilize. They advised that even though the end-goal may be ambitious, it is important to establish achievable milestones and initially pursue the easily achievable goals of BIM, such as 3D coordination and clash detection that yield the greatest return for the minimum effort.

3. Develop Advancement Strategy; a transition plan to implement BIM

Furthermore, interviewees stated that client and BIM manager shall develop together a clear set of guidelines and design a specific roadmap outlining an effective strategy and methodology for achieving BIM integration and establishing new ways of working. This is in accordance with Messner, et al. (2012), which defined that the third objective of the client is to specify clearly a strategy and determine a transition plan with certain actions for the integration of BIM into organizational business practices.

Interviewees pointed out that this new strategy may affect many organizations levels and hence they shall take into consideration the specific characteristics and needs of the organization. Their suggestions comply with the idea that limitations, barriers and risks shall be clearly defined and actions shall correspond to the size, resources and needs of the organization (Messner, et al., 2012).

An analytical checklist with suggested actions is described at appendix chapter 9.1.

6.4.2 BIM Organizational Execution Planning

The common belief of most interviewees was that after establishing a strategic plan, the organization shall develop a detailed plan of certain actions for the BIM implementation within the operations of the organization. Interviewees highlighted the importance of defining easy steps and achievable goals in order to drive and facilitate the BIM integration into organization processes, and subsequently follow the strategy. Their suggestions comply with the second planning procedure elaborated in the theoretical framework, which determines that the project management team shall specify certain steps necessary to accomplish the strategic objectives.

Specifically, the directives shall be translated into specific simple tasks and easy-to-achieve projects (Messner, et al., 2012). Furthermore, interviewees also underlined that consistent and continuous communication of the plan is very important for the success of the strategic plans.

The following sections are categorized into six consecutive steps which are connected to the Organizational Execution Planning mentioned in *chapter 2.4.2*.

1. Determine BIM Vision and Objectives

According to the first planning procedure elaborated earlier, the BIM Organizational Strategic Plan has established the broad long term corporate mission, organizational goals and BIM vision.

Consequently, it is now critical to evaluate these organizational mission and goals, and determine if the BIM vision and objectives are achievable within the timeframe of the plan. The importance of this careful evaluation of mission and goals was emphasized by the interviewees, who declared that the management team shall take into consideration the strengths and weaknesses of their organization while evaluating the organizational mission and goals.

Thereupon, it is imperative to formulate clear BIM objectives for the duration of the Execution Plan of a certain project. This approach is in consistence with the suggestions of the interviewees who proposed that BIM goals and objectives shall be aligned to the capabilities, available resources and current needs of the organization. It was further supported that the project management team shall take into consideration many aspects of the organization in order to understand what they really need by implementing BIM into the organization processes.

2. Evaluate Internal BIM Uses

In regard to this step of the second planning procedure, interviewees pointed out that the project management team shall collaborate closely with competent employees and BIM manager and having an internal focus they shall evaluate the internal organization processes. It is imperative for the management team to benefit from the organization employees who have technical and extensive knowledge about the internal operations and facility management. The later shall firstly assess their practices and evaluate which processes can be improved. Consequently they shall determine how BIM can be integrated within the internal organization in order to improve their internal processes.

In respect to the facility management needs of the client organization, interviewees highlighted that BIM manager in collaboration with the technical personnel can decide how BIM can be integrated and improve their current facility management practices. Taking into consideration the organization needs and characteristics, they shall evaluate BIM Uses such as record model, maintenance scheduling, building system analysis, asset management, space management, tracking and identification of building elements, and digitalizing the drawings.

Furthermore, interviewees pointed out that the client can benefit from the technical knowledge of BIM managers about the new BIM technologies and how BIM Uses can improve the organization processes. They supported that evaluating available software solutions is a critical process in BIM implementation, and ought to be undertaken in consideration of specific user requirements. The proper software shall be selected according to facility management criteria. The software shall be able to extract information from the BIM model and store the details in a proper format which is compatible with the facility management systems. IFC, COBIE and Fi2 formats should be supported in order to facilitate these information transactions.

Lastly, at this step it is critical to assess and benefit from the knowledge acquired through past projects. Interviewees highlighted the importance of documenting the BIM level of maturity the organization obtained after the completion of the execution of previous projects. Assessing the outcomes of previous implementation was demonstrated as the best way of improving their BIM practices.

3. Design BIM enabled Process

In the previous step the management team have determined corporate mission and BIM vision, and evaluated how BIM can be used to improve the internal organization processes.

Thereupon, interviewees highlighted the importance of the fact that the client shall have a clear image of the organization processes in order to advance them effectively. Therefore they underlined the necessity to record and document the overall organizational structure and map the existing organizational processes which will integrate BIM, in consistency with the directives elaborated by Messner et al. (Messner, et al., 2012).

