UNIVERSITY OF TWENTE & VAN OORD

DIRECTIONS FOR ENHANCING BIM MATURITY IN AN ORGANIZATIONAL CONTEXT

MASTER THESIS

ALBERTO MAIOLI

December 2020

UNIVERSITY OF TWENTE.

Van Oord
Marine ingenuity

DIRECTIONS FOR ENHANCING BIM MATURITY IN AN ORGANIZATIONAL CONTEXT

MASTER THESIS

Location	Enschede
Date	December 2020

Author	
Name	J.A. (João Alberto) Lopes Maioli
Student Number	s2079062
E-mail	j.a.lopesmaioli@student.utwente.nl

Study	
Organization	University of Twente
Faculty	Engineering Technology
Programme	Construction Management and Engineering
1st Supervisor	Dr. J.T. Voordijk
2nd Supervisor	Dr. Ir. M. van den Berg

Graduation Organization	
Organization	Van Oord N.V.
Supervisors	M. (Martin) Edelman & J. (Jeroen) Meijs

ACKNOWLEDGEMENTS

The present report is the result of my master's project as part of the MSc programme in Civil Engineering and Management at the University of Twente. With this project, I finish my academic journey in the Civil Engineering field, that started in Brazil and ends in The Netherlands.

Along this laborious and challenging journey, many people were present in different moments of my life and helped me achieve everything I have achieved so far. First, I would like to thank both professor Hans and Marc for all the coordination and help during the elaboration of this master's project. Second, my supervisors at Van Oord, Martin and Jeroen, for having trusted in my capabilities and for always having provided professional and friendly guidance during my period at Van Oord. Your way of working is an inspiration for me as an engineer.

In addition, I would like to thank my friends Lucas, Carol and Gabriel for always being there for me, providing support whenever necessary. I cannot imagine how this second act of my life in The Netherlands would be without your presence. To Kevin, the one that I have been sharing my life for a long time and that will always be on my side. You are the reason behind many turns my life takes and together we will always accomplish great things in life.

Finally, to my parents, Lourdinha and João, and my sister Karol for always being the solid base necessary for my personal, academic and professional growth. I would not have gone this far if it wasn't for you and the priority you always gave to my education. This is not only an achievement of my own. This is our achievement.

João Alberto Lopes Maioli

EXECUTIVE SUMMARY

Many organisations from the construction sector experience frustration by facing the differences between the promises and the reality of BIM - a set of interacting policies, processes and technologies that generate a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle. Several benefits can be associated with the use of BIM, such as the gains in the overall quality of the construction due to the higher level of design and construction process integration. In addition, BIM tools provide a careful evaluation of the proposed scheme in order to determine if the functional requirements of the construction are being met. This early evaluation of design alternatives results in gains in the overall quality of the construction.

Previous research point out that the major cause for unsuccessful BIM implementation is the lack of strategic planning, in which companies prioritize the deployment of technology instead of the policy, process and people aspects. By tackling the policy aspect, companies elaborate BIM vision and goals in order to orientate itself during BIM implementation, avoiding efforts to be misguided and uncoordinated. By tackling the process aspect, guidelines and work instructions are elaborated in order to document the different uses of BIM, orienting the project teams toward a uniform and standardized way of working, and avoiding knowledge to get lost over time. By tackling the people aspect, companies address one of their most valuable assets: human resources.

In order to measure the way BIM implementation is being conducted, organisations can apply maturity models in which different categories and subcategories for BIM implementation are evaluated. From the outcomes of the maturity models, organisations are able to determine what categories should be prioritized and follow with the elaboration of implementation plans to tackle the identified issues.

An investigation was carried out at the marine contractor Van Oord, an organisation that has been facing setbacks during BIM implementation. There is no common understanding across the management and tactical levels on BIM, its processes and how its potential to add value to the company's practices. In addition, BIM implementation has not been implemented strategically considering the four aspects for BIM implementation. The objective of the research was to initially measure Van Oord's current BIM maturity and provide recommendations in order to assist the company in increasing its BIM level of maturity. This leads to the following research question:

What recommendations can be proposed in order to assist a marine contractor in achieving higher levels of BIM maturity?

In order to answer the research question, a BIM implementation acceleration plan is developed. This acceleration plan is tailored to the requirements of Van Oord and to its desire to achieve higher levels of BIM maturity via impactful steps. In order to develop the acceleration plan, the research was divided into three phases.

Phase 1: Theoretical framework

Phase 1 consisted of gathering several scientific publications in order to draw a conceptual framework around the subjects of technology adoption, organisational BIM implementation, BIM maturity models and BIM implementation strategies. A theoretical BIM implementation framework was built in order to serve as reference for the third phase. This theoretical framework classifies 11 steps for BIM implementation gathered from guidelines according to five groups: preliminary, policy, process, people and technology. Preliminary actions are those that are necessary to be taken before BIM implementation takes place. The actions included in this group are: articulate BIM benefits across management level and establish BIM planning committee. The actions included in the policy group are: conduct current BIM implementation assessment, align BIM with corporate mission and define current and future BIM model uses. The action included in the process group is: document BIM processes and work instructions. Actions included in the people group are those that relate to the human resources within the organisation: revise organisational roles and establish BIM skills. The last group of actions for BIM implementation is technology and it relates the aspects related to IT infrastructure: mobilize supporting software solutions, mobilize supporting hardware and network, and adapt BIM facilities to support BIM uses.

Phase 2: Case study

Phase 2 consisted on the case study of the research and it comprehends two parts: measurement of the BIM maturity of the organisation and discussion meetings around the organisation's specificities. For the first part of the case study, semi-structured interviews were conducted with 8 individuals from different decision-making levels of the organisation, and their output was used for the BIM maturity model. For the second part of the case study, four discussion meetings were conducted with key individuals on BIM implementation at Van Oord around the topics related to the company's specificities, such as current organisational mission and current digitalization initiatives, and the outcomes of the first part of the case study in order to define priorities for the last part of the research. The combination between the two parts allowed not only to provide the organisation with its current level of BIM maturity, but to select the categories that needed more

attention. Four categories were selected: strategy, organisational and project structure, people and culture, and processes and procedures.

Phase 3: BIM implementation acceleration plan

Phase 3 consisted of developing a BIM implementation acceleration plan in order to assist the commissioning organisation in increasing its level of BIM maturity. For that, the outcomes from the two parts of the case study were used as input, together with the theoretical implementation framework from the first part of the research. This resulted in the BIM implementation acceleration plan, that considers 7 of the theoretical steps from the theoretical framework: align BIM with corporate mission, define current and future BIM model uses, document BIM processes and work instructions, revise organisational roles, and establish BIM skills. Besides theoretical steps, one additional step is included in the acceleration plan: the integration of current digitalization initiatives, a necessity raised during the discussion meetings conducted in the case study.

By conducting the maturity measurement and designing the acceleration plan, it is determined Van Oord's current level of BIM maturity and directions are provided in order to enhance this maturity. This answers the research question.

Future recommendations

The practical recommendations of this research are:

- The organisation should maintain consistent evaluation of the performance of the BIM acceleration plan by observing the impact of the steps on the maturity model in practice. This will enable the organisation to measure the proposed model's efficiency and make necessary adjustments on the proposed steps.
- For further details on the recommended actions, it is highly recommended for the organisation to consult the references included in this study.
- The organisation should give priority on the inclusion of current digitalization initiatives into the BIM process in order to skip the bureaucratic steps necessary to establish a new department within a complex organisation such as Van Oord, facilitating allocation of resources and personnel via a digitalization initiative already in place.
- Other initiatives and working groups linked to digitalization should be investigated further and considered in order to facilitate the execution of current and future BIM uses.

The scientific recommendations of this research are:

- In order to improve external validity of the results and to verify if they are representative of the sector, the methods applied in this research should be replicated at other marine contractors embedded in the same context;
- Literature on BIM maturity models mainly focus on how to measure BIM maturity, but do not go further toward how to develop an implementation framework based on the model outcome. Therefore, further research on the topic should be developed;
- The evaluation of the implementation is necessary in order to verify if the recommendations elaborated do in fact have direct impact on the subcategories from the BIM maturity model. This is crucial in order to verify and improve the validity of the recommendations proposed;

Contents

1. INTRODUCTION

1.1. Problem definition

Building Information Modelling (BIM) consists of a set of interacting policies, processes and technologies that generate a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle (Succar, 2009). One of its key characteristics is the interoperability provided between diverse software applications used in the design and other construction processes – such as planning and cost estimation. Data format is shared between the applications, aiming to exchange construction information and knowledge in an efficient way (Bataw et al., 2016). Several benefits can be associated with the use of BIM, such as the gains in the overall quality of the construction due to the higher level of design and construction process integration (Eastman, 2008). However, in practice, many organisations experience frustration by facing the differences between the promises and the reality of BIM. In practice, companies realise that the availability of BIM tools – such as software programs that integrate project design with schedule – is no guarantee that BIM is being implemented in an efficient way.

Unsuccessful BIM implementation

Even though BIM is considered as a disruption with the traditional fragmented way of working in the construction industry (Bataw et al., 2016, Häkkinen and Belloni, 2011, Baldwin, 2019), BIM implementation itself can fall prey to fragmentation. The introduction of BIM based tools in order to assist construction management is still a problematic task in practice (Hartmann et al., 2012). This can be associated to the fact that challenges related to its implementation are difficult to overcome. Conservative attitudes towards BIM in the construction industry can be originated from the lack of maturity, limiting knowledge and experience among professionals. (Hardi and Pittard, 2014). In addition, BIM is, in many cases, an idea that cannot proceed due to the lack of assessment and the misunderstanding of BIM implementation within an organisation, what casts a shadow on the benefits that BIM can provide in practice (Bataw et al., 2016). Previous studies (Häkkinen and Belloni, 2011; Wu and Issa, 2015) have suggested that BIM applications – such as 4D BIM – are not hindered by a lack of technologies and assessment methods, but by organisational and procedural difficulties entailed by the adoption of these applications.

In order to tackle the challenges that hinder BIM implementation and support BIM adoption within organisations, implementation plans and arrangements – such as organisational BIM strategy - are required. The processes covered in BIM implementation plans must be evaluated and investigated by organisations in order to make the implementation process of BIM clearer and overcome the

issues associated with it (Bataw et al., 2016). However, before an organisation starts to elaborate on a BIM implementation planning, it is necessary to obtain a clear perspective on how BIM is being currently conducted. This can be done via BIM maturity modes that aim to evaluate several BIM aspects on the organisation (Baldwin, 2019; Siebelink, Voordijk and Adriaanse, 2018). This allows to obtain an insight on the aspects that are lagging behind on the process of BIM implementation. The determination of the organisation's BIM maturity is, then, a first and crucial step in order to develop an implementation plan that aims to tackle the issues that are hindering organisational BIM implementation.

Van Oord B.V.

The research took place at the head office of the company Van Oord N.V. situated in Rotterdam within the department of EE Process Management. Van Oord is a Dutch marine contracting company present in 46 countries, employing around 5000 professionals and with four main fields of expertise: dredging, offshore oil & gas, offshore wind and infrastructure. Several well-known projects were conducted by Van Oord worldwide, such as the Gemini, an offshore wind energy production plant; the Dubai Palm islands; and several dike reinforcement constructions, such as the reinforcement of the Dutch Afsluitdijk Dam.

The interest from Van Oord for this study relied on the fact that the company has been facing setbacks during BIM implementation. There is no common understanding across the management and tactical levels on BIM, its processes and how its potential to add value to the company's practices. This results in a lack of BIM strategic planning aligned with the organisation's visions and missions. In addition, clients' requirements for BIM have been increasing over the years and for some projects, the company can only participate as a potential contractor during a tender process in case it is proven that BIM can be applied for project information production and sharing. By trying to implement BIM successfully in order to correspond sufficiently to the clients' requirements, the organisation is facing complexities that hinder the process of BIM implementation. Moreover, the causes behind these complexities are not known due do the lack of BIM expertise present in the company. Therefore, there was a need to evaluate the current situation of BIM implementation within the organisation in order to identify the areas and aspects of BIM in which the company was lagging behind. Identifying the BIM aspects that require special attention is the first step in order to elaborate an action plan that aims to facilitate the organization in achieving higher levels of BIM maturity.

1.2. Research objectives

General research objective

The overall objective of this research is twofold: (i) measure the BIM maturity of a marine engineering contractor and (ii) provide a set of recommendations in order to assist the commissioning company in increasing its BIM level of maturity.

Specific research objectives

The general objective can be decomposed into specific objectives to assist the development of the research, as follow:

I. Elaborate a conceptual framework around the topics of information technology and BIM implementation, the aspects and factors to be considered during implementation, as well as BIM maturity models;
II. Determine how organisational BIM implementation is being carried out in a practical case via the application of a BIM maturity model chosen from theory;
III. Elaborate on solutions that aim to provide guidance to the organisation in achieving higher levels of BIM maturity.

1.3. Research questions

Considering the research problem and the research objectives, the following main question can be drawn:

What recommendations can be proposed in order to assist a marine contractor in achieving higher levels of BIM maturity?

The solution for the main question is provided by answering the following sub questions, associated with each specific research objective:

I) What aspects should be considered during BIM implementation according to strategies from theory and how to measure this organisational implementation?

II) What is the current BIM level of maturity of the commissioning organisation according to the BIM Maturity Model?

III) What actions should be taken in order to increase BIM maturity of the commissioning organisation?

1.4. Research framework and methods

In order to the fulfil the objectives, answer the research questions and tackle the research problem, the research took the form of a step-by-step approach. The different steps can be grouped in three phases according to the research objectives: literature review, case study an BIM implementation acceleration plan. The research framework is shown in Figure 1 and each phase, together with the methodology, will be elaborated in the following items.

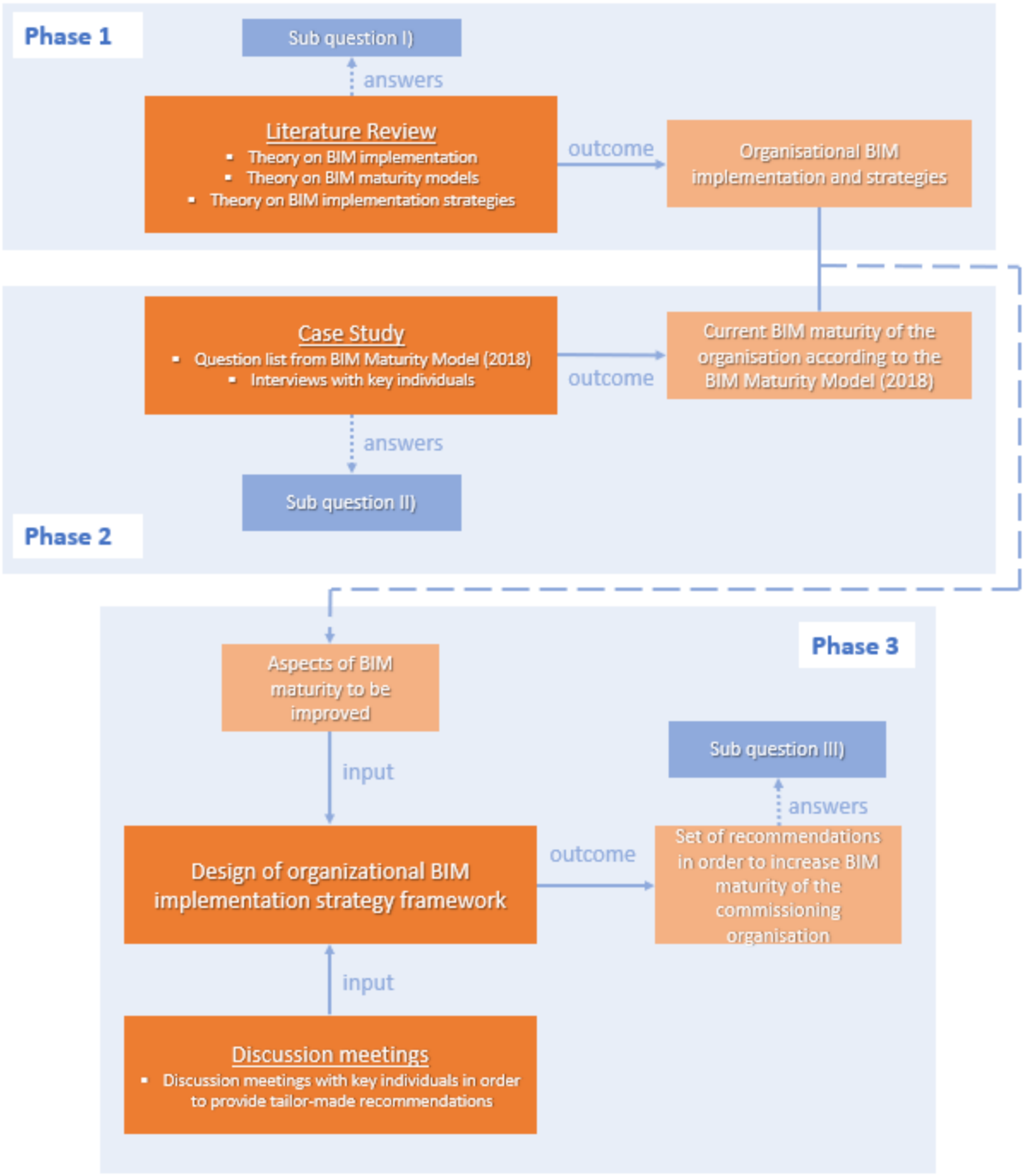


Figure 1 - Research framework

In the table below, the data collection methods applied for each phase of the study is shown in details.