Recording and mapping the existing processes in their current state was considered a method of great importance since it can help the client to compare carefully the existing corporate processes with the new BIM processes, get a solid image and thus develop a reliable transition plan for each BIM Use.

It was highlighted that a successful comparison required the technical knowledge of the team responsible for the facility management and the technical knowledge of the BIM manager on the capabilities and requirements of BIM technology.

Lastly, it was considered imperative for the client to employ a transition plan for each BIM Use, since the latter constitutes an effective way to map the new BIM processes, determine directions for each BIM Use and document the future process for each operational activity (Messner, et al., 2012).

4. Document Internal Model and Facility Data Information Needs

The interviewees highlighted the importance of the role of the facility management team for this step. The team responsible for the facility management shall focus on the internal organization processes and document the operational information needs.

It was considered of great importance the fact that facility management professionals shall define all the information requirements including both the Geometric Model and Facility Data Needs. Specifically, they shall include the necessary objects' attributes for the digital models and secondly specify the software requirements concerning compatibility and interoperability. Interviewees stated emphatically that this team shall have the expertise and the necessary skills to specify clearly what kind of information they need in their internal processes

Moreover, interviewees pointed out that it is critical to implement these facility information data needs and requirements into project demands and document both of them into contracts and manuals. Many of the interviewees agreed on that it is preferred to define clearly these requirements at the contracts and project manuals at the early beginning of a project.

5. Determine Infrastructure Needs

Interviewees supported that the management team shall collaborate closely with the facility management team in order to define how the firm uses information and what resources are needed for this aim. It is also important to define a precise way of expressing information which is required in order to successful implement BIM inside organizational processes.

Respectively, the management team taking into consideration the available and planned resources shall collaborate with the facility management team and the BIM manager and determine operational infrastructure needs including hardware, software, and physical spaces.

Many interviewees complied with the idea that infrastructure needs shall be also considered the necessary BIM uses, processes, and information needs.(Messner, et al., 2012)

6. Determine Personnel Needs

Interviewees pointed out that BIM implementation necessitates a new way of working and thinking. Implementing BIM within the organizational operations requires changes in personnel roles and responsibilities.

Respectively, clients and management teams shall reconsider the organization personnel needs in order to facilitate the BIM implementation. Concerning personnel needs, they shall consider changes in the organizational structure, new roles and responsibilities, training of the existing personnel or hiring new professionals with the necessary expertise and experience.

Interviewees illustrated that one of the most critical factors of successful implementation and integration of BIM is having the proper personnel. Therefore, professionals shall adapt to the new changes and develop themselves in order to follow the market trends and remain competitive.

An analytical checklist with suggested actions is described at appendix *Chapter 9.2*.

6.4.3 BIM Project Procurement Planning

The interviewees supported the idea that it is critical for the client to develop a clear procurement strategy. Specifically, the client shall develop early the contract documentation where project requirements, client demands, BIM needs and other key contractual issues shall be addressed and clearly defined.

Interviewees declared that the contract documents and manual shall specify clearly and in great detail all the project requirements concerning both client and BIM demands in order to give better directions to the project participants and control more effectively their performance. In this manner the client can determine the direction of the project in advance. Accordingly, the client shall establish the proper procurement language in order to ensure that the project participants understand the client's needs and the scope and details of the project requirements (Messner, et al., 2012).

Furthermore, interviewees pointed out that it is imperative to document the BIM needs, demands and specifications in advance of the project initiation, since it gives the possibility to the project participants to start the BIM processes earlier and increase their effectiveness.

Many interviewees recognized the uncertainty of controlling the investment for BIM implementation and its outcomes. Respectively, interviewees supported that the client shall choose an appropriate contract type that can facilitate BIM implementation. They further stated that a contract type that encourages the collaboration between participants towards the common BIM goals and defines the share of benefits and risks is the best way to drive the change and motivate everyone towards changing the way of working and adopting BIM principles.

Concerning the most appropriate contract type for facilitating BIM implementation, some interviewees agreed with the directives developed by Messner et al (2012). According to their directives, adopting the principles of the IPD approach empowers early involvement of key project participants. In this manner, project teams can incorporate their knowledge earlier, assisting the BIM integration. This early collaboration can affect their way of working and interacting (Messner, et al., 2012).

Likewise, some individuals highlighted the importance of partnering contracts which facilitate the active involvement of the contractor in the design phase and the integration of his technical knowledge towards better integration of BIM in design and construction phase. Respectively, new contracts are required that encourage close collaboration, sharing of information, sharing profits, sharing risks and setting fees (Eastman, et al., 2011).

BIM project procurement planning comprises three areas in which the client shall emphasize while developing the contract documentation.

The following sections are categorized into three consecutive steps which are connected to the Project Procurement Planning mentioned in *chapter 2.4.3*.

1.Team selection

Many of the interviewees highlighted the importance of careful selection of the right participant with the right expertise in a project. This is considered the greatest factor on whether the project will be successful or not.

In addition, it was considered of great importance the fact that the management team shall assign responsibilities only to competent and engaged people who knows to work with BIM and are willing to follow this new BIM practice. In this way the client can maximize the benefits of BIM.

Based on the literature review, the request for qualifications is a proposed contract document that client shall use to determine the necessary BIM experience and expertise that potential project team members shall have. (Messner, et al., 2012).

Concerning the cost of BIM services, the majority of the interviewees supported that in many cases the client decided to choose the cheapest professionals even though this choice can cause various problems in a project. They argued that professionals willing to dump their services price are those who do not have the adequate experience and qualifications about BIM.

An interviewee suggested that there shall be a strictly structured tender process with a detailed and careful evaluation where the participants are evaluated based more on their qualifications rather than on the cheapest offer. Based on literature review, for this purpose, it has been developed the Request for Proposal which is a proposed contract document that can provide the client with a clear image regarding the cost and description of the suggested BIM Uses. Thus the client can have a trustworthy estimation of the expenses necessary for the effective performance of BIM Uses (Messner, et al., 2012).

2.Contract procurement

In the case of a typical contract, the clients develop contracts where they shall document the standard client requirements and project goals. In the case of BIM, they shall additionally develop BIM contract where they shall document the standard BIM organizational objectives, aiming to drive the participants concerning the BIM implementation.

Most of the interviewees pointed out that it is critical to develop contract documents where specific project requirements are clearly defined concerning competences, necessary experience and responsibilities of each person. In this manner the clients can ensure that they make the right choice and avoid hiring wrong person. Besides, the client shall be very specific and precise in documenting his needs and demands at the procurement process, in order to help the candidates to understand early their duties.

Later on, the BIM Project Execution Plan will be developed at the fourth planning procedure and shall document with precision the BIM requirements for each specific project (Messner, et al., 2012).

3.Execution requirements

Interviewees stated that at current practice, typical BIM Project Execution Plan Templates have started being used for the procurement planning. These templates are predefined by professionals with relevant BIM experience. The role of these templates is significant since they can serve as a structured basis for the BIM Project Execution Plan and determine most of the necessary client information needs and requirements, such as data requirements for facility management systems (Messner, et al., 2012).

The interviewees underlined the importance of the templates' role since they can facilitate effectively the development of the BIM Project Execution Plan. It was also highlighted that all project participants shall contribute to this plan development at the same time as they get involved in the project.

Interviewees also pointed out the second role of the typical BIM Project Execution Plan Templates which is to further help the client with procurement strategy and facilitate the evaluation of the potential participants. This can be accomplished because the templates help the client to understand if actors are capable of performing the objectives of BIM project execution plan (Messner, et al., 2012). Concerning this manner, the interviewees declared that the client needs the assistance of BIM professionals to evaluate effectively the capabilities and qualifications of actors regarding BIM expertise and experience.

Since the development of the BIM Project Execution Plan has been completed, the client shall decide the formal approval and attach it to the contract as appendix (Messner, et al., 2012).

An analytical checklist with suggested actions is described at appendix chapter 9.3.

6.4.4 BIM Project Execution Planning

Most of the interviewees supported that in a BIM project it is necessary to have a structured way of executing BIM processes. Therefore it is imperative to follow the BIM Project Execution Planning procedure which is a structured method to design the execution strategy for BIM in a project. Specifically, it is a detailed plan that contains the BIM requirements which are set by the client and are specific for each BIM project. It furthermore describes how a project shall be executed, supervised and organized concerning BIM processes.

It is imperative to manage effectively the creation and process of the digital BIM models. Therefore it is critical to assign responsibilities and roles to project participants for these tasks. Regarding these issues, the BIM project execution plan shall define the exact content and the proper time of each information exchange. Only with proper data management and clearly defined information plan, they can improve the efficiency of communication and collaboration in the project.

In order to further develop the BIM Project Execution Plan, it is essential to form a planning team at the early stages of a project. With a cooperative process, the team shall agree on how, when and to which extent BIM can be used to support the project outcome and goals. Representatives from all the primary project team members should participate including the client, designers, contractors, engineers, major subcontractors and facility manager (Messner, et al., 2012).

The following sections are categorized into four consecutive steps which are connected to the Project Execution Planning mentioned in chapter 2.4.4.