Table 1 - Relation between research phases, objectives, questions, subjects and data collection methods

Phase	Objective	Research question	Subject	Data collection method
1	I	What aspects should be considered during BIM implementation according to strategies from theory and how to measure this organisational implementation?	Information technology and BIM implementation	Literature review
2	II	What is the current BIM level of maturity of the commissioning organisation according to the BIM Maturity Model?	Organisational BIM maturity	Interviews, documentation
3	III	What actions should be taken in order to increase BIM maturity of the commissioning organisation?	Organisational BIM implementation strategies	Discussion meetings

1.4.1. Literature review

Phase 1 consisted of gathering several scientific publications in order to draw a conceptual framework around the subjects of technology adoption, organisational BIM implementation, BIM maturity models and BIM implementation strategies. In this phase, a BIM maturity model was chosen in order to be used for measuring BIM maturity of the organisation during the case study (Phase 2). In addition, an implementation framework was developed by gathering different guidelines on organisational BIM implementation. Phase 1 aimed, then, to answer sub question I), reaching the correspondent specific objective I.

1.4.2. Case study

Phase 2 consisted on the case study of the research and it comprehends two parts: measurement of the BIM maturity of the organisation and discussion meetings around the organisation's specificities. According to Hartmann (2017), a case study research is "an investigative approach used to describe complex phenomena, such as recent events, important issues, or programs, in ways to unearth new and deeper understanding of these phenomena". A case study research enables the researcher to investigate in depth one or several objects or processes by looking into a small domain of selected research units such as observation, analysis of documents and interviews (Yin, 2014).

The objective of the first part of the case study performed at the commissioning organisation was to get an understanding on the current state of BIM implementation within the company via the use of the BIM maturity model developed by Siebelink, Voordijk and Adriaanse (2018). For that, several interviews were conducted with key personnel involved with the BIM implementation in different degrees, to be further specified in the next item. By applying the BIM maturity model, it was intended to investigate the categories of BIM implementation in which the company is lagging behind, identifying the gaps that needed to be filled. For that, interviews were conducted with several individuals from different levels of decision making within the organisation, answering, then, sub question II), reaching the correspondent specific objective II.

The second part of the case study had two objectives: (i) define priority categories to be considered for the third part of the research based on the outcomes from the maturity model, (ii) conduct discussion around the company's specificities aiming to obtain more information that would allow to shape the recommended actions into company-specific tailor-made recommended actions.

Data collection methods

For the first part of the case study, semi-structured interviews were conducted. The decision of performing semi-structured interviews relied on the fact that it was intended to allow the interviewer to explore themes that emerged during the interview process. Thus, guaranteeing flexibility while certain key elements contained in the pre-determined open-ended questions are being fully covered, what can be accomplished via semi-structured interviews (Yin, 2014).

The individuals considered for the interviews – eight, in total - belong to different levels of decision making in company, and all of them have in common the fact that they are involved with the implementation and use of BIM within the organisation. The individuals interviewed can be grouped in three categories related to their level of decision making: strategic, tactical and operative. Individuals assigned for the strategic level are those from the management level of the organisation, such as business units directors and department managers. Individuals assigned as from the tactical level are those identified as discipline managers and lead engineers. The individuals assigned as from the operative level are those involved with the execution of BIM, such as BIM coordinators and information managers. This hierarchy of individuals considered is shown in Figure 2.

Some of these individuals are responsible for the elaboration and implementation of BIM strategies and others with the coordination of BIM related processes – such as setup of a Common Data Environment and training – for the task team members in company and project levels. The variety of individuals to be interviewed enables capturing more information and supporting it by several professionals. Thus, precise mapping of the current state is achieved (Bryman, 2012). Documentation was analysed as an additional data collection method in order to verify the

consistency of the information provided during the interviews, such as BIM contracts in the form of BIM Execution Plans and internal work instructions related to certain BIM uses.

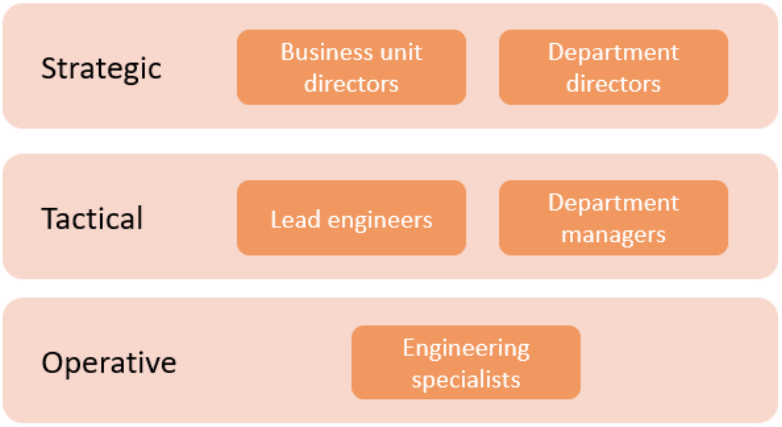


Figure 2 - Groups of individuals assigned for the interviews according to level of decision making

- Interview protocol

According to Bryman (2012), in a semi-structured interview, the researcher follows a pre-determined list of questions to be covered during the interview, often referred as interview guide or protocol. The interview protocol used in this research was the interview protocol from the BIM Maturity Model elaborated by Siebelink, Voordijk and Adriaanse (2018). The protocol was provided by the authors under request from the researcher. As mentioned previously, the authors elaborated a BIM maturity model for organisations in which a level of maturity could be defined according to a series of questions split between 6 categories and 18 subcategories, which individuals from the organisation should answer. By answering the questions under each category, it is possible to associate one of the six BIM Maturity Stages, as defined in the study from Siebelink, Voordijk and Adriaanse (2018). The interview protocol is included in Appendix I.

It is important to highlight that the interview did not limit to the questions from the interview protocols. Freedom was provided to the interviewees to elaborate on other BIM-related topics not considered in the protocol. In addition, additional questions were asked to the interviewees considering obtained answers for their colleagues during previous interviews, in order to verify if opinions around a same topic converge or diverge.

In total, 8 individuals from different decision levels were interviewed. Each individual interview lasted around one hour and counted with the permission of the interviewees for the audio recording of each interview to be posteriorly manually transcribed by the researcher.

For the second part of the case study, discussion meetings were conducted around the topics related to the company's specificities, such as current organisational mission and current digitalization initiatives. Four discussion meetings were conducted in total, each with different target subjects, as detailed in Table 2. The topics chosen for discussion considered the theoretical BIM implementation framework – approached in item 2.7.1 – together with additional important topics raised during the interviews conducted in the case study. The order of the topics

The individuals considered for the discussion meetings were those with more involvement with BIM implementation in the organisation, also considered for the BIM maturity measurement. That consisted of a department manager and a lead engineer.

Table 2 - Discussion meetings of the third phase of the study

Meeting	Topics for discussion
Discussion meeting 1	▪ BIM definition for the organisation ▪ Corporate mission and BIM vision
Discussion meeting 2	▪ BIM model uses I ▪ Relation between BIM and current digitalisation initiatives I
Discussion meeting 3	▪ BIM model uses II ▪ Relation between BIM and current digitalisation initiatives II
Discussion meeting 4	▪ BIM planning committee

1.4.3. BIM implementation acceleration plan

The main goal of Phase 3 was to draw recommendations in order to assist the commissioning organisation in increasing its level of BIM maturity. For that, the outcomes from the two parts of the case study were used as input. The set of recommendations compose the BIM implementation acceleration plan. Phase 3 aimed, then, to answer sub question III), reaching the correspondent specific objective III.

1.4.4. Validity of the research methods

According to Wieringa (2014), it is important to verify if the measurement instruments measure what they really intended to. For that, the interview protocol already developed for a previous scientific study - the BIM Maturity Model developed by Siebelink, Voordijk and Adriaanse (2018) - was used in order to measure the BIM maturity of the organisation. Additionally, validity was reinforced via member checks. Member checks consist of asking the participants of the research – for this stage, the interviewees – for feedback on the accuracy of the data raised and to respond to the researcher's interpretations (Wieringa, 2014). This took place in the form of a feedback

meeting after all the interviews were carried out. The objective was to present the results obtained via the BIM Maturity Model and the discussion meetings, discuss possible divergences between different opinions, and to obtain feedback on the results presented. Additionally, the validity of the study was improved by performing triangulation during data collection, in which the analysis of documentation aimed to support and validate the data collected from the interviews.

SECTION I

THEORETICAL FRAMEWORK

Questions to be answered:

I) What aspects should be considered during BIM implementation according to strategies from theory and how to measure this organisational implementation?

2. THEORETICAL FRAMEWORK

2.1. Introduction

This chapter aims to present diverse theories around the topic of BIM implementation, highlighting the benefits expected from BIM for an organisation and the promises that implementing an information system such as BIM can offer. The discussion starts with presenting the general concepts that circle around BIM and can be found in literature, in order to introduce readers that are not familiarized with the term. Additionally, it is important to point out what definition of BIM this research will be based on, since BIM can be seen from different perspectives. Since this project aims to elaborate on BIM implementation on organisational level, it is important to initiate this discussion from a conceptual level. The implementation of BIM can, then, be seen as the implementation of an information technology and its implementation as a result from its interaction with the organisational context. For that, the model proposed by Silver et al. (1995) is presented. Next, the discussion will focus on BIM implementation from the perspective of level of decision making – strategic, tactical and operative –, and its aspects – policy, processes, technology and people – as defined by Baldwin (2019). Next, a discussion will be made on how to measure BIM organisational implementation via the application of BIM maturity models, in which proposed models developed by several researchers will be presented. Focus will be given on the BIM maturity model developed by Siebelink, Voordijk and Adriaanse (2018), in which the maturity levels, categories and subcategories will be presented. A comparison, then, will be made between the aspects for BIM implementation according to the information technology theory from Silver et al. (1995), the theory from Baldwin (2019) and the criteria from the BIM maturity model from Siebelink, Voordijk and Adriaanse (2018). This comparison aims to form a link that compose the theoretical base for a BIM implementation framework to be developed during the third phase of this study from the evaluation of the BIM level of maturity of an organisation via the BIM maturity model. Next, a selection of several implementation guides and additional references will be presented and will form a step-by-step conceptual framework for organisational BIM implementation. This conceptual framework is refined further in this research in which tailor-made recommendations will be presented in order to direct the commissioning organisation towards higher levels of BIM maturity. The last part of this chapter will point out the benefits of a proper BIM implementation strategy considering previous studies that went further on not only elaborating a strategy for implementation, but testing the strategy in practical cases.

2.2. The concept of BIM

Building Information Modelling (BIM) is one of the most promising developments in the AEC (Architecture, Engineering and Construction) industry from the last decades (Eastman, 2008) and can be defined as "*a set of interacting policies, processes and technologies that generate a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle*" (Succar, 2009). BIM technology provides an accurate virtual model of a

construction element that contains geometry and relevant data in order to support the construction, fabrication and procurement activities. The application of BIM tools has been helping the AEC industry to overcome some long-dated issues present in the construction industry, such as communication and information exchange problems (Bataw et al., 2016). One of the most common problems related with traditional methods of information exchange is the amount of time and expense required to generate a critical assessment information on cost estimate and planning schedule (Eastman, 2008).

BIM can be used as a mean to create visual data for additional aspects related to construction, e.g., costs, resource materials and construction sequence. Several other benefits related to the application of BIM can be mentioned. By allowing the development of a schematic model before the generation of a detailed one, BIM tools provide a careful evaluation of the proposed scheme in order to determine if the functional requirements of the construction are being met. This early evaluation of design alternatives results in gains in the overall quality of the construction (Eastman, 2008). In addition, BIM allows higher level of design and construction process integration, resulting in the increase of the quality of the constructions to be performed at lower cost and optimized project duration (Eastman, 2008). Given the benefits associated, the interest in BIM has been increasing within the construction industry over the past decades in a global level (Hardi and Pittard, 2014).

2.3. Organisational BIM implementation

The use of BIM is often seen as a manner to fulfil the desires of the building industry to increase productivity and efficiency of the business. This is because BIM promises to eliminate design errors, increase quality of design, to help management of processes in construction and to deepen collaboration and communication between parties involved in a project (Miettinen and Paavola, 2014). In addition, companies desire to implement BIM in response to a client need in the form of a contractual requirement, to get better outcomes on a project and as part of an overall organisational programme (Kjartansdóttir, 2017). However, in practice, many organisations experience frustration by facing the differences between the promises and the reality of BIM. Companies deal with the fragmentation, adversarial relationships between partners, discontinuities of projects, and organisational conditions that prevent and retard BIM implementation (Miettinen and Paavola, 2014). In practice, companies realise that the availability of BIM tools – such as software programs that integrate project design with schedule – is no guarantee that BIM is being implemented in an efficient way within the organisation. Technology alone cannot influence the required changes necessary for an effective BIM implementation (Khosrowshahi and Arayici, 2012). In this context, in order to implement BIM effectively, a detailed and comprehensive BIM implementation strategy is needed (Saluja, 2009). Khosrowshahi and

Arayici (2012) claim that BIM implementation does not only require learning new software applications, but also requires learning how to create the workflow within the organisation and how to train staff and assign responsibilities. Developing a BIM implementation strategy is an important first step for all organisations involved with BIM, since a well-elaborated strategic plan helps in aligning BIM with the core business principles (Baldwin, 2019).

Moreover, to succeed in BIM implementation in an organization, an effective strategy should be formed regarding the current situation of an organization in BIM utilization and its level of BIM maturity (Alaghbandrad and Forgues, 2013).

2.3.1. The information technology interaction model

A building information model can be seen as an information system as part of an organisational context due to the fact that it is not an isolated system but forms part of a larger whole, embedded in a specific context (Siebelink, Voordijk and Adriaanse, 2018). The information technology interaction model proposed by Silver et al. (1995) is well established in literature and has been used to explore implementation process in diverse fields of study (Parkes, 2016). This is the case for the study conducted by Siebelink, Voordijk and Adriaanse (2018), in which a BIM maturity model was elaborated considering the aspects of information systems and the context they are embedded in, as defined by Silver et al. (1995). This maturity model is part of the study and has been applied for the case study, as it will be further elaborated on. Therefore, it is relevant to mention the theory from Silver et al. (1995) behind the maturity

The information technology interaction model was proposed by Silver et al. (1995) in order to shine a light on the interaction between information system and its organisational context. The model relies on the premise that the effects of information systems in organizations result from the interaction between the system design features and the organisational context (Figure 3). The system features relate to the properties of an information system that affect system use, such as functionality and interface, while the context comprehends the external environment together with internal elements of the organisation.