1. Identify high value BIM goals and uses for a project

One of the most important objectives of the BIM planning procedures which were highlighted by the interviewees is to clearly define the overall goals of BIM implementation. Thus the management team shall define the overall goals in the early beginning of the planning phase of a BIM project.

In consistency with the planning procedures elaborated at the theoretical framework, interviewees described that the overall BIM goals mostly concern project performance such as increasing efficiency or productivity of the processes, shortening the project length, enhancing quality of product or services, decreasing cost impact of changes, or producing valuable operational data for facility management

Consequently, the planning team shall afterwards identify the most appropriate BIM Uses for each particular project. In this process they shall consider the specific project characteristics, client demands, available resources, participants' capabilities, and the desired risk allocations.

Interviewees declared that the above issues necessitate great expertise and experience in BIM practices. Therefore, in order to achieve reliable identification of BIM goals and BIM Uses, the contribution of BIM manager is critical. Clients shall benefit by employing a BIM manager who shall work directly for the benefit of the client company.

2. Design the BIM project execution process

After identifying each necessary BIM Use, the planning team shall design a detailed process map for the implementation of each BIM Use during the entire project.

The interviewees commented that this process map has significant role since it can help the project participants to comprehend the content and scope of each information exchange and to effectively perform their tasks. Furthermore, they highlighted the fact that the process map can indicate the sequence and interaction between the primary BIM Uses on the project. Due to these two outcomes that the process map can produce, it can subsequently help the team members to understand how their work processes interact with the processes performed by other team members (Messner, et al., 2012).

Interviewees highlighted that process map, relationship maps and process flow charts can provide great assistance for a smooth cooperation among project participants, identifying steps, relations, sequences and interactions. However, they declared that the creation of the BIM process map requires great knowledge and previous relevant experience in similar subjects.

3. Develop Information Deliverables and Exchange Requirements

After the development of the process map, the planning team shall design an Information Exchange Worksheet to shall identify the information deliverables and exchanges which will be shared between multiple parties

Interviewees espoused this approach and supported that it is important for the team members to clearly understand the information content for each information exchange transaction. They further underlined that the author and receiver of information transactions shall be able to understand what information is necessary to deliver for each BIM Use.

Interviewees stated emphatically that by mapping BIM processes and defining the precise information necessary to successfully carry out tasks, successful BIM implementation can be realized.

Many interviewees highlighted also the significant role of the Information Delivery Manual (IDM) which ensures that the relevant data are communicated in such a way that they can be compatible with the receiver's software. They demonstrated that IDM is a standardized methodology that defines how to capture, document and specify processes and information flow between parties during the lifecycle of a facility.

Respectively, interviewees supported that it is critical for the efficiency and success of BIM implementation to define the level of detail needed at a particular stage of a BIM project. For this aim the Information Exchange Worksheet shall clarify when and what information is needed to implement a BIM process

4. Define supporting infrastructure for BIM implementation

The planning team shall define the supporting infrastructure which is necessary for the BIM implementation throughout the project. For this purpose the planning team shall determine the delivery structure and the communication procedures which shall be followed during the creation and process of the information.

Interviewees highlighted also the importance of appropriate contract documentation and language. Clearly defined demands and specifications can significantly support the BIM implementation during the project execution.

Regarding technology infrastructure, many interviewees declared that choosing the compatible software with ifc formats and international classification standards can facilitate BIM implementation and smooth collaboration among actors.

Moreover, interviewees supported that it is critical to determine quality control procedures in order to ensure high quality information models and reduce deficiencies.

An analytical checklist with suggested actions is described at appendix chapter 9.4.

6.5 BIM framework and technical aspects

The technical issues addressed by interviewees concerned only ways of transferring information between actors and possible ways of storing them properly. There were not any concerns about available software and their capabilities.

The IFC format was the format that most interviewees mentioned. However it was not all interviewees who agreed that IFC is the most suitable format to use. However, the IFC format is the most common format used to transfer information between actors in the construction industry. It is furthermore a neutral format that most software can read. Another format mentioned from the interviewees was the fi2 format which can extract information from a BIM model and transfer it to a facility management system. This fact could be of great interest for a facility management company and convince them to utilize fi2 and develop further (Föreningen för Förvaltningsinformation, 2006).

Another matter that was discussed was the possibility to link the BIM model to a classification system like the Swedish BSAB where each object has its own id number so all actors can know what that object contains. This method could be of a great interest for all actors in a project since the main purpose of a classification system is to create a common language between different actors with the industry.

The idea of using a BIM cloud to store information during a project was also brought up in the interviews and is that method used in many projects today and could be a feasible choice to use. The main benefit of using a cloud is that it can merge and filter the BIM-model and generate IFC files right away (Open source Building Information Modelserve, 2013).

6.6 Barriers and Challenges

The main concerns of the interviewees when talking about barriers and challenges related to BIM implementation was that the actors in the industry did not understand the value that BIM can offer and that they were too narrow sited since they could not see why they should spend the extra effort on doing it this way instead of the old traditional way. This reflects the barriers and challenges mention by Arayici and Khosrowshahi (2012) where they describe the main barriers and challenges. The main challenge and barrier seem to be the lack of understanding and a resistance to make a change and other factors that can be directly related to these facts. Another matter that is addressed is that organizations lack the capital to invest in proper infrastructure to be capable of implementing BIM properly.

The fact that creation of the 3D-models is expensive was also argued in the interviews and can that be an obstacle for smaller organizations. However if the processes with the BIM method are done effectively it should outweigh that cost and save time during construction and therefore money as well. In addition it was seen from the results that there was some resistance to adapting to the BIM methods. This resistance was mostly among those who had been working the longest in the industry. However as Hartman and Fischer (2009) state some resistance is needed to make the implementation of a construction IT successful within a project.

According to the opinion of several interviewees the main challenge of BIM implementation was the resistance to change the way of working and adapt to a new workflow. It was highlighted by many academic reports that BIM technology implementation not only requires learning new software applications, but also requires learning how to reinvent the workflow, how to train staff and assign responsibilities, and the way of modelling the construction.

Implementing BIM requires a fundamental shift in working practices compared to the traditional design and collaboration process. BIM is about changing the workflow for the future. It requires effort and leadership to move teams forward from established tried and tested traditional delivery methods. In many ways it’s about changing hearts and minds, moving people out of their comfort zones into new ways of working and thinking.

6.7 Risks of BIM implementation

Legal and technical issues

The main risks that the interviewees expressed their concern about was that the contracts that are related to BIM are not developing fast enough and that it is not clear enough who is held responsible if something goes wrong, where they stated that the rights of the model is not strong enough. This argument is supported by Thomson and

Miner (2006) where they express their concerns about the contracts and the ownership of data in the models.

The contracts seem to be developing to slowly compare to the enthusiasm of the industry to implement the BIM methods. When technical risks are considered the main problem seem to be the use of different software's where interoperability problem occurs where people are using different software. In this context the IFC format was the most mentioned to be the solution to this problem, further discussion about that can be seen in *Chapter 6.5*.

Azhar, et al. (2008) argued that this interoperability risk can be mitigated by stating in a contract what software will be used in a project. However that might cause some problems since organizations that might have invested in different software's might feel like they have lesser chance of getting a project due to the choice of their software. Another angle of this is that this can promote one type of software over another and vendors might feel like they are being discriminated.

7 CONCLUSION

This chapter will cover the conclusion of this thesis by addressing the research questions. It ends with a revised proposal that can help the client to follow while governing the BIM implementation.

7.1 What main aspects should the construction client consider when governing the BIM implementation process?

The BIM implementation process can be considered a rather complicated process for an organization that has limited knowledge and experience from BIM. However by taking into consideration the main aspects the process can be made easier. It is important for the organization to understand what BIM is and to have a common goal to work towards. In addition there are many other aspects that the client has to look at. It is significant for the client to realize what are its main roles and responsibilities in a project. Furthermore the client has to create strategies where it is described how the organization aims to work with BIM and how it will execute a BIM project. Another important aspect to consider is the selection of project participants and what contract is the most suitable for the project and the organization. The emphasis on the creation of a BIM Guidelines should be high for the client. These Guidelines should be developed as the organization gains experience in practicing BIM. When creating the BIM Guidelines it is wise to get assistance from a BIM professional like a BIM manager. Additionally it is important for the client to get familiar with the technical aspects of BIM to gain deeper understanding of what the organization can benefit from BIM. If the construction client takes all those aspects into consideration it will be better prepared for risks and the process of implementing BIM should be easier and more likely to succeed.

7.2 Which processes should the client follow in order to implement BIM effectively?

Firstly, the theoretical framework of this thesis provides the fundamental knowledge that the client should have about BIM and its implementation. Secondly, the interview findings give a better view of the BIM issues concerning real practice. Having a better knowledge and understanding of all these BIM issues, the client can then have a better perspective of this approach of implementing BIM elaborated in this thesis and be able to utilize effectively the described planning procedures.

These four planning procedures can be considered as an effective and easy to follow guide for the client to implement BIM since it defines analytically all the actions necessary for successful BIM implementation (see appendix chapter 9).This detailed list of needed actions can be used by the client as a checklist to facilitate the implementation process.