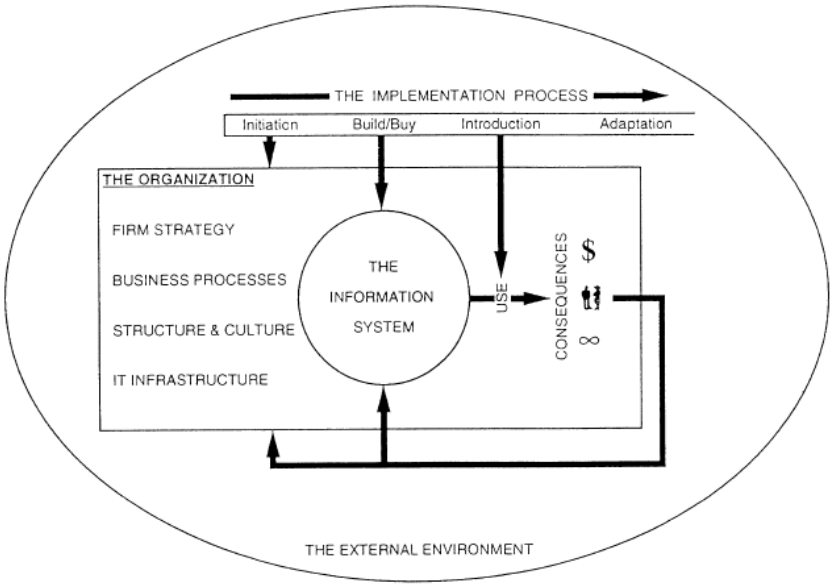


Figure 3 - The information technology interaction model (source: Silver et al., 1995)

Since it is intended by this research to elaborate on the topic of BIM implementation in a context, it is interesting to analyse the dimensions of an organisational context as defined by Silver et al. (1995). According to the author, the organisational context comprehends two dimensions: the external environment and the internal elements of the organisation. An organisation's external environment relates to the competitive structure of the industry in which the organisation is situated in. Additionally, the external environment and the position that the organisation occupies in this environment influence what information systems an organisation chooses to implement.

The other dimension of the organisational context relates to the internal elements of an organisation, as defined by the model proposed by Silver et al. (1995). According to the author, the internal elements can be grouped in four categories: firm's strategy, its structure and culture, its business processes, and its IT infrastructure. The firm strategy is a crucial factor to be considered when analysing information systems since an information system is a key element in executing a specific organisational strategy. Business processes are the set of activities which the organisation make use of to accomplish the intended goals. Organisations have often used information technologies as a mean to improve the operation of their business processes. Organisational structure relates to the formal aspects of organisational functioning such as division of labour, hierarchical authority and job descriptions, and has influence on the consequences of information systems. Organisational culture relates to the pattern of shared basic assumptions that an organisation learns as it integrates and adapts to the environment, and passes along to new members. IT infrastructure represents the resources that give the firm the capacity to generate new IT applications, such as physical components and the technical capabilities of users.

According to the authors, organisations are not only concerned if an information system has been built and is being used in practice, but also if the use of a built system delivers on its promise of improved organisational performance. And that is where implementation comes into play. When the information system is transformative, implementation must aim to support and facilitate organisational transformation, which demands changes in the aforementioned internal elements of the organisation. The implementation process can be seen, then, as a crucial factor in order to transform the structure and culture of an organisation in order to implement information technology effectively (Silver et al, 1995).

2.3.2. The aspects on organisational BIM implementation

Different theories on technology implementation have been developed over the years, some more conceptual, such as the information technology interaction model introduced in the previous item, and other specifically focused on BIM implementation. Jung et al. (2008) focuses on BIM implementation in the project level Khosrowshahi and Arayici (2012) evaluated BIM adoption in the UK's construction industry in order to develop a strategy plan to increase BIM adoption in this market. These two different theories deal with BIM implementation on a project-level and industry-level, respectively. However, for the present research, it was necessary to find a theory that would fit between these two levels, considering the aspects and the specificities for BIM implementation on an organisational level. The theory for BIM implementation according to Baldwin (2019) was, then, chosen, since it considers not only aspects for organisational BIM implementation, but also the different levels of decision making within an organisational structure.

According to Baldwin (2019), the implementation of BIM on an organizational level has to be analysed from two perspectives (Figure 4). The first perspective relates to the three levels of BIM implementation within an organisation. These are: strategic, in which a vision is defined and goals are set; tactical, in which these goals are expressed in an action plan; and operative, in which these principles are executed in project work.

The other perspective considers the four aspects of BIM implementation within an organisation: policy, process, people and technology. The aspect of policy relates to how the BIM implementation affects business operations by optimizing existing activities and enabling new opportunities of business to develop. In this context, re-assessing the current business model of the organization and identifying new areas of growth are the first steps of a BIM implementation strategy. The aspect of processes relates to necessary redefinition of work processes due to the change of business activities. These processes have to be supported by internal guidelines that provide a reference and framework for BIM implementation. The aspect of people relates to the impact that BIM implementation brings on the organisation's team. This involves recognising the organisational culture as well as the technical management and social competencies of the team.

The aspect of technology corresponds to the biggest investment for BIM implementation and have implications on future resourcing, training and software interoperability.

Figure 4 - BIM implementation according to levels (left) and aspects (right). (source: Baldwin, 2019)

By combining the levels and aspects of BIM implementation, an implementation matrix is developed (Figure 5). This matrix allows the organisation to identify the necessary components for BIM adoption, serving as a roadmap for BIM implementation (Baldwin, 2019). According to the author, companies that fail during implementation tend to start the process from the bottom right corner instead of from the top left corner. In practice, this means that these organizations start with BIM implementation from the operative technology region, related to the mobilization of software applications, and work backwards toward the strategic policy region, related to the definition of implementation goals.

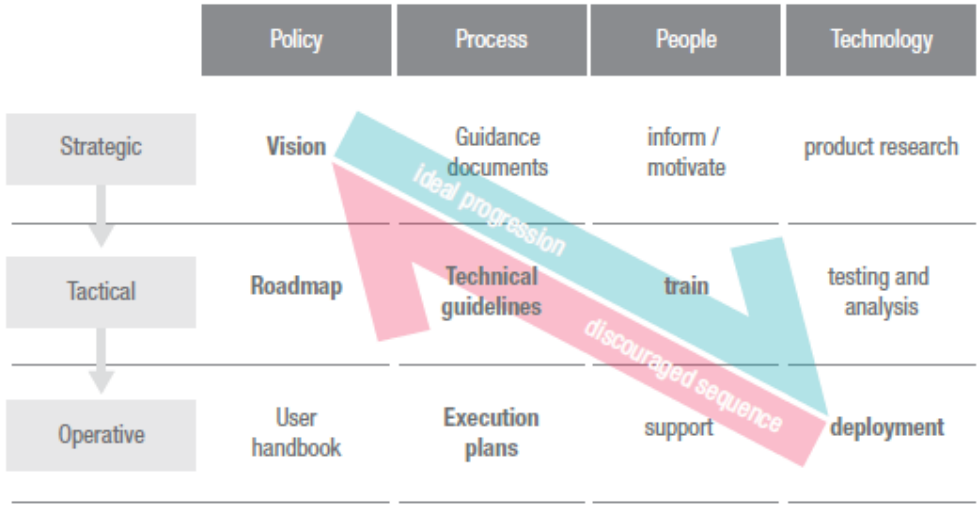


Figure 5 - The BIM implementation matrix (source: Baldwin, 2019)

2.4. Organisational BIM maturity levels and measurement models

In an organisational level, BIM maturity indicates the degree of advancement of BIM utilization in which BIM maturity stages provide a systematic framework for the classification of BIM implementation within an organisation (Jung and Joo 2011, Khosrowshahi and Arayici 2012).

Several studies were dedicated to develop different measurement tools in order to measure BIM maturity on organisational level, including the creation of measurement frameworks, determination of evaluation approaches, validation and optimizations. The different measurement tools present distinct classification structures to accommodate indicators or measures due to the lack of established standards on the matter (Wu et al., 2017). Examples of measurement tools present in literature are the Capability Maturity Model (National Institute of Building Sciences, 2012) part of the National BIM Standard, the BIM Proficiency Index developed by the Pennsylvania State University (CIC, 2013), the BIM Maturity Matrix developed by Suucar (2009), the BIM Quickscan (Sebastian and van Berlo, 2010) developed by the Netherlands Organization for Applied Scientific Research (TNO), and the BIM Maturity Model proposed by Siebelink, Voordijk and Adriaanse (2018). Each maturity model has its own defined levels of BIM maturity and categories of BIM-related aspects considered for the measurement of an organisation's BIM maturity level. Special attention will be given in the next item to the model developed by Siebelink, Voordijk and Adriaanse (2018).

2.4.1. The BIM Maturity Model

The Maturity Model proposed by Siebelink, Voordijk and Adriaanse (2018) in order to assess BIM maturity of organisations was developed aiming to fill in the gaps and tackle shortcomings identified in other maturity measurement models, as the ones presented, such as (i) the little attention given to the collaborative aspects of the models assessed, (ii) the complexity of frameworks often applied, making the maturity assessment results rather unclear and not transparent, (iii) the meaning and requirements for the various maturity levels are often poorly defined in the related literature, (iv) the insufficient attention given to organisational processes, focusing mostly on technological characteristics of BIM, (v) the excessive focus of many maturity models on the evaluation of specific disciplines. This was enough evidence to support the development of a new BIM maturity model that would tackle the shortcomings and consider the strong elements present in previous models. A summary of the five BIM maturity levels described by the authors is included in Appendix II. Each maturity level is described considering internal and external processes in order to make supply chain aspects more explicit.

A model measurement framework was elaborated based on the elements of information systems since a building information model can be seen as an information system embedded in an organisational context (Siebelink, Voordijk and Adriaanse, 2018). The framework was, then, translated into 6 criteria and 18 sub criteria (Figure 6) based on the information technology interaction model from Silver et al. (1995) – presented in item 2.3.1 - and on other existing BIM maturity models criteria. The complete description of each sub criteria according to the different levels of maturity is included in Appendix III.

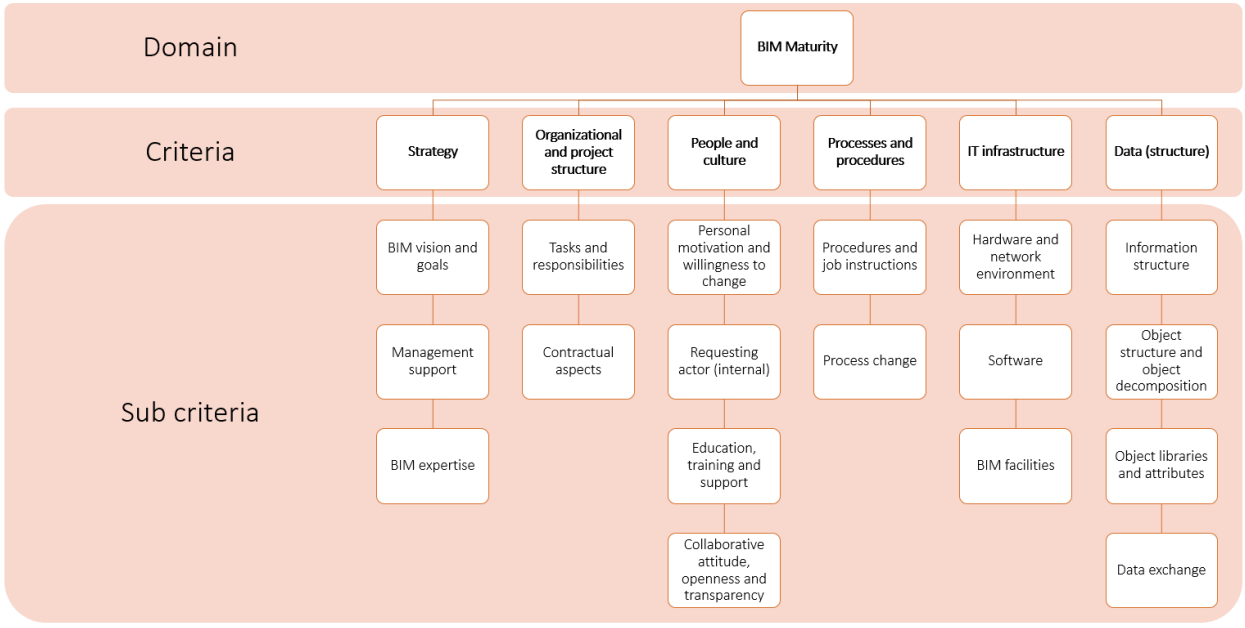


Figure 6 - Criteria and sub criterion of the BIM Maturity Model (source: Siebelink, Voordijk and Adriaanse, 2018)

Strategy

According to the authors, BIM can be a key element in a marketing or production strategy and needs to be aligned the organisation's strategy. The absence or not alignment of the BIM strategy is pointed out as one of the causes for ineffective BIM implementation. More specifically, BIM vision and goals should be aligned with the organizational strategy and vice versa. For that, management support, both in spoken words and by management committing financial, is required. Further, dedicated time and expertise from a BIM expert or working group are fundamental elements for the formulation of the BIM strategy.

Organizational structure

The division of tasks and responsibilities of the employees according to BIM should be part of the formal structure of the organisation, as defined by Siebelink, Voordijk and Adriaanse (2018), due to the new working methods and roles related to the use of BIM. The adaption of job profiles in order to incorporate BIM reflects the ability of the organisation to support BIM processes. Additionally, the adoption of BIM in projects requires new contractual arrangements due to the changed collaboration between parties. The sub criterion contractual aspect relates, then, to the formalization of BIM-related processes between different parties.

People and culture

According to the authors, this criterion is composed by a set of basic assumptions and habits that are anchored in an organization and which will be transferred to new employees. This determines the personal motivation for working with BIM and expand its uses. For that, it is crucial to have a requesting actor – or BIM champion - for the BIM implementation process. This individual acts as an internal requesting actor for the application and development of BIM. Additionally, the organization should provide education and training to the individuals part of the BIM process. The organisational culture also has effects on the openness to external parties and the degree of collaborative attitude toward the supply chain. An attitude aimed at cooperation and willingness to change traditional culture, structure and processes is necessary in order to achieve an integrated and multidisciplinary BIM approach.

Processes and procedures

The authors define a process as a collection of related activities aimed at a specific result or output. In the BIM context, processes need to contribute to the desired applications of BIM and vice versa. The performance of such BIM processes depends on the extent to which these processes are formalized in procedures and job instructions with regard to the present BIM uses. Job instructions are detailed step-by-step acts or practices, while procedures provide a set of guidelines for the BIM processes. According to the authors, the temporary nature of collaboration between different organizations hampers the process of building trust since trust is influenced positively by past experiences and future expectations of collaborating partners. BIM can, then, be considered as a driver of change and improvements in this collaboration process, what is represented by the sub criterion process change.

IT infrastructure

This criterion relates to the technical means within the information system, consisting of the BIM solutions (software) and IT infrastructure (hardware and network environment) that support the use of the software and data exchange. Additionally, the extent to which project parties can work in an integrated way depends on the quality of the network environment. Another sub criterion is the BIM facilities, facilities that enable interactive coordination sessions with project parties.

Data (structure)

According to the authors, this criterion refers to the management, structuring, (re-)use, and exchange of project-related information. It is crucial to store project data in a structured way and to make these data accessible by other project parties, being this information structure facilitated by a document management system (DMS). Additionally, an object-oriented approach in lieu of a traditional document-oriented approach is part of the core of the BIM definition. This is formed by drafting an object structure and decomposition, and using unique codes for all the objects in the project model. The use of object libraries can be helpful in standardizing and easing the BIM model design processes depending on the required BIM use. In addition, integration with other models from project partners and supply chain parties is determined by data exchange regarding object information, discipline-specific models, or merged models.

2.5. The relation between the models

According to Siebelink, Voordijk and Adriaanse (2018), a building information model can be seen as an information system as a part of an organisational context due to the fact that it is not an isolated system, but forms part of a larger whole. In fact, in order to define the criteria related to the domain of BIM maturity for the BIM Maturity Model proposed by the authors, the internal elements of the information system from the theory of Silver et al. (1995) were considered. Similarly, the aspects for BIM implementation from the theory of Baldwin (2019) consider the same internal elements as aspects for implementing BIM, being BIM an information system that is embedded in an organisational context. Having said that, a relation can be made between the internal elements of an information technology from the theory of Silver et al. (1995), the aspects for BIM implementation from the theory of Baldwin (2019) and the criteria used in the BIM Maturity Model developed by Siebelink, Voordijk and Adriaanse (2018). This relation (Table 3) aims to make a link between the different theories and the model. This link ensures that a framework for BIM implementation that considers the aspects for BIM implementation from Baldwin (2019) is aligned with the criteria from the BIM Maturity Model used to measure the BIM

maturity level of an organisation. The subject of BIM implementation framework is approached in item 2.7.

Table 3 - Relation between internal elements, BIM maturity model criteria and aspects for BIM implementation

Internal elements from Silver et al. (1995)	Aspects for BIM implementation from Baldwin (2019)	BIM Maturity Model criteria from Siebelink, Voordijk and Adriaanse (2018)
Firm strategy	Policy	Strategy
Structure and culture	People	Organisational structure
		People and culture
Business processes	Process	Processes and procedures
IT infrastructure	Technology	IT infrastructure

2.6. Factors that hinder successful BIM implementation

As mentioned previously in this chapter, organisations experience frustration by facing the difference between the promises of BIM and the real benefits experienced in practice, indicating that some challenges on practical BIM implementation are hindering the real benefits of implementing such a system (Miettinen and Paavola, 2014). Therefore, it is important for an organisation that is experiencing difficulties on the implementation of BIM to understand what the origins of such issues are. That way, a strategy in order to tackle them can be formulated (Saluja, 2009).

Several publications from the literature address the possible challenges that organisations might face while implementing BIM that hinder the process of BIM implementation. Common issues approached literature are related to cultural resistance, reluctance of team members to share information, lack of BIM training on an organisational level, lack of client demand, high costs of investment and a lack of BIM implementation strategy (Olugboyega and Windapo, 2019; Miettinen and Paavola, 2014; Bataw et al., 2016).

2.7. BIM implementation strategy

Literature on BIM demonstrates that the focus of studies in the field of BIM has surrounded the “what” and “why” of BIM by providing discussions on the context in which BIM is embedded in and the benefits and reasons for adopting BIM in construction projects. However, there is a gap in understanding “how” an organisation should take measures in order to adjust and adapt to the diffusion of BIM (RICS, 2014). In order to fulfil this gap, studies and guidelines around the topic of BIM implementation framework have been conducted along the years. According to Jung and Joo

(2011), a framework consists of a set of relationships in the form of a conceptual scheme in order to guide research efforts, enhance communications and integrate relevant concepts.

Several studies approach the topic from a theoretical perspective, in which concepts and theories for BIM implementation barriers and strategies compose a framework for implementation. Khosrowshahi and Arayici (2012) elaborated a strategy and recommendations for enhancing BIM implementation for the context of the UK construction industry by tackling the aspects of technology, process and people issues in BIM implementation. The outcome of the research was a roadmap for implementation of BIM in the UK entailing barriers for BIM implementation that should be considered in that context. Jung and Joo (2011) proposed a BIM framework for evaluating promising areas and identifying driving factors for practical BIM effectiveness. The framework consists of major variables classified into three dimensions in a hierarchical structure: BIM technology, perspective and construction business function.

Other studies have developed frameworks in the form of step-by-step practical approaches in order to assist with the process of BIM implementation in organizations, such as the National BIM Guide for Owners (National Institute of Building Sciences, 2017), the International BIM Implementation Guide (RICS, 2014) and the Planning Guide for Facility Owners (CIC, 2013). What these guides have in common is the fact that they present sequential orders of steps and procedures that are necessary in order to implement BIM in an organisation, trying to answer the "how" question for organisations that experience the setbacks of implementing BIM in practice.

Several studies have measured and analysed the impacts of the elaboration and implementation of BIM implementation strategies in the construction sector elaborated in order to tackle the issues that hinder BIM implementation. According to Baldwin (2019), BIM implementation strategies affect positively business operations, internal processes, roles and competencies of personnel and technology within an organisation.

A research conducted by Saluja (2009) outlines a four-step procedure to develop a company-specific implementation strategy, which was put into practice in a real project. The results of the research concluded that by developing the implementation plan, the project team became able to design an execution process appropriate for the business practices and BIM workflows. Similarly, a study conducted by Kharoubi (2019) that aimed to measure the impacts of a BIM implementation strategy with a focus on 5D BIM in an engineering company concluded that one of the impacts found was the enhancement of the process of communication between team members. The implementation strategy developed by Saluja (2009) enabled the task team members involved in the implementation to understand better their roles and responsibilities when it comes to BIM. This result was also obtained by the research conducted by Kharoubi (2019). Similarly, Fisher (2011) noted that a BIM implementation strategy provides a better understanding of roles and responsibilities attached to each personnel, teams, department, and management

A study conducted by Hartmann et al. (2012) investigated how different BIM based tool implementation strategies work in practice. The authors implemented two BIM based tools in the context of construction companies. The first implementation strategy aimed to support the activities at the estimating department of a construction company, while the second aimed to assist the risk management activities via 4D models. For each case, BIM software programs and associated processes – creation and management of models – formed the implementation strategy. For both case studies, the authors concluded that the elaboration and adoption of a BIM implementation strategy increased the project team's awareness of the importance of BIM and its uses. In addition, it was noted that the overall communication was improved, since the implementation strategy supported interaction between different project teams.

2.7.1. BIM implementation actions

This item elaborates on a framework for BIM implementation actions based on several publications that deal with organisational BIM implementation, such as the BIM Planning Guide for Facility Owners (CIC, 2013), the study conducted by Siebelink, Voordijk and Adriaanse (2018), the research from Panaitescu (2014) and the BIM Essential Guide elaborated by the Building and Construction Authority (2013). The actions are grouped in five categories (Figure 7), in which four of these categories relate to the aspects for BIM implementation from Baldwin (2019) – policy, process, people and technology – and one category refers to the preliminary actions that should be taken according to the literature consulted.

The framework for BIM implementation actions will serve as an input for the elaboration of a set of tailor-made recommendations for the commissioning company, presented in Chapter 4.

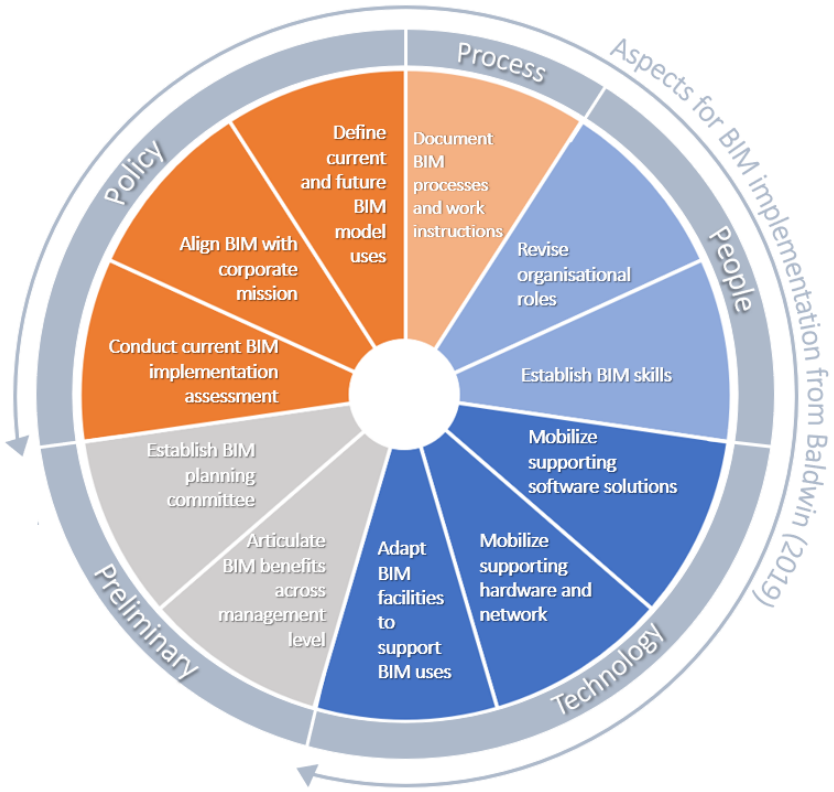


Figure 7 - BIM implementation actions according to literature

`

2.7.1.1. Preliminary actions

- Articulate BIM benefits across management level

Management buy-in is essential for aligning processes with organisational vision and goals, ensuring strategic guidance and appropriate allocation of financial and human resources. Located on the strategic level of decision making, the management should guide the direction of BIM implementation, ensuring it stays aligned with organisational vision and goals, and making decisions on resourcing for BIM (Baldwin, 2019; Building and Construction Authority, 2013; CIC, 2013).

In order to spread BIM awareness across the management level, an internal marketing campaign can be developed, aiming to show and better promote the BIM capabilities of the firm (Panaitescu, 2014; Demarchi, 2018). Seminars and marketing meetings should focus on the definition of BIM in order to, how BIM is currently being applied and the added value that the use of BIM has provided to projects. These actions promote homogeneous understanding among managers, creating a common view on BIM within the management level. Further, a marketing campaign can enable the identification of BIM implementation champions for each department (Panaitescu, 2014).

- Establish a BIM planning committee

According to CIC (2013), an organisation should conduct a strategic planning process in order to stablish the BIM vision, BIM objectives and set directions to focus implementation efforts. BIM strategic planning facilitates effective allocation of organisational resources for key BIM competencies and priorities, which is enabled by the establishment of a BIM planning committee. According to CIC (2013), the BIM planning committee should include individuals with background knowledge and experience with BIM and its related processes. It is important that the individuals that are part of the BIM planning committee can represent diverse group members from across the different departments and levels of decision making of the organisation. It is crucial for the BIM planning committee to count with representation from members from the strategic level of decision making, such as high-level executives and business areas directors. According to Panaitescu (2014), there is a need for individuals from the strategic level to steer the adoption process in the direction set by the strategy plan, guaranteeing necessary resources to support the BIM plan. As stated by Baldwin (2019), management buy-in is crucial for aligning processes with organisational vision and goals, ensuring strategic guidance and appropriate allocation of financial and human resources. In addition, individuals from the tactical level of decision making should be included, such as department managers. These managers should be involved in the core planning necessary and are responsible for operating and managing their departments in achieving the BIM goals set. Finally, the BIM planning committee should include individuals from the operative level of decision making, personnel directly involved with the technology and processes that drive BIM implementation on a daily basis. These individuals are responsible for the standard workflows subject to change due to integrating BIM.

2.7.1.2. Actions related to the policy aspect

- Conduct current BIM implementation assessment

The assessment of how an organisation has been conducting BIM is an essential initial action to be taken, in which the BIM planning committee measures the BIM maturity of the company by making use of measurement models (Badlwin, 2019; CIC, 2013; Muñoz-La Rivera et al., 2019). Additionally, BIM maturity measurement enables the identification of critical aspects for BIM implementation that require improvement, and allow organisations to benchmark their performance against other organisations from the same sector to determine opportunities for improving their internal and external processes (CIC, 2013).

- Align BIM with corporate mission

The elaboration of the vision and objectives is a task to be conducted by the BIM planning committee pushed through individuals from the tactical level in collaboration with the strategic level individuals, as suggested by Panaitescu (2014). Initially, an organisation should elaborate its vision regarding BIM by making a relation between defined corporate visions – or strategy – and the expected developments of BIM. In other words, identifying corporate visions implies in understanding the organisation's definition on how it has acted and how it projects itself towards the future for the use of BIM, defining current and desired business processes. The main objective is to answer how BIM will help an organisation in meeting these corporate visions, fitting the broader organisational vision (Muñoz-La Rivera et al., 2019).

The BIM planning committee should, then, identify goals that support the overall organisation goals, mission and visions (CIC, 2013). The goal setting is an important part of the BIM strategic implementation since it helps the organisation in overcoming the initial opposition and create short, medium- and long-term goals (Muñoz-La Rivera et al., 2019). BIM goals should be measurable and target operational aspects, such as reduce operational and lifecycle costs, improve operational workflows, develop internal quality assurance systems, etc. – and workforce capabilities – such as provide BIM education and training.

- Define current and future BIM model uses

The main objective of this action is to identify where BIM use cases can address the stated needs according to the BIM goals defined (Baldwin, 2019). According to CIC (2013), a BIM use is defined as method of applying BIM during a facility's lifecycle in order to achieve one or more BIM-specific objectives. Where BIM can be seen as a supporting process, a list of associated BIM model uses can be elaborated. The identification of BIM model uses enables the definition of future uses and this process can be assisted by using the BIM Project Execution Planning Guide as reference (Messner et al., 2019).

2.7.1.3. Actions related to the process aspect

- Document BIM processes and work instructions

According to CIC (2013), the integration of BIM into current organisational processes is a crucial step in order to implement BIM effectively. These new BIM integrated processes associated with each BIM use should be mapped, documented and included along with the different activities from the organisation in order to provide a basic understanding of the activity to be performed, in the form of work instructions and process maps. According to Siebelink, Voordijk and Adriaanse

(2018), the extent to which organisational and project-based BIM processes are documented – in the form of work instructions – affects the consistency and performance of processes. These work instructions are documented in the form of so-called organisational BIM guidelines and provide guidance for project setup, modelling methodologies and model structure and define workflows (Baldwin, 2019). In order to map these processes into workflows, organisations count with several different methods available, such as Business Process Modelling Notation (BPMN) and Unified Modelling Language (UML). Additional references can be consulted in order to facilitate the creation of process maps according to specific BIM uses, such as the BIM Project Execution Planning Guide (Messner et al., 2019).

According to Baldwin (2019), general principles and best practices for internal collaborative BIM work should be introduced in a company guideline. Topics such as internal data and document management systems, linking and referencing files, user access rights, internal review and approval processes; and file storing and sharing procedures should be addressed in an organisational BIM guideline. On the other hand, external project collaboration – between the contractor and the client – should be detailed in a BIM Protocol or BIM Execution Plan (BEP).

2.7.1.4. Actions related to the people aspect

- Revise organisational roles

Traditional roles and responsibilities within an organisation are required to change once the organisation decides to apply the BIM approach and initiate BIM implementation (Panaitescu, 2014). BIM roles assign tasks and responsibilities to different members from the organisation and are not necessarily related to specific positions. In addition, BIM roles can be developed by more than one person or allow one person to exercise more than one role (Muñoz-La Rivera et al., 2019). BIM roles and responsibilities within a company structure are still being refined across industry and there is no international consensus on how these roles should be defined (Baldwin, 2019).

A general guidance provided by Baldwin (2019) structures BIM implementation roles according to three structure levels: strategic, tactical and operational (Figure 8). According to the author, on the strategic level of decision making, the management should guide the direction of BIM implementation, ensuring it stays aligned with organisational vision and goals, and making decisions on resourcing for BIM. Individuals located at the tactical level of decision-making guides the direction of BIM within the parameters established by the management, being the primary party responsible for BIM implementation within the organisation. This involves the development of company BIM guidelines, general processes and project templates – such as the BIM Execution Plan (BEP). The end-users of BIM are located on the lowest level of decision making and are the ones directly involved with model authoring, design analysis, schedule generation, among others.

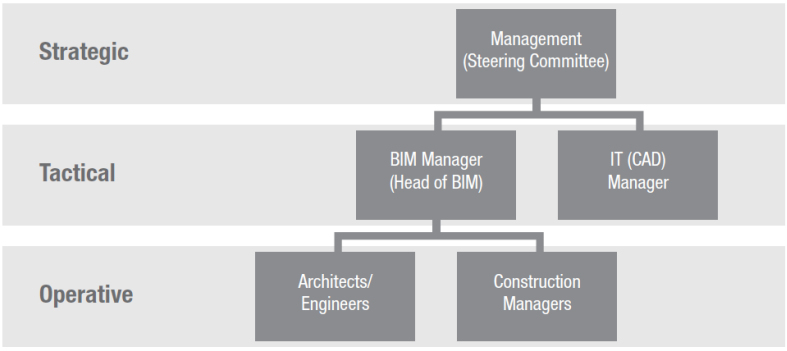


Figure 8 - BIM roles within an organisation (Source: Baldwin, 2019)

- Establish BIM skills

According to CIC (2013), it is crucial for an organisation to establish BIM skills by developing a consistent education program for the staff about the true capabilities of BIM. This action aims to educate the staff and help them in better understanding BIM and the organisation's purpose for using it. Therefore, the focus and objective of a BIM education program is to spread awareness on BIM, how it can be used and how it influences organisational roles and processes. Education on BIM can be provided internally via workshops developed and conducted by the implementation team, or externally.

BIM training, as defined by CIC (2013), relates to specific processes and software systems, including new and existing organisational processes and procedures, and new and existing software systems. Similar to BIM education, training can be provided internally and externally, being external training necessary when none of the members at the company has experience with the software, for example. It is important for the key BIM personnel to receive continuous external training, since BIM processes and technologies are continuously evolving, what can be done by enabling the key BIM personnel in attending to national and international conferences

According to CIC (2013), in order to structure BIM education and training, it is necessary to elaborate a strategy that includes (1) what subject to educate/train on, (2) who needs what education/training, and (3) what are the methods to be applied.

Competency map

The education and training programs should be tailored to the needs of people and target groups due to the multiple levels of expertise required in order to achieve higher levels of BIM maturity for this sub category. Managers, for example, might only need basic introduction to BIM and its benefits for the company, while those that conduct BIM implementation need a deeper

understanding of what BIM is, how it can be used (CIC, 2013). This exposes the need for developing a BIM competency map. According to the Building and Construction Authority (2013), a BIM competency map consists of a blue print that shows the types of skill set to be developed within the organisation according to different roles and their involvement with BIM. This competency map assists in the identification of what individuals should be considered for specific BIM education program and training according to their function at the company. Additional guidelines to be used in order to assist with this process are the BIM Essential Guide (Building and Construction Authority, 2013) and the BIR BIM leaflets from *Bouw Informatie Raad*.