7.3 What are the potential benefits that a client can get from BIM implementation?

The benefits that an organization can get from BIM implementations are many. However, it is important for the organization to realize that each project is unique and therefore the need for each benefit should be considered before entering a project. By keeping this in mind, the client can choose from various benefits that are mentioned in *Chapter 6.2* and *Chapter 2.2* but of course it is not a complete list of all BIM benefits available. Benefits like visualization, clash control and better design can be considered the most common one. However each project is unique and therefore the client should evaluate what benefits are suitable for the project and how much they cost. The client should furthermore consider getting a professional assistance from for example a BIM Manager to help him to understand better what each benefits can deliver and what benefit it should focus on to be able to develop that skill further within the organization.

7.4 What are the possible challenges and risks that a construction client should consider while implementing BIM in a construction project?

The challenges when implementing a new method like BIM in an organization are many. However the main challenge that was observed during this study is that the actors in the industry do not understand BIM enough to realize the value of BIM compared to the traditional way of executing a project. Another challenge that was addressed is the fact that the initial cost is too high for smaller organizations and it can be difficult for them to have the initial capital to be able to implement BIM. Risks that the client might face while implementing BIM can be put into two categories, contractual and technical. For a construction client like Poseidon the contractual risk can be considered more important. However it is still important for them to understand the technical risk that might occur and therefore it might be wise for the company to get professional assistance to be able to understand and mitigate those risks. Further discussion about the challenges and risk can be seen in Chapter 6.6 and 6.7.

7.5 Revising the BIM implementation process

This proposal that is presented in ***Figure 15*** is a combination of results from the interviews and material from the theoretical framework. It furthermore reflects the authors' opinions on how the client can execute the BIM implementation process and should help the client to better understand the BIM implementation process and guide the client through it.

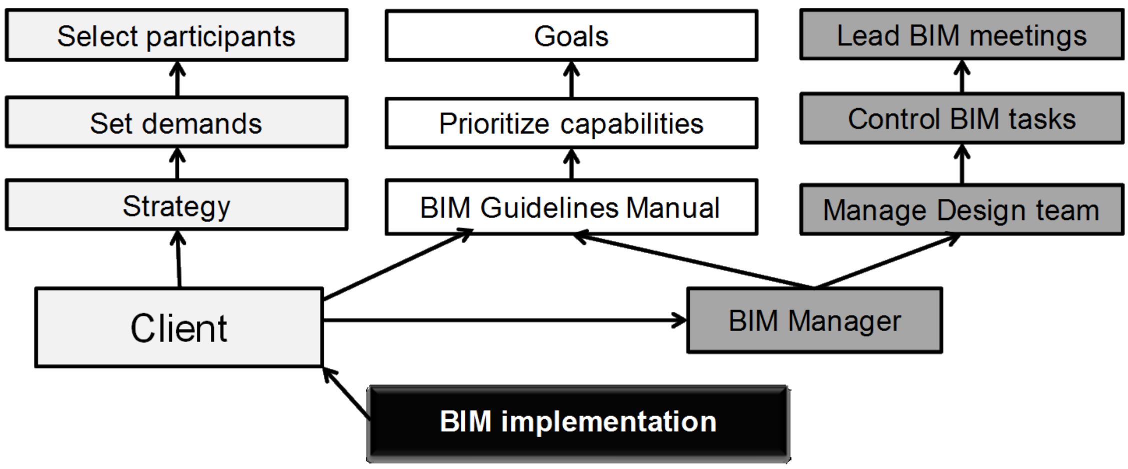

Figure 15: A pathway for the client to follow while executing BIM implementation

The pathway for the client to follow will be explained step by step.

- The client should come up with a strategy or a plan for the organization to follow, that plan should contain information on how they shall execute a BIM project (Bloomberg, et al., 2012).
- The client needs to decide what the company wants to get from BIM and set demands for all project participants. During this step it might be wise to get help from a BIM professional that can make it easier to understand what parts from BIM the client should focus on for each project (Bloomberg, et al., 2012).
- The client shall select project participants by using a procurement process where the client has prioritized what skills are important (Messner, et al., 2012). In addition it is important to make sure that all actors that are chosen to participate have the competence and are capable of delivering the requirements that are set for the project (Eastman, et al., 2011).

It was observed during this study, both from the interviews and theory that the importance of a BIM Manager is significant. The BIM manager should work directly for the client and together with the client shall develop a BIM Guidelines (Bloomberg, et al., 2012). Furthermore the client and the BIM manager should together discuss and choose the capabilities that are suitable for each project. In addition to this they shall decide a common goal to work towards together. Some of the roles and responsibilities of the BIM manager are counted on the pathway that can be seen on ***Figure 15***, further analysis about the roles of the BIM Manager can be seen in *Chapter 2.3.3.*

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9 APPENDIX

9.1 BIM Organizational Strategic Planning

General

- The management team of the company is involved.
- Develop a strategy for the BIM implementation.
- Focus on the organizational level of BIM planning.
- Ensure the organization is ready for BIM implementation with planned resources.