Education roadmap

In order to structure a training or education program in BIM, it is recommended to elaborate a training roadmap. The function of this roadmap, as defined by Building and Construction Authority (2013), is to list the education/training programs to be provided to the staff, the functions of the personnel included in the program, the number of individuals considered, the timeframe and the training provider (internal or external). Documenting and listing such information are a way of structuring the education/training program, crucial for achieving higher levels on the BIM maturity scale for this subcategory (Siebelink, Voordijk and Adriaanse, 2018).

Education/training database

Additionally, a database should be created in order to allow practitioners involved with BIM to share learning points for BIM implementation, discuss obstacles and document learning points such as bad and good practices for BIM execution within the company. According to Siebelink, Voordijk and Adriaanse (2018), consider practical experiences for the improvement of BIM education and training within the company, with good and bad BIM practices experienced during projects, is crucial in order to achieve higher levels of maturity for this sub category.

2.7.1.5. Actions related to the technology aspect

In order to enable the implementation of BIM according to the objectives and intended BIM uses, it is necessary to develop the technical resources required by determining the infrastructure needs (Panaitescu, 2014). Technical resources incorporate BIM software, adequate hardware and network components, and physical spaces (CIC, 2013).

- Mobilize supporting software solutions

The definition of the necessary software part of the BIM implementation depends on the establishment of the BIM goals and uses. Once this has been defined, it is possible to start with the identification of BIM software that meets the organisation's specific needs (Baldwin, 2019). Besides the intended uses, other criteria are relevant and should be considered during this stage, such as software interoperability to work in BIM environments, an important aspect for exchange of project data between internal departments and external partners. The interoperability should focus on open standards and data formats for large scale use, such as Industry Foundation Class (IFC), a largely used open standard that allows interoperability (Panaitescu, 2014).

- Mobilize appropriate hardware and network environment

It is important to ensure that the hardware and network environment support the BIM uses that were selected for the operation of the facility (CIC, 2013). Required hardware capabilities are closely related and dependent on the project size and the models to be modelled during the project life cycle (Muñoz-La Rivera et al., 2019). Therefore, the selection of adequate hardware has to be made dependent on these aspects. In addition, since the core of BIM is the connection of processes, files, models and project parties, a suitable network environment is required to allow data exchange between the project team. To this end, cloud computer environments are recommended (Muñoz-La Rivera et al., 2019).

- Adapt BIM facilities to support BIM model uses

In order to achieve greater and better interaction essential for a collaborative environment such as BIM, workspaces within the company should be adapted. Such spaces allow the visualization of a central model on screen and serves as a meeting and decision-making room for all project members during model review sessions (Muñoz-La Rivera et al., 2019). Aspects such as size of space, number of people it supports, presence of high-definition monitors, and interactive displays are important to be considered (CIC, 2013). In addition, the BIM working group should develop a physical space remodelling plan, as defined by Muñoz-La Rivera et al. (2019). This plan should be proposed regarding the necessary physical spaces resources for the BIM workflow and the organisation's current physical space in order to adapt the size of the workspaces.

2.8. Conclusion

This chapter aimed to build a theoretical perspective around the subject of organisational BIM implementation, its benefits when done successfully and its shortcomings when done unsuccessfully. Several considerations for BIM implementation were approached, such as the

three levels of decision making and the four aspects for BIM implementation as defined by Baldwin (2019). Additionally, literature on the measurement of organisational BIM maturity via BIM maturity models was consulted, in which several models found in literature were mentioned. Special attention was given to the BIM Maturity Model developed by Siebelink, Voordijk and Adriaanse (2018) due to the shortcomings and limitations of the other models available in literature. The different levels of BIM maturity and the criteria considered for maturity measurement according to the model were approached. This answered question I). In addition, a framework for BIM implementation was presented in order to group the different implementation actions gathered from relevant literature according to the aspects from Baldwin (2019), with the addition of a preliminary category. This framework will be considered for the elaboration of tailor-made specific recommendations in Chapter 4.

The conceptual model should, then, be read as follows: based upon literature search, the researcher has chosen to study the aspects that compose organisational BIM implementation and maturity model that aim to measure the BIM maturity of an organisation. The conceptual model is shown in Figure 9, in which the numbered items are associated with each concept and its correspondent item introduced in this theoretical framework.

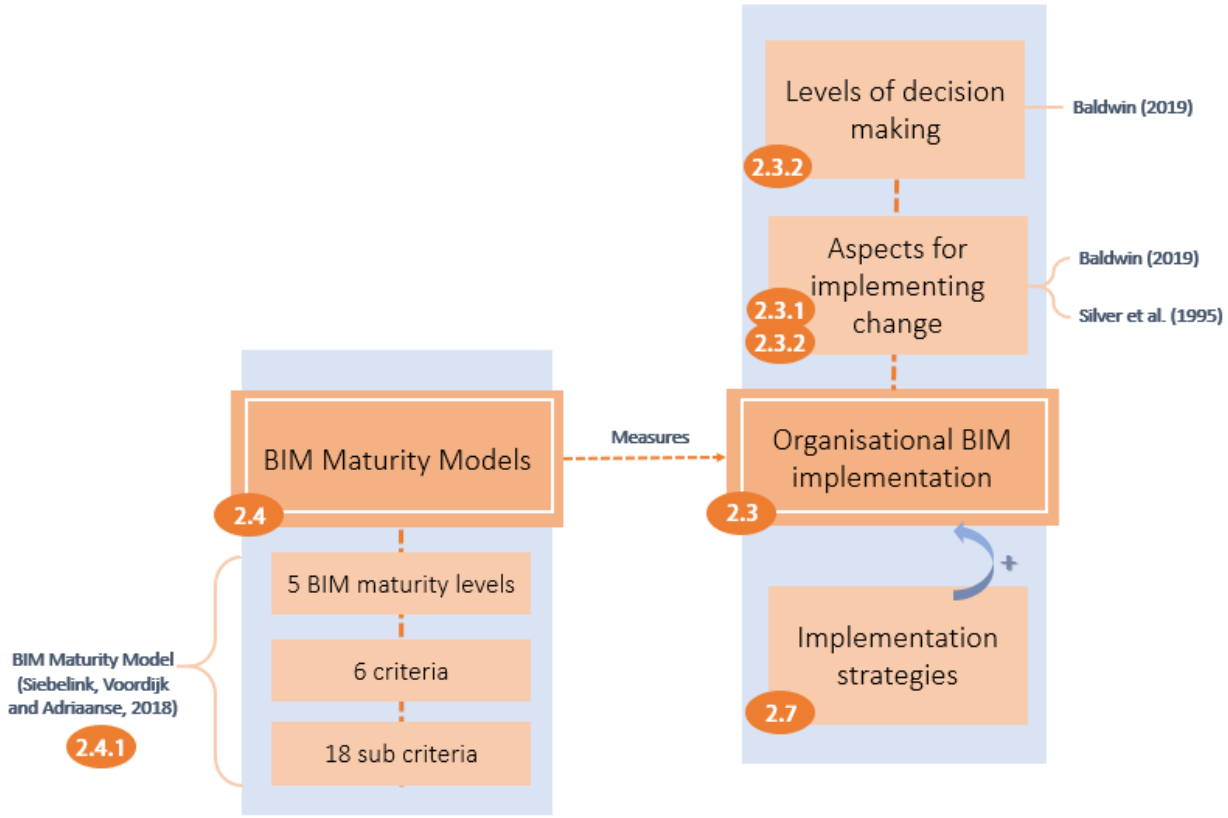


Figure 9 - Theoretical framework

SECTION II

CASE STUDY RESEARCH

Question to be answered:

II) What is the current BIM level of maturity of the commissioning organisation according to the BIM Maturity Model?

3. RESULTS FROM THE CASE STUDY

3.1. Results from the BIM maturity model

The analysis of the current BIM implementation in the organisation is done via the BIM Maturity Model as proposed by Siebelink, Voordijk and Adriaanse (2018). The data gathered from the interviews served as input for the maturity model and in this item the results shown in Figure 10 will be further discussed. A summary of the interviews according to the topics is included in Appendix IV.

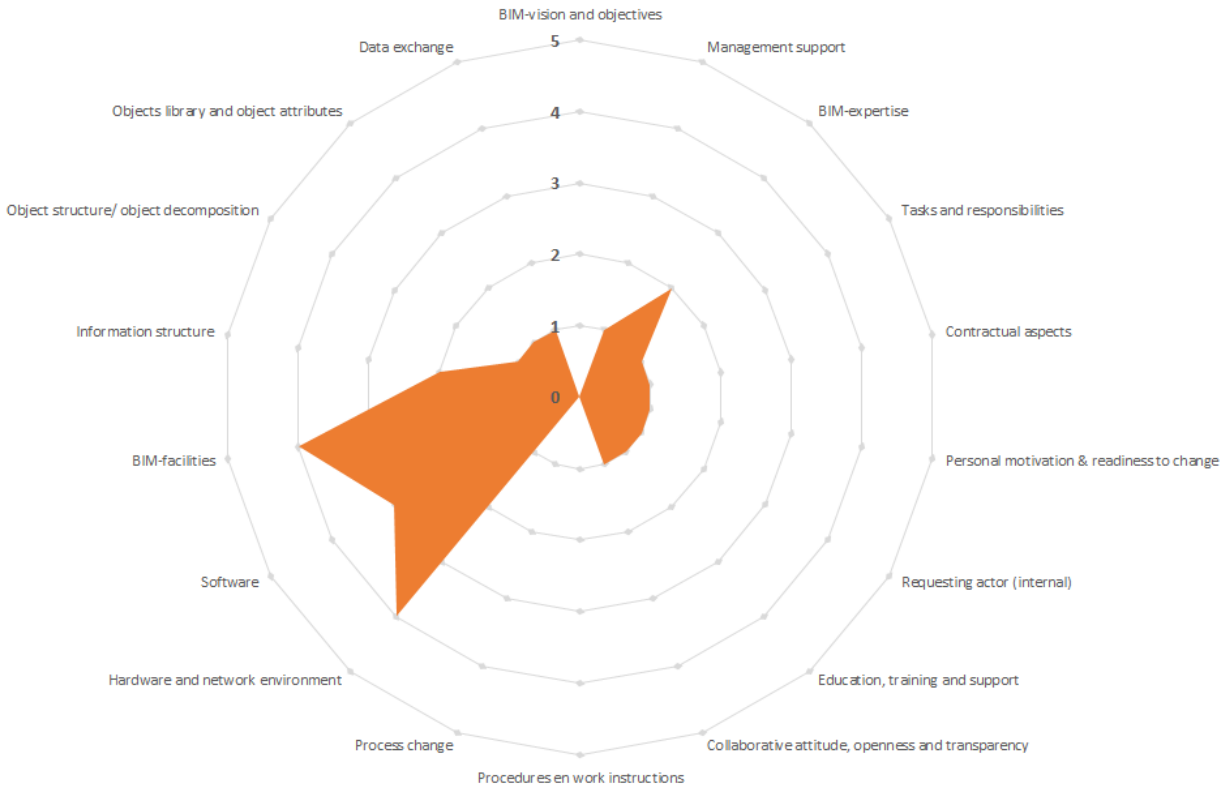


Figure 10 - Maturity scores according to sub criterion

Strategy

Sub criterion 1: BIM vision and objectives

It has been a consensus among the individuals interviewed that BIM vision and goals have not been set up properly as part of a strategic implementation specifically for BIM. According to a lead engineer interviewed “There are general company visions and strategic goals that can be indirectly related to BIM, but this is not done explicitly”. In other words, the goals elaborated so far are

fragmented and relate to certain applications of BIM, and not BIM as a whole. Some specific goals related to the application of BIM have been defined such as the desire from the company to have 4D modelling implemented until the end of 2020. However, specific goals such as this are not part of a broader picture on where the company wants to go with the implementation of BIM. As pointed out by interviewee 1, interviewee 2 and interviewee 4, this is due to the fact that there is a lack of understanding of what BIM is and what it represents for the company, making it difficult to elaborate specifically on a BIM vision and goals. In addition, the lead engineer added "We have in our company strategy something about digitization, which is part of BIM, but not specifically for BIM". This sub criterion was assigned with level 0.

Sub criterion 2: Management support

The support given from the management level for BIM is quite limited. The management understands the necessity of delivering BIM due to project requirements, but there is a lack of consensus of the meaning of BIM, what it incorporates and its benefits for the organisation (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 6, interviewee 7, interviewee 8). As stated by the Interviewee 4, "At this moment BIM is not supported because it has not been explained clearly what is BIM for us. Considering that BIM is not explicitly identified, we never discussed it in a conscious way". The practical consequence of this is that the management only supports BIM due to the fact that BIM is required by the client, and not as a process that should be encouraged in order to improve the practices in the company. The allocation of resources is unstructured and ad hoc since it is made on specific initiatives and BIM uses, but not for the implementation of BIM as a whole. This sub criterion was assigned with level 1.

Sub criterion 3: BIM expertise

Within the organisation, a limited number of BIM experts can be identified (interviewee 1, interviewee 3, interviewee 4, interviewee 7, interviewee 8). These individuals coordinate the processes of specific BIM uses, such as 3D modelling and use of Common Data Environment (CDE). However, these individuals do not form a structured working group, since, in practice, they accumulate functions and their support for BIM is dependent on the time they have left besides other activities (interviewee 1, interviewee 3, interviewee 4, interviewee 6). It is recognized by the managers interviewed that there is a need for a structured BIM working group in order to facilitate BIM implementation, but this has not been done yet. According to interviewee 6, "The BIM experts identified in the company steer BIM from their own, but it has never been a company decision to implement BIM and structure a BIM working group". In addition, it has been a consensus among all interviewees that senior management cannot be identified among the BIM experts. This sub criterion was assigned with level 2.

Organisational structure

Sub criterion 1: Tasks and responsibilities

The documentation/formalization of roles and responsibilities when it comes to BIM is insufficient. Some sort of BIM roles description and formalization is only carried out on the project level when the client requires for a description of BIM roles. However, these roles are not formalized and are not defined on the organisational level (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 6, interviewee 7, interviewee 8). As pointed out by interviewee 1, "Documentation that relates to tasks and responsibilities of BIM functions are laid down on the project level in the form of BIM Execution Plans (BEPs)", but not on the organisational level. This has been confirmed by analysing BEPs elaborated for previous tenders. The consequence of that, as pointed out by individuals from different individuals during the interviews, is that it is difficult to form a BIM working group if there is no definition of what BIM roles are necessary and what are the responsibilities of each role. It has been recognized that there is a need for division of tasks and responsibilities associated with BIM. This sub criterion was assigned with level 1.

Sub criterion 2: Contractual aspects

Within the organisation, there is no standard or directive available when it comes to the use of BIM, such as project 3D design. The absence of a standardized BIM guideline/protocol for internal use at Van Oord has been a consensus among the individuals interviewed. BIM is included in contracts only due to project requirements when requested by the client, as stated by interviewee 1, interviewee 2, interviewee 4 and interviewee 7, and confirmed by the analysis of BIM Execution Plans elaborated by the organisation. This sub criterion was assigned with level 1.

People and culture

Sub criterion 1: Personal motivation

The motivation for the use of BIM is quite limited. Despite motivation from a group of adopters, there is little enthusiasm for BIM among the majority (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 6, interviewee 7, interviewee 8). There is quite some resistance at the company when it comes to BIM and this might be related to the workforce that we have since they are used to traditional practices, making them not embrace the concept. Additionally, this can be associated with the lack of awareness and consensus of what BIM represents and its benefits, as pointed out by several interviewees. On the other hand, it has been pointed out by interviewee 1, interviewee 4, interviewee 7 and interviewee 8 that once the barrier of lack of awareness is overcome and BIM becomes part of the strategic goals explicitly, the motivation will be there due to the fact that relevant motivation can be identified for specific BIM applications. As stated by the interviewee 1, "If the members from our organisation see exactly what BIM is and

its benefits, they are also willing to adapt their way of working. But getting to the point in which they see the benefits, that is where the challenge relies on". This sub criterion was assigned with level 1.

Sub criterion 2: Requesting actor/BIM champion

Within the organisation, there is limited number of individuals that can be identified as BIM Champions located in different departments. These individuals mobilize efforts in order to stimulate other project team members on the use of BIM (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 7, interviewee 8). However, these individuals do not have sufficient time and capacity to fulfil this role properly, nor participate in any BIM discussion or form a BIM working group. It has been a consensus that no individual within senior management acts as a BIM champion, what is associated by some of the interviewees with the difficulties faced during the process of BIM implementation. This sub criterion was assigned with level 1.

Sub criterion 3: Education, training and support

Education and training for BIM within Van Oord is unstructured and ad hoc. In practice, no extensive training sessions are provided to project team members focused on BIM applications. In addition, no general information on BIM is provided organisation-wide to motivate and to raise awareness in the form of BIM workshops (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 6, interviewee 7). According to the interviewees, Van Oord provides the possibility for individuals to attend external courses held by external organisations, such as software developers, according to their specific needs. "This is the case for 4D modelling, in which the organisation mobilizes necessary resources for individuals to attend a training course provided by a 4D software developer", as stated by interviewee 1. Therefore, the training provided is limited to individual development plans and the focus is, then, the competences that individuals need to acquire in order to fulfil their roles. But as a whole, there is no specific BIM related in house training program. This sub criterion was assigned with level 1.

Sub criterion 4: Collaborative attitude, openness and transparency

Only basic processes are defined to foster collaboration with other parties, but external cooperation is not part of the organisation strategy, allowing to say that the organisation is internally oriented (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 6, interviewee 7, interviewee 8). As stated by interviewee 1, "in general, Van Oord is quite closed in sharing information, especially when it comes to sharing financial information and production information". Some of the interviewees pointed out that the mutual trust between partners is growing, even though there is no joint functioning network for BIM that exceeds the individual

interests of the organisation and making collaboration part of the company's strategy is one of the goals of the organisation. As stated by interviewee 8, "I consider that collaboration with other companies is improving. We are looking especially at companies to work with us considering capabilities we do not have, such as for BIM (integrated contracts). For BIM, the problem is that we build knowledge during joint activities but we do not know how to bring this knowledge and set it up for Van Oord". This sub criterion was assigned with level 1.

Processes and procedures

Sub criterion 1: Procedures and work instructions

Within the organisation there are no standardized procedures or job instructions for most of the BIM uses. BIM-related processes – such as setup of a CDE and 4D implementation – have been initiated but are not formalized in any type of job or work instruction. Sorts of process formalization can rarely be found (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 7, interviewee 8). This has been mentioned by several interviewees as one of the most relevant issues currently when it comes to organisational BIM implementation. As stated by interviewee 1, "Work instructions are limited to some applications of BIM, such as for design activities, but BIM is barely explicitly mentioned". This sub criterion was assigned with level 0.

Sub criterion 2: Process change

BIM is currently not considered as a driving force for improving processes (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 7, interviewee 8). As interviewee 1 stated "BIM is not being perceived as a change on the way we work. It is still being more perceived as a tool for specific activities, what does not lead to fundamental process change". Individuals from the management level attributed this to the fact that there is a lack in identifying what BIM is, what it means to the company and its benefits as a process that promises to change traditional work practices (interviewee 5, interviewee 8). This sub criterion was assigned with level 0.

IT infrastructure

Sub criterion 1: Hardware and network environment

The available hardware provided organisation-wide is able to run advanced BIM software applications and the quality of the network environment allows cloud-based working on building model by multiple parties, being sufficient to support the current required BIM uses (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 8). However, future needs with respect to BIM is not an aspect considered in order to identify necessary changes in time and to keep hardware systems up-to-date (interviewee 1, interviewee 4). As stated by interviewee 4, "The

reason why this sub category does not score higher levels is that our database is not configured in such a way that supports working simultaneously on a building model by multiple parties". This sub criterion was assigned with level 4.

Sub criterion 2: Software

Software availability is not a barrier for BIM implementation at Van Oord since the available BIM software is appropriate for the intended BIM uses (interviewee 1, interviewee 2, interviewee 3, interviewee 4). The organisation counts with a vast quantity of BIM tools available, such as software licenses for BIM applications that can be requested by any individual under approval. As stated by interviewee 4, "Up to 4D we have everything in the company to make it happen". Additionally, the organisation ensures that the BIM tools used are kept in line with the latest developments in the field by maintaining a constant contact with software developers (interviewee 3). However, future needs for BIM are not mapped regularly in order to keep used software aligned with these needs (interviewee 1). This sub criterion was assigned with level 3.

Sub criterion 3: BIM facilities

Van Oord provides necessary well-equipped facilities to accommodate meetings and coordination sessions with BIM. In general, the availability of spaces and meeting rooms that support BIM collaboration is not a limitation within the organisation (interviewee 1, interviewee 3, interviewee 4, interviewee 8). However, the needs of BIM-related activities are not actively monitored in order to identify necessary changes and to be able to make changes accordingly (interviewee 1, interviewee 4). This sub criterion was assigned with level 4.

Data (structure)

Sub criterion 1: Information structure

On the organisational level, the organisation counts with a digital document management system, a Van Oord platform on SharePoint, in which every employee at the company has access to. This platform is used to share company information, such as organisational policies and description of generic processes (management of the organisation, document management, incidents, etc.). The so-called Van Oord Management System (VOMS) is an integrated, compact, management system in which the main processes of the company are described in corporate procedures. On the project level, the project team makes of Common Data Environments (CDEs) as DMS for the exchange of project-related information (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 7). The type of application used as CDE is project specific and depend on contract requirements from the client. However, documents are not linked directly to objects in a BIM

environment (interviewee 1, interviewee 2, interviewee 4, interviewee 8). This sub criterion was assigned with level 2.

Sub criterion 2: Object structure

The company does not have a uniform methodology for decomposition/structure of building object parts on the organisational level, only on the project level (interviewee 1, interviewee 2, interviewee 3, interviewee 4, interviewee 5, interviewee 7). However, a company-wide uniform approach for object structure is under development (interviewee 1, interviewee 5). Additionally, agreements on object structure are only made on a project level, and sector wide standards are followed depending on the client's requirements (interviewee 1, interviewee 4). This sub criterion was assigned with level 1.

Sub criterion 3: Objects library and objects attribute

The organisation makes partial use of object library for creation of building models. Partially because it varies according to different departments. Some departments such as CAD design make use of object libraries, but these object libraries are not part of a uniform approach and are not aligned and centrally managed (interviewee 1, interviewee 4, interviewee 5, interviewee 7). This sub criterion was assigned with level 1.

Sub criterion 4: Data exchange

Within the organisation, data exchange of project-related information is mainly limited to internal teams/departments. How well defined the process of data exchange with other parties is (e.g. clients) in contracts or protocols – BIM Execution Plan (BEP) and Employer's Information Requirement (EIR) –, depends on the project contract. Depending on the project contract, data exchange with other parties is defined in contracts or protocols, to a limited level. Additionally, data is not exchanged via the building model, but mostly from the building model (interviewee 1, interviewee 2, interviewee 4, interviewee 5, interviewee 7, interviewee 8). Project information is extracted from the models and shared with the client, instead of using the BIM model itself as a data exchange platform. The organisation does not make use of IFC and data exchange does not focus on measuring and improving the performance (interviewee 1, interviewee 2, interviewee 4, interviewee 5). This sub criterion was assigned with level 1.

3.2. Results from the discussion meetings

Discussion meetings were conducted with key members from the organisation in order to discuss the outcomes from the maturity model and set priorities for the third phase of the study. In addition, several topics were discussed as presented in Table 2 in order to provide input for the third phase and allow the elaboration of tailor-made company-specific recommendations. The outcomes of the discussion will be presented in the items that follow.

BIM definition for the organisation

As pointed out during the interviews, one of the most relevant issues for BIM implementation at the organisation is the lack of understanding of what BIM means. Therefore, there is a need for choosing a definition of BIM before the strategic planning – with the definition of BIM vision and goals - is initiated. For that, different definitions of BIM according to relevant literature were presented and discussed together with key individuals during the first discussion meeting. The objective was, then, to choose a definition of BIM that (i) uses non-complex terms for defining BIM is; (ii) is understandable by all individuals involved in the discussion; and (iii) can be associated with BIM processes and initiatives that are already in place at the organisation. The definition of BIM chosen is a combination of what is defined by Siebelink, Voordijk and Adriaanse (2018) and Borrmann et al. (2018):

BIM consists of an object-based multidisciplinary approach that describes both the process of creating digital facility models as well as the process of maintaining, using and exchanging them throughout the entire lifetime of the built facility. It is aimed to facilitate collaboration between parties and to integrate object-related information, a function supported by Information Technology (IT).

From this definition it was possible, then, to identify and associate the BIM initiatives throughout the organisation. This was done by considering the first part of the definition that relates to the process of creating, using and maintaining facility models; and the second part that relates to the process of exchanging facility models. Table 4 shows the relation between the chosen definition, the BIM initiatives detected in the organisation and some of the associated BIM platforms currently being used. More on BIM Model Uses is discussed in the following paragraphs.

Table 4 – Grouping of the initiatives and platforms present according to the BIM definition

		Initiatives	Platforms
BIM	Process of creating, using and maintaining facility models	3D modelling 4D modelling 5D modelling Additional BIM Model Uses	Autodesk Revit© Autodesk Civil 3D© Navisworks© Synchro 4D© Graphisoft ArchiCAD©
	Process of exchanging building models	Use of Common Data Environment (CDE) for the exchange of building modelling information	BC Business Collaborator© Relatics© SharePoint©

Corporate mission

The second topic of the discussion meetings was related to the existence of a corporate mission. The relevance of this topic is due to the fact that, as part of BIM strategic planning, it is important for an organisation to formulate a BIM vision aligned with the corporate mission. Therefore, in order to allow the researcher to provide recommendations in the third phase of the study related to a BIM vision, there was a need to identify the corporate's vision and mission. According to the individuals considered for the discussion meetings, there is an organisational vision and mission in place considering its areas of expertise and the relation with external clients. The analysis of corporate documents and brochures supported that affirmation, and a fragment of the corporation's mission and vision is shown in Figure 11.

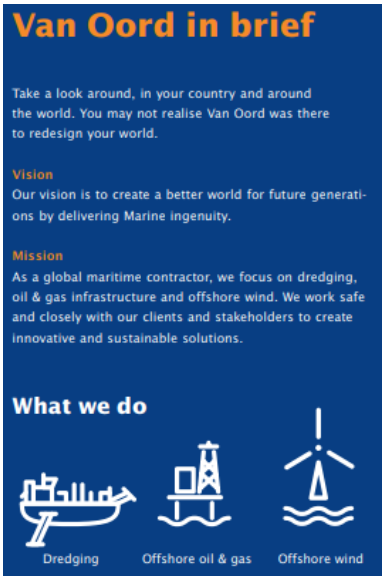


Figure 11 - Corporate vision and mission

Current BIM model uses

In order to provide input for the third phase of the study to provide recommendations for the organisation, it was necessary to conduct a discussion around the BIM model uses currently applied. The starting point for this discussion was the implementation guide from CIC (2013) that presents a list with the BIM model uses commonly applied in the construction industry. The individuals considered for the discussion meetings were asked to provide their insights on each BIM model use in order to identify these uses within the company's practices. Model uses were classified between *Not applied, Under development* and *Applied to some extent*. Even though an in-depth analysis is necessary in order to confirm the insights provided and classify the model uses according to business unit and department, they were sufficient to serve as a starting point for providing recommendations on BIM strategic planning. A list of the model uses is included in Appendix V.

Current digitalization initiatives

A discussion was made around current digitalization initiatives in order to define convergences and divergences between these initiatives and BIM. This provided an important input for the recommendations part of the BIM acceleration plan to be approached in the next chapter. Currently, two initiatives that have relevant similarities with BIM can be identified, and the following chapter will elaborate further on these initiatives. A scheme on the convergences and divergences is presented in Figure 12.

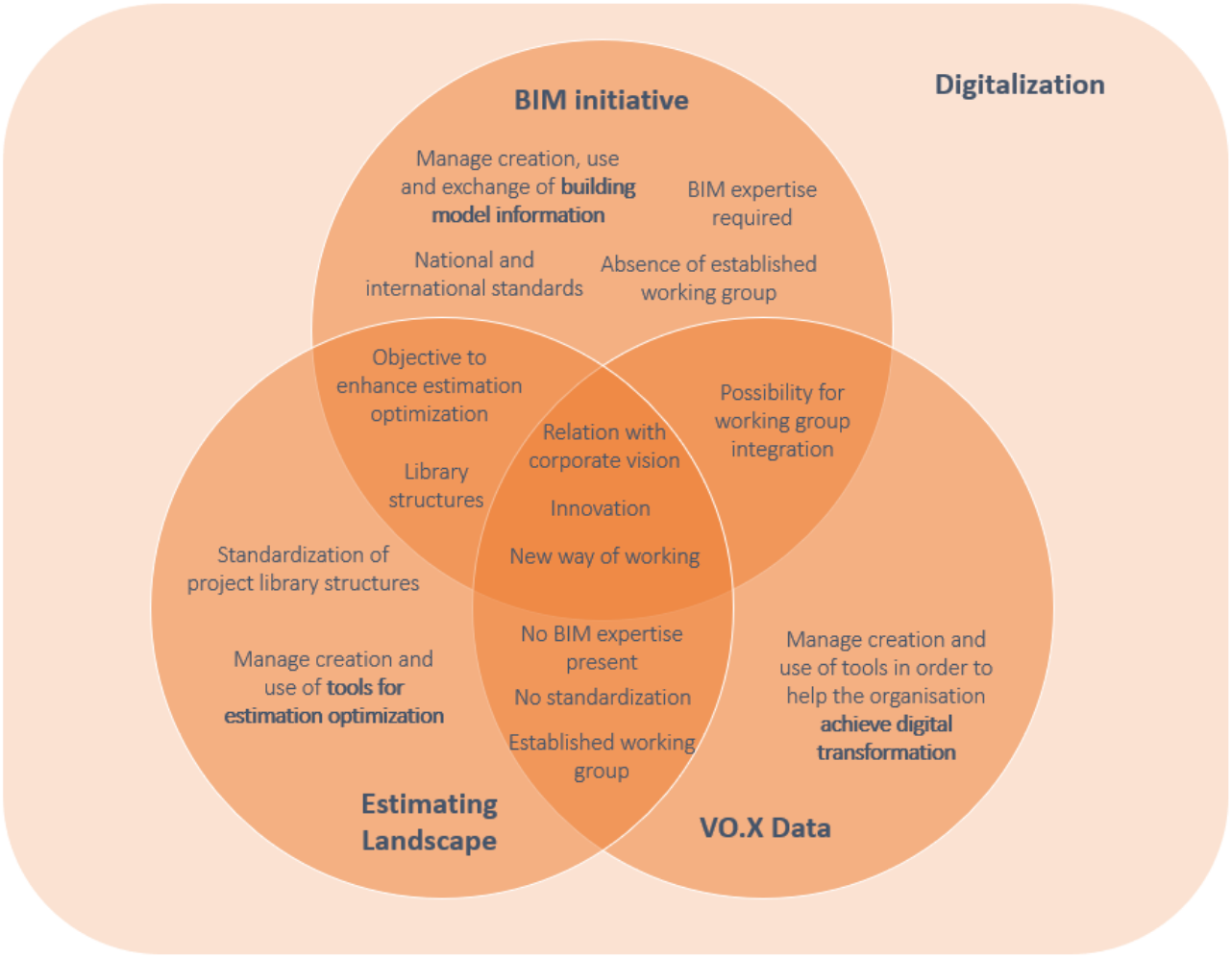


Figure 12 - Convergences and divergences between a BIM initiative and existing digitalisation initiatives

VO.X Data and BIM

At the commissioning organisation, there is one initiative dedicated to elaborate, implement and manage digitalisation. This initiative – called VO.X Data – consists of a working group that counts with ten personnel dedicated for carrying out digitalisation within the organisation. This is done by developing digital tools that aim to create value for the clients and the company's business, such as the Commercial Intelligence Platform. This platform is a digital application linked to internal and external databases and generates client and market information to the user, aiming to enhance communication and collaboration between the organisation and its clients.

In order to make a parallel between this initiative and BIM, their convergences and divergences were discussed during the discussion meetings. VO.X Data and BIM converge in an important aspect: the context and its relation with the corporate vision. Both VO.X Data initiative and BIM are embedded in the digitalisation context, that aims to add value and support organisation by

introducing digital technologies. By going through the business strategy of VO.X Data, it is possible to identify terms commonly used by BIM initiatives, such as “digital technologies”, “new way of working”, “digital movement” and “data management”. As stated in the document, the main objective of the initiative is to make the digital transition happen within the organisation and to improve the data quality used. In addition, the initiative’s vision relates to the corporate vision by focusing in innovation and collaboration. These two aspects were also considered in order to provide direction on how the organisation should create a BIM vision aligned with the corporate vision.