1. Assess existing organizational conditions

- Evaluate the organization to determine areas of focus for future BIM implementation,
- Conduct internal organizational assessment to determine the company status,
- Examine the organizational aspects that need change or modification in order to facilitate the transformation,
- Evaluate which aspects of the organization are working well,
- Identify which aspects of the organization require improvement,
- Identify possible areas of adoption and implementation of BIM processes,
- Ensure the organization is ready for the implementation of each new BIM process with planned resources,
- Conduct external organizational assessment to determine its performance within its business environment,
- Assess the market needs and current BIM practice,
- Assess strengths and weaknesses of competitors.

2. Align: Establish Desired Level of Implementation,

- Define the purposes of BIM implementation,
- Establish the long-term organizational mission and goals considering the organization capabilities, experience, knowledge, and readiness for change,
- Establish BIM vision and objectives,
- Establish desired levels of BIM implementation (or BIM maturity) the company aims to achieve at every project,
- Align BIM objective and goals with organizational mission and vision,
- Determine the BIM Uses to achieve organizational goals and BIM objectives,
- Define next prospective BIM objectives and BIM Uses for the company.

3. Develop an effective strategy, a transition plan to implement BIM

- Develop an effective implementation strategy,
- Develop and document a transition action plan to adopt and implement BIM into organizational business practices,
- Determine and document a careful and structured transformation plan to integrate BIM within the organization processes,
- Define the boundaries and barriers to avoid the risk of escalating costs and misdirected time and resources.

This transition plan should document:

- Mission and vision of the organization,

- Organizational goals in accordance with BIM objectives,
- BIM organizational planning elements to be addressed,
- Expected results for planning elements with the time frames and schedules,
- Roles and responsibilities for the implementation period,
- Communication structure and channel,
- Documentation procedure,
- Technological, time and financial resources required for the duration of the planning procedure,
- Midcourse risk management procedure,
- Feedback loop.

9.2 BIM Organizational Execution Planning

General

- This is the first phase of implementation.
- The management team shall determine precisely how to accomplish the integration of BIM within the organization processes.
- The goals of the strategy are interpreted into daily regular projects and assignments to enable integration.
- The management team shall develop comprehensive planning of specific steps required to attain the strategic objectives.

1. Determine BIM Vision and Objectives for the duration of the execution plan

- Evaluate the corporate goals,
- Formulate clear BIM objectives,
- Determine if BIM objectives are achievable within the timeframe of the plan.

2. Evaluate Internal BIM Uses

- Focus internally
- Aim to integrate BIM within the internal organisation,
- Determine how the organization will use BIM in order to improve their internal organizational processes,
- Translate the goals of the strategic plan into day-to-day projects and tasks to integrate BIM into the organizational processes,
- Apply BIM during a facility's lifecycle and aim to achieve one or more specific objectives,
- Record, Evaluate and Document the BIM level of maturity obtained after the completion of the execution plan of previous projects.

3. Design BIM enabled Process

- Assess and document the overall organizational structure and processes in order to advance them,
- Record and Map the current existing processes which will integrate BIM in their present state,
- Develop a detailed transition plan for each BIM use,
- Map new BIM processes,
- Document the future process for each operational activity,
- Repeat a loop of these steps if needed

4. Document Internal Model and Facility Data Information Needs

- Define and document information needs,
- Summarize all the information requirements,
- Control if they can comply with organizational information requirements,
- Define information needs which shall include Geometric Model and Facility Data Needs,
- The Geometric Model is a digital, virtual, three-dimensional representation of building elements with assigned features and correlated characteristics,
- The Facility Data is non-graphical information, communicated by plain text, stored on digital objects and can determine several aspects (manufacturing characteristics, materials, project identification numbers),
- Include both types of information when documenting information needs

5. Determine Infrastructure Needs

- Consider infrastructure needs including software, hardware, and physical spaces,
- Consider the BIM uses, processes as infrastructure needs,
- Consider the information needs of the organization as infrastructure needs.

6. Determine Personnel Needs to support BIM implementation

- Ensure that the organization has the appropriate human resources,
- Consider the organizational structure,
- Consider the different roles and responsibilities,
- Consider the appropriate experience and necessary training,
- Consider how to manage change within the organization

9.3 BIM Project Procurement Planning

General

- The client shall develop a definite procurement strategy.
- The client shall develop BIM contract documentation for procuring BIM services.
- The client shall determine key contractual issues in the contract documents.
- The client shall specify clearly the project demands and specifications and BIM needs for the upcoming project.
- The client shall choose the appropriate contract type that better incorporates key project participants through a BIM-driven process (i.e. Integrated Project Delivery).

1.Team selection

- Determine the direction of the project before design or construction begins,
- Determine the BIM experience and skills of potential project team members,
- Plan carefully the procurement of BIM services,
- Develop the contract documentation for the upcoming project,
- Document the Request for Qualifications (RFQ) which is the tool a client uses to determine the BIM experience of potential project team members,
- Document the Request for Proposal (RFP) which can provide the owner with a price and description of the proposed BIM uses to be performed,

- Ensure that the project team understands the scope and detail of the requirements to which they are agreeing.

2.Contract procurement

- Establish the proper procurement language,
- Determine the requirements expressed in the contract documents before design begins,
- Document with the BIM contract the standard client requirements concerning BIM,
- Ensure that the owner's needs will be met,
- Set standard project goals and BIM organizational objectives,
- Plan and determine the BIM needs for the project,
- Document the BIM requirements prior to the start of the project,
- Later the BIM Project Execution Plan will contain much of the project specific BIM requirements.

3.Execution requirements

- Develop a typical BIM Project Execution Plan, which shall serve as a structured basis for the next project execution plans,
- Determine the major information needs and requirements, such as facility management system requirements,
- Consider the necessary client specified information and requirements,
- Develop this typical plan in collaboration with all project participants at the earliest stage of each member's involvement in the project,
- After completion of the plan, the client shall evaluate and approve the formal BIM Project Execution Plan and submits it as an appendix to the contract,
- The typical BIM project execution plan can help the client with the procurement strategy and with evaluation of potential project participants.

9.4 BIM Project Execution Planning

General

- All participants shall know the exact content and the proper time of each information exchange, in order to improve the efficiency of communication and collaboration in the project,
- This planning procedure shall be a structured method for the project team to design the execution strategy for BIM on a project,
- The BIM project Execution Plan shall describe how the project will be executed, supervised, organized and controlled concerning BIM processes,
- The BIM project Execution Plan shall develop further and offer a data management and information plan.
- The BIM Project Execution Plan shall assign responsibilities and roles to all project participants for the creation and process of the models,
- The BIM Project Execution Plan shall contain the specific project requirements,
- The client shall follow up the latest improvements in technology and to help the design team to realize the BIM current capabilities of the construction industry,
- The client shall consider all stakeholders and project participants.

1. Form a planning team

- Form a planning team in the early stages of a project,
- Define representatives from all the primary project team members,
- Include at least key participants that represent the client, designers, contractors, engineers, major subcontractors and facility manager,
- Develop further the BIM project execution plan in collaboration with these key participants,
- With a cooperative process, the team can agree on how, when and to which extent BIM can be used to support the project outcome and goals

2. Identify high value BIM goals and BIM uses for a project

- Identify the most appropriate BIM uses at the early project planning phase
- Base each decision on the project characteristics, participants' capabilities and goals and the desired risk allocations,
- Define clearly the overall goals of BIM implementation
- Define these goals concerning project performance, such as increasing of efficiency, increasing of productivity, shortening project length, enhancing the quality of product or service, decreasing cost impact of changes, producing valuable data for facility management,

3. Design the BIM project execution process

- Complete the identification of each BIM Use,
- Understand and design a high level process map for the implementation of each BIM Use,
- Understand and design a high level process map for the project as a whole,
- Indicate with this process map the sequencing and interaction between the primary BIM Uses on the project,
- Indicate with this process map how the team's work processes interact with the processes performed by other team members,
- Indicate with this process map how the teams should perform effectively their tasks,
- Indicate with this process map the overall BIM process and help the participants to understand the entire BIM implementation,
- Identify the information exchanges that will be shared between multiple parties,
- Define clearly the processes necessary to be performed for each particular BIM Use.

4. Develop Information Exchange Requirements

- Complete the development of the appropriate process maps,
- Specify clearly the information deliverables and exchanges between project processes,
- Indicate the information content and scope for each information exchange that will be held between project teams,
- Indicate for the author and receiver the information content for each information exchange transaction,
- Indicate what information is necessary to deliver each BIM Use,
- Design the Information Exchange Worksheet,

- Define the content of model information deliverables and the level of detail needed at a particular stage of a BIM project,
- Complete them in the early stages of a project after designing and mapping the BIM process.

5. Define supporting infrastructure for BIM implementation

- Define the infrastructure needed to support the BIM process during the project,
- Define the delivery structure, contracts and contract language,
- Define the communication procedures, the technology infrastructure,
- Identify the quality control procedures to ensure high quality information models.