However, divergences could also be identified between VO.X Data and a possible BIM initiative. First, the level of expertise of the existent initiative does not include BIM. In other words, no individual present in the working group has prior experience and knowledge on managing BIM processes. This is quite relevant especially if it is considered that conducting BIM implementation requires sufficient knowledge on the definition of BIM, what it comprehends, its associated processes and national and international standards. Next, the focus of the current initiative is considerably different from a BIM initiative. While for a BIM working group, the focus is to manage the process of creating, using and exchanging building model-related information; for VO.X Data the focus is to develop in-house digital applications that uses databases in order to enhance collaboration between client and organisation.

Estimating Landscape and BIM

The second digitalisation initiative object of discussion during the discussion meetings was the Estimating Landscape initiative. This also-called digital system was created aiming to automate routine tendering and estimating processes for some business units within the organisation. The system logs how long operations take and the amount of material used in a database. This database delivers validated and verified product and cost information that supports more accurate tendering. In addition, Estimating Landscape aims to standardize different project structures within the organisation by creating library structures that facilitate the creation and federation of BIM models. Even though it is a recent initiative, it is already possible to identify the quality boost that Estimating Landscape provided during tenders.

Similarly to the VO.X Data initiative and BIM, Estimating Landscape is also embedded in the digitalisation context, as part of one of the initiatives that aim to transform business processes via the use of technology. However, Estimating Landscape focuses in managing the creation and use of tools for estimation optimization, and does not necessarily involve building information models.

<u>BIM planning committee</u>

At the commissioning organisation, a BIM planning committee was never established and formalized, as pointed out during the interviews and discussed in the first part of the case study.

Additionally, it was a consensus that several individuals can be identified as BIM champions, even though scattered between different departments and located in different levels on the decision-making scale. Therefore, in order to establish a BIM planning committee according to the theoretical framework presented in item 2.7.1, key individuals for BIM implementation were consulted during the discussions meetings to deal with this matter. The information provided on the possibilities to integrate different individuals in a BIM planning committee was a necessary input to formulate the recommendation on that topic, presented in the next chapter.

3.3. Conclusion

This chapter aimed to present a case study conducted at the marine contractor Van Oord with the objective of measuring its BIM maturity via the BIM Maturity Model developed by Siebelink, Voordijk and Adriaanse (2018). In addition, four discussion meetings were conducted with key personnel in order to discuss specificities of the organisation to provide input for the tailor-made recommendations. In order to apply the maturity model and allow the measurement of the BIM maturity level, interviews were conducted with several individuals from different levels of decision making from the company. By going through the questions from the interview protocol (Appendix I), individuals were able to assign a maturity score for each of the 18 sub criterion from the 6 criteria considered in the BIM Maturity Model according to their own perceptions. The results presented in Figure 10 relate to the maturity levels according to each sub criterion, while Figure 13 presents the results in average values according to each criterion. The criteria values do not represent defined maturity levels but the average between the levels assigned to each corresponding sub criterion.

As pointed out during the interviews and shown in Figure 10 and Figure 13, the organisation has been focusing on BIM implementation almost exclusively from the technology deployment perspective, and has not been putting sufficient attention on the other aspects of BIM – policy, process and people, as defined by Baldwin (2019). This way of managing BIM implementation – and the problematics consequent from this – is exactly what Baldwin (2019) has associated in his publication as a “discourage sequence”, as shown in Figure 5. Companies that focus almost exclusively on the technology aspect and do not tackle the other aspects sufficiently, tend to face expressive difficulties during BIM implementation, what can be identified in the commissioning company, as proved by the BIM Maturity Model.

The company has been making use of BIM over the years, especially when it comes to 3D modelling and use of Common Data Environments (CDEs) on the organisational and project specific levels. However, this use of BIM is limited and unstructured. No sufficient attention was given so far in structuring a BIM department, elaborating a BIM strategic plan with defined visions and goals, assigning BIM-specific roles and responsibilities, elaborating and documenting BIM processes and work instructions, and on increasing awareness of the importance of BIM for the organisation among key individuals, especially those from the management level. The combination of these

factors explains why the company is facing the current issues with BIM implementation. And this diagnosis was obtained via the BIM Maturity Model that this case study applied, evidencing the applicability of the measurement method, answering sub question II).

From the discussion meetings, it is possible to define the critical categories of BIM implementation that demanded special attention. According to the insights provided during the discussion meetings, there was a desire from the organisation to focus on the criteria that scored the lowest levels and relate to the initial aspects for BIM implementation. In other words, the organisation wanted to focus on the aspects that belong to the upper right corner of the BIM implementation matrix from Baldwin (2019) in order to elaborate the recommendation steps. This identification was necessary in order to define priorities for the elaboration of the recommendations, to be approached in the next chapter. Figure 13 shows that among the BIM implementation criteria, 4 criteria were assigned with an average level of 1 or less – strategy, organisational and project structure, people and culture, and processes and procedures -, while two criteria scored higher average maturity levels, being ICT (infrastructure) the criteria that scored higher. Therefore, in order to elaborate the recommendation steps to be taken by the organisation, the four criteria that scored the lowest average levels were considered for the third phase of the study.

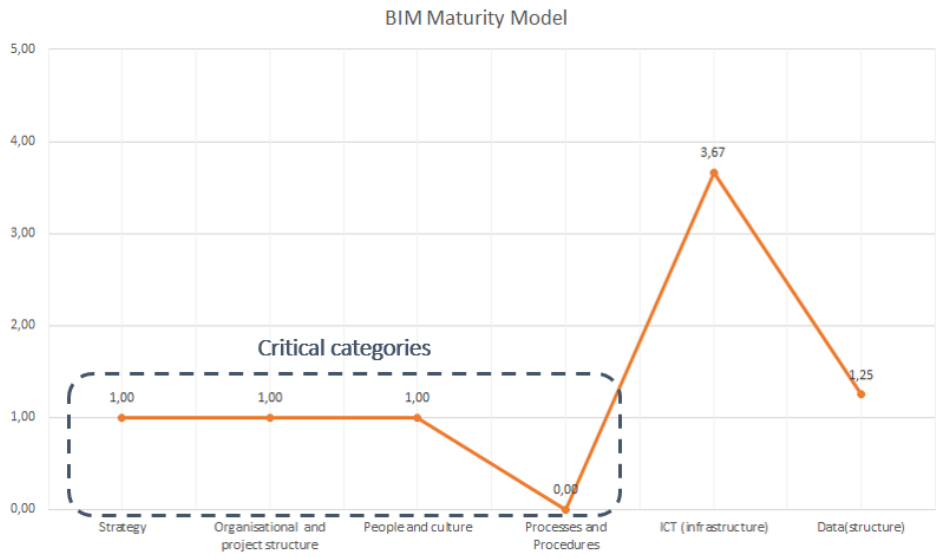


Figure 13 - Average maturity for each criterion

SECTION III

ELABORATION OF SET OF RECOMMENDATIONS

Questions to be answered:

III) What actions should be taken in order to increase BIM maturity of the commissioning organisation?

4. BIM IMPLEMENTATION ACCELERATION PLAN

4.1. Introduction

The case study conducted at the commissioning organisation provided an insight on the current BIM maturity of the company considering six different criteria from the BIM Maturity Model. Based on the outcome from the interviews conducted, it was possible to draw a diagnosis on the aspects of BIM in which the company is lagging behind. For that, a prioritization had to be made in order to provide the organisation with impactful actions to be taken to accelerate BIM implementation. The categories from the BIM Maturity Model were grouped according to the relation they have to the aspects for BIM implementation from Baldwin (2019).

This chapter develops an acceleration plan for BIM implementation in the form of recommended actions organised following the same structure as approached in item 2.7.1 from the theoretical framework and considering the prioritized categories from the case study. Therefore, linking the BIM implementation framework from the theoretical framework and the outcomes from the case study in order to provide tailor made directions for the company – here called BIM implementation acceleration plan - to enhance its current BIM level of maturity considering its specificities.

The first part of this chapter elaborates on the recommended actions part of the acceleration plan, while the second part of the chapter elaborates on the expected impacts of the proposed actions.

4.2. Recommended actions

As discussed previously, the outcomes of the case study were crucial in order to prioritize the categories to be considered for the recommendations to be elaborated in the third phase of the study. For that, the four categories that scored the lowest average values of BIM maturity were considered. This was crucial in order to select what implementation actions included in the implementation framework from item 2.7.1 should be proposed for the organisation, aiming to increase its level of BIM maturity via impactful tailor-made actions. The rationale behind this selection is included in Appendix VI. The company specific tailor-made actions that compose the BIM implementation acceleration plan (Figure 14) will be further elaborated in the following items.

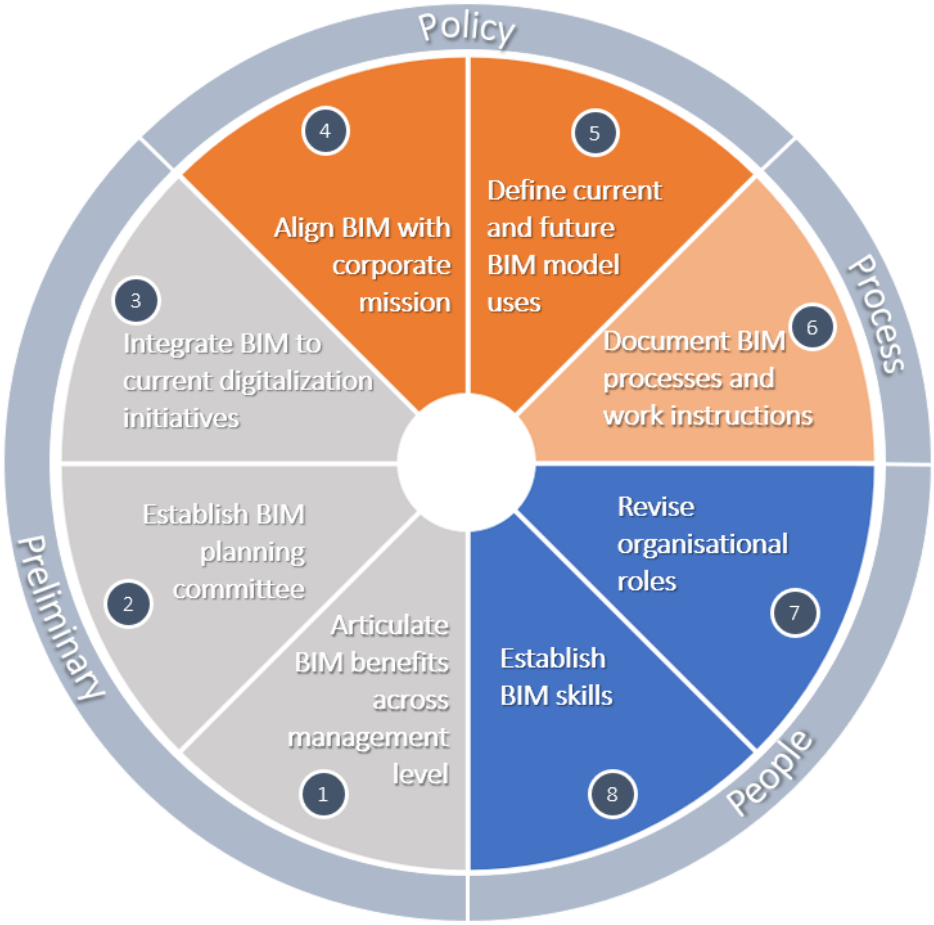


Figure 14 – Proposed BIM implementation acceleration plan

4.2.1. Recommendations on preliminary actions

- Action 1: Articulate BIM benefits across management level

As discussed in item 2.7.1.1, management buy-in is essential for aligning processes with organisational vision and goals, ensuring strategic guidance and appropriate allocation of financial and human resources. Located on the strategic level of decision making, the management should guide the direction of BIM implementation, ensuring it stays aligned with the organisational vision and goals, and making decisions on resourcing for BIM.

As concluded in the case study, there is a lack of management support given to BIM mostly due to the lack of consensus of the meaning of BIM, what it incorporates and its benefits for the organisation. Therefore, due to the importance that management has in supporting all the following proposed actions for BIM implementation, it is recommended for the commissioning

organisation as the first impactful action to articulate the BIM benefits across the management level.

This can be initiated by identifying what individuals from the management level need to obtain awareness on BIM, and this decision should be done considering the different business units and departments within the organisation. Even individuals from the management level that already possess a certain level of understanding on BIM should be considered, since, as observed during the case study, there is a lack of common understanding on BIM even among those that are familiarized with the concept. It is recommended to consider individuals from the management level from the departments in which BIM uses are already in place or under development, such as the business unit Netherlands and the Engineering and Estimating department. In addition, it is recommended to include the managers from the VO.X Data digitalization initiative since the consideration of this initiative is an important aspect for BIM strategic implementation within the organisation, as it will be further elaborated in this chapter. The action here described will ensure that individuals from the management level share a common view on BIM, how it has been applied in the organisation and the added value that current and future BIM uses provide.

- Action 2: Establish BIM planning committee

Two aspects were considered for during the discussions around individuals to compose the BIM planning committee: their level of BIM expertise and their position on the decision-making scale, guaranteeing executive, middle management and technical workforce representations. For the executive and management representations, individuals from the business units and departments with prior experience and knowledge on BIM should be considered.

At Van Oord, it is recommended to consider the director of the business unit Netherlands, the director and team lead of the Plan & Control and Engineering department for management representation. For the workforce representation, the CAD manager from the Netherlands business unit can be considered due to the level of expertise owned by this individual and to the fact that the graphic design working group is the one that makes the most use of BIM applications.

In addition, due to the possibility of incorporation of a BIM working group in the already in place digitalization initiative VO.X Data, individuals from this initiative should be considered, such as the program managers. The relevance of current digitalisation for the BIM strategic planning will be approach in the next item. Therefore, at least 6 individuals can be considered in order to represent different working groups and levels of decision making for a BIM planning committee.

- Action 3: Integrate BIM to current digitalization initiatives

As concluded in the case study, the commissioning organisation does not count with a dedicated BIM department, an important aspect to be considered during BIM strategic implementation as

discussed in item 2.7.1.2. However, it was also pointed out during the discussion meetings that there are initiatives within the organisation that can be associated with the concept of digitalization, the same context in which BIM is embedded in. Therefore, it is important for the commissioning company to evaluate these initiatives in order to verify their relation with BIM and if there is a possibility for integration between the already existent digitalisation initiatives and BIM. This is relevant if it is considered that the establishment of a new dedicated department can be a complex, time costly and expensive business decision, especially for large size contractors.

In this context, since it is the desire of the organisation to set up a working group in order to guide BIM implementation, the involvement and incorporation of the other initiatives already in place can be considered as strategic. The potential involvement between VO.X Data and BIM relates to the integration of these two initiatives. As discussed in the previous chapter, VO.X Data is an already established working group that has gone through the bureaucratic organisational internal procedures necessary when it is intended to transform a desired project into a business decision. Considering the relevant similarities between a BIM initiative and VO.X Data, especially when it comes to context and objectives, the incorporation of a BIM initiative within VO.X Data facilitates the implementation of BIM by skipping the bureaucratic procedures previously mentioned. This is even more relevant if the urgency that the company gives for strategic BIM implementation is considered.

For the case of Estimating Landscape, even though the incorporation of a BIM initiative within this working group seems less likely due to the lack of similarities between the purposes and focus, the organisation should put effort in enhancing collaboration between these two initiatives. Since Estimating Landscape is focused on estimation optimization, the execution of BIM can be facilitated by a possible close collaboration. This is the case, for example, of 5D modelling. As discussed previously during the identification of current BIM model uses, quantity take-off for cost estimation (5D modelling) was identified as one of the model uses that can be part of a BIM implementation strategy for the short and long terms. Estimating landscape could use BIM models for more precise quantity take-offs. This helps the initiative in providing more reliable and realistic cost estimates during a tender procedure. On the other hand, the enhanced cost estimates can be used as input for the elaboration of 5D models, a BIM use that has a considerable adding value and is worth being considered for future plans of the organisation. This collaboration is shown in Figure 15. Closer collaboration between both initiatives can enhance the implementation of other BIM uses, such as 4D modelling, considering the production estimates produced by Estimating Landscape. Other potential benefit from a closer collaboration between BIM and Estimating Landscape is related to the fact that the initiative works with the standardization of project object structures. This standardization facilitates the execution of BIM and object structure one subcategory for BIM maturity, as presented in the maturity model discussed in item 2.4.1. Even though the category Data (structure) was not considered as critical for the acceleration plan, it is relevant to briefly point out how the collaboration between Estimating Landscape can allow advancements on this category, in case this will be considered by the organisation in the future.

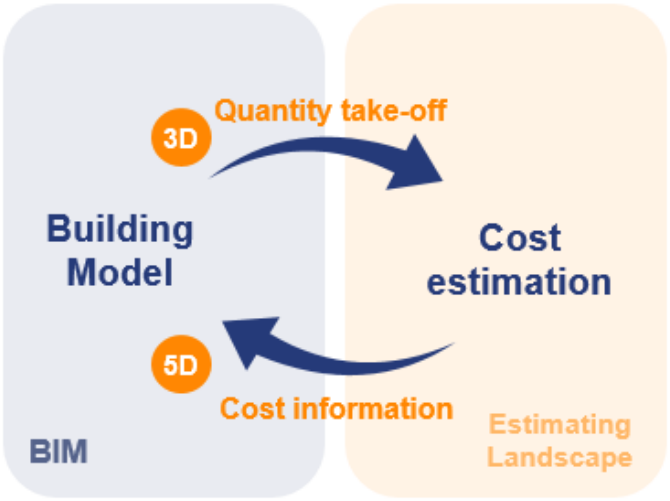


Figure 15 - Collaboration between BIM and Estimating Landscape initiative

This action is considered as preliminary since it is part of a strategic assessment of BIM in which the organisation should define the scope of BIM and evaluate the inclusion of current digitalization initiatives in the process. This is necessary in order for the organisation to define how these initiatives have influence and will help with the process of aligning BIM to the corporate mission and to achieve the intended objectives, an action to be elaborated further in the next item.

4.2.2. Recommendations on policy aspect

- Action 4: Align BIM with corporate mission

As presented in item 2.7.1.2, it is crucial for BIM strategic planning the elaboration of a BIM vision that is in line with the corporate vision and mission. This enables the definition of BIM objectives and associated BIM uses. As identified in the case study, the definition of a BIM vision aligned with the corporate mission of the organisation has not been carried out at the organisation. This composes the third action proposed to the commissioning organisation. From the corporate vision and mission, subjects of discussion during the discussion meeting, four key concepts that associated with the use of BIM can be identified: innovation, collaboration, sustainability and safety. The following scheme (Figure 16) presents a relation between the corporate vision and four aspects for BIM vision and objectives recommended for the organisation to consider during the strategy definition.

Figure 16 - Relation between corporate mission and the key concepts for a BIM vision

Therefore, it is recommended for the organisation to make an alignment between BIM and the corporate's mission considering the four key concepts as shown in Figure 16. The definition of this BIM vision considering the key concepts will facilitate the execution of the actions further to be described.

- Action 5: Define current and future BIM Model Uses

The identification of the key concepts for a BIM vision aligned with the corporate mission enables the organisation to make a parallel between the current BIM model uses applied and the BIM vision, an important step for strategic BIM implementation, as discussed in item 2.7.1.2. From the discussion meetings, BIM model uses could be identified. From that, a parallel can be made between the key concepts for a BIM vision and these identified BIM Model Uses, as shown in Figure 17. It is important to highlight that the identification of current model uses was made superficially, indicating concrete applications of BIM across the organisation's practices. An in-depth investigation on these initial directions needs to be performed.

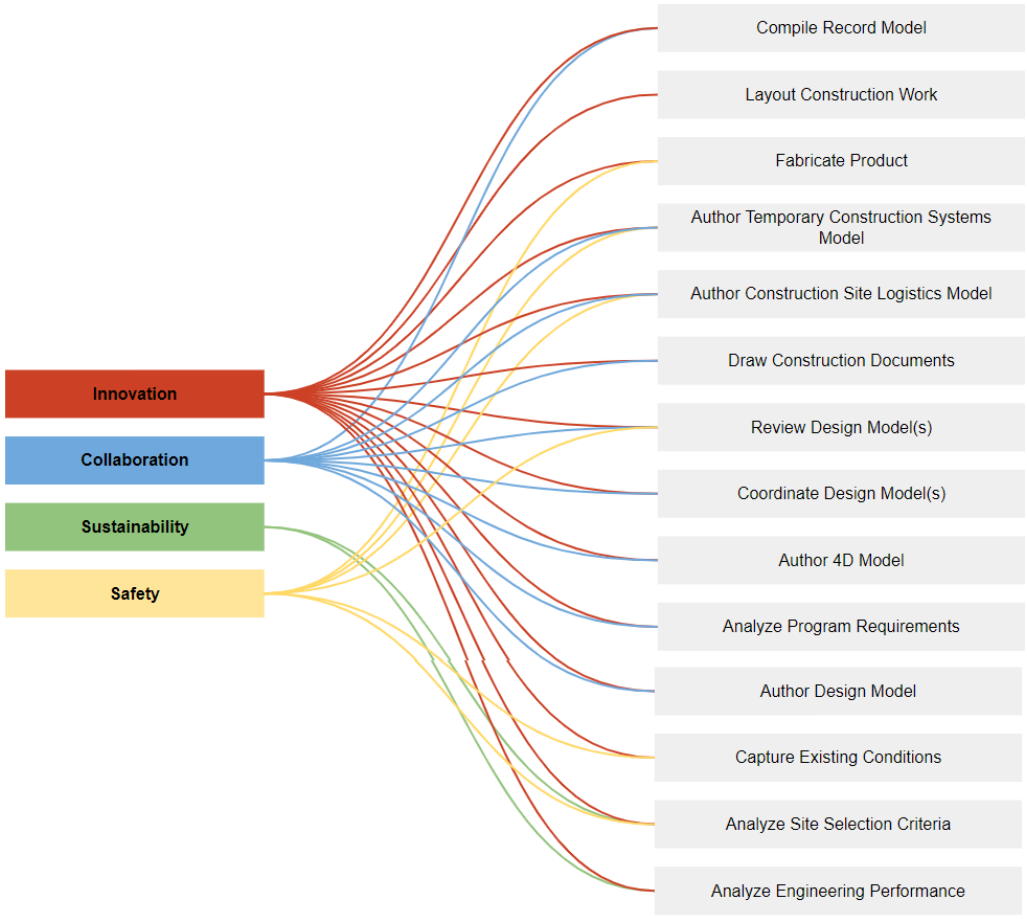


Figure 17 - Relation between key concepts from corporate mission and BIM model uses

In addition, the BIM vision associated with the corporate mission via the proposed key concepts can facilitate the organisation in defining BIM objectives that will be necessary for the definition of the future BIM model uses to be incorporated into the company's practices.

Therefore, the identification of current BIM model uses, their alignment to the BIM vision connected to the corporate mission, together with the definition of future model uses to be considered, are crucial for strategic BIM implementation, as defined in item 2.7.1.2.

4.2.3. Recommendations on process aspect

- Action 6: Document BIM processes and work instructions

At the commissioning organisation, the sub criterion related to processes and procedures scored the lowest level on the maturity scale, according to the data collected from the interviews. Currently, no procedures or work instructions for the BIM use are documented in guidelines or protocols. Many interviewees associated this with the lack of clear and uniform understanding of

what BIM is and what it involves. It is the case, for some specific applications of BIM such as 3D parametric design, that departments make use of work instructions, but these are unstructured, and lack in further refinement.

Therefore, it is recommended for the commissioning organisation to, initially, gather the work instructions that have been developed by the organisation and have relation with specific BIM model uses already in place strategically selected to be further developed. Next, the organisation should plan and initiate the elaboration of the work instructions that relate to the future BIM model uses defined during the elaboration of the BIM strategy. The possibility for collaboration between BIM and another digitalization initiative shown in Figure 15 is an example of that. In case the organisation decides to include other initiatives in the BIM process, the internal changes that this inclusion brings should be reflected in the work instructions and procedures.

For the process of external project collaboration during a project life cycle, it is recommended for the commissioning organisation to elaborate a standard BIM guideline – the BIM Execution Plan – in line with the ISO 19650 series. This standard series defines information management principles and requirements within the digitalization context and it has been required for a growing-number of international projects, as highlighted during the interviews. In addition, it has been pointed out during the interviews that a standard organisational BEP has not been elaborated. For the tendering procedures in which a BEP are currently requested, the organisation faces difficulties in its elaboration, since there is a lack of standardization of a general company BEP. A general organisational BEP could, then, help avoiding unnecessary rework and accelerate the elaboration of execution plans for projects that require the use of BIM according to the ISO 19650 series. The use of references for the elaboration of BIM guidelines – work instructions and BEP – is highly recommended. The AEC (UK) BIM Technology Protocol (AEC UK Initiative, 2015), the Finnish Common BIM Requirements (BuildingSMART Finland, 2012) and the CIC BIM Protocol (Construction Industry Council, 2018) are recommended sources.

4.2.4. Recommendations on people aspect

- Action 7: Revise organisational roles

At the commissioning organisation, the sub criterion tasks and responsibilities scored relatively low on the BIM Maturity Model since it was a consensus among the interviewees that BIM roles and responsibilities are defined and documented on insufficient level. It was pointed out that the organisation has not defined and assigned specific roles related to BIM on the organisational level, only on the project level, when required. Therefore, there is a need for the commissioning company to define and assign tasks and responsibilities on an organisational level in order to conduct the process of BIM implementation internally. More on tasks and responsibilities is discussed in item 2.7.1.4.

Initially, it is recommended for the organisation to analyse current human resource in terms of functions and capabilities on working with BIM, considering the three structure levels, and evaluate what roles are necessary to conduct BIM implementation. In order to assist the process of roles definition, several guides can be used as reference, such as the Planning Guide for Facility Owners (CIC, 2013), the BIR BIM leaflets from *Bouw Informatie Raad* and the publication from Baldwin (2019).

A decision, then, has to be made between creating new job roles for the BIM functions or to incorporate these BIM functions in already existing job roles. The latter option is aligned with how the organisation would like to follow with the definition of BIM roles on the organisational and project levels, as pointed out during the discussion meetings. This is in line with the theory from Baldwin (2019). As suggested by the author, the organisation has to look at standard roles on a traditional project and see how these could be supported with BIM competency. In this way, instead of expanding project teams, existing roles would be augmented with additional BIM competencies.

On the organisational level, there is a need to involve members from the strategic level of decision making in order form a steering committee that guides the strategic direction of BIM and guaranteeing resources for it. Due to the different business units and departments within the commissioning organisation, representativeness is a relevant aspect to be considered. It is recommended to involve at least one individual from the management level from each business unit, preferably those already considered for the BIM planning committee. Additionally, it is recommended for the organisation to assign an individual from the management level as a BIM Team Manager, a role described by *Bouw Informatie Raad*. A BIM Team Manager is responsible for initiating and drafting new policies in cooperation with the other members from the management level, and to initiate the implementation of necessary processes and systems.

On the tactical level, it is recommended for the organisation to assign an individual as Head of BIM, a role described by Baldwin (2019). The Head of BIM manages the development of the company guideline, general processes, project templates – such as the BEP -, and should have a good understanding on national and international BIM standards and guidelines. Since there is no intention to hire new personnel in order to perform the Head of BIM role, this role can be incorporated by an engineer from the Plan & Control department due to the fact that this department has been currently conducting BIM implementation. The planning committee should consider that the individual might need additional external training in order to acquire knowledge on BIM processes more in depth and on national and international standards. An alternative to this is to assign the Head of BIM role to an individual from the VO.X Data initiative due to the similarities between this working group and a BIM initiative, as discussed previously. However, there is no individual with BIM specific knowledge and experience in this working group, and additional training/courses might be necessary as well. A scheme of the proposed organisational BIM structure is presented in Figure 18.

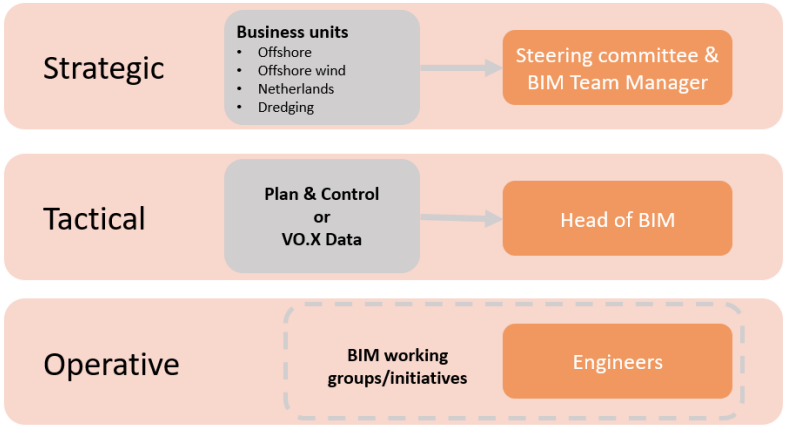


Figure 18 – Division of organisational BIM structure

- Action 8: Establish BIM skills

At the commissioning organisation, the sub category that relates to education and training scores relatively low. According to the interviewees, education and training on BIM is unstructured and ad hoc, in which training is provided for the certain applications of BIM, but it does not constitute a general BIM education and training program. Therefore, it is crucial for the organisation to set up a BIM educational program as part of its implementation strategy, in line with item 2.7.1.4. For that, the first action to be taken is to define the education/training needed. This has to be in line with the current and future BIM uses included in the strategic plan.

According to the interviews and the BIM model uses identified during the discussion meetings, it was possible to gather information on the education and training currently provided. This helps the organisation to identify what are the current educational gaps when it comes to BIM. Currently, no education or training is provided to key individuals aiming to provide knowledge on the concepts of BIM and its associated processes. Therefore, actions should be taken in order for the organisation to develop BIM workshops that might include the following items:

- BIM definition and concepts;
- The value added by BIM for the organisation;
- Current uses of BIM within the organisation;
- Intended future uses of BIM (strategy plan);
- Collaboration with other digitalization initiatives.

The organisation provides training related to the solutions associated with the current BIM model uses already approach. For example, external training is provided to individuals involved in 3D and 4D model authoring. It is recommended for the organisation to consider the future intended BIM

model uses – part of the BIM strategic plan – in order to define the additional training necessary to develop capabilities for executing these future uses.

After defining the education/training needed aligned with the BIM strategic plan, it is recommended for the organisation to develop a competency map, one of the three components for BIM education and training, as discussed in item 2.7.1.4. This competency map will help in identifying what individuals should be considered according to their function at the company for specific BIM education program and training. Currently, competency maps are considered for specific education and training programmes. However, they do not include BIM. The competency map will be the input necessary for the elaboration of a training roadmap, in which, as discussed in item 2.7.1.4, lists the education/training programs to be provided, the functions and number of the individuals considered, the timeframe and the training provider (internal or external).

In addition, it has been pointed out during the interviews that there is a space dedicated for BIM documentation in the platform used for internal collaboration among the personnel. However, it has not been set up aiming to serve as a database that steers and stimulates BIM discussion, nor to document learning points around BIM implementation within the company. The way this environment is currently set up only allows sharing of BIM literature references and some additional internal documents related to BIM on an unstructured way. Therefore, it is highly recommended to adapt this environment in order for it to function as a supporting tool for BIM education and training.

4.3. Conclusion

This chapter aimed to present a set of recommended impactful actions part of a BIM implementation acceleration plan with the objective to provide the commissioning organisation with directions for enhancing its BIM maturity, answering question III). The action steps were elaborated considering the conceptual implementation steps from literature, the outcomes of the case study and the information provided during the discussion meetings. A detailed argumentation on the expected positive influence that each proposed action has on different subcategories, together with the impacts expected on the maturity levels, is included in Appendix VII.

Considering the expected influence that each action has on the subcategories, it is possible to measure the real gains that the commissioning organisation would have by applying the acceleration plan in terms of BIM maturity. Figure 19 and Figure 20 plot the outcomes of the case study as presented in the previous chapter, together with the expected maturity levels after the BIM acceleration plan. It is important to highlight that the expected maturity levels are an estimation of the impact of the proposed acceleration steps considering the desire of the organisation to achieve higher levels of maturity but not necessarily the highest levels for each sub category.

A parallel can be made between the recommendations elaborated and the matrix for BIM implementation from Baldwin (2019). As discussed in item 2.3.2, the matrix is the result of the combination between the aspects and levels of BIM implementation and serves as a roadmap for organisational implementation of BIM. The actions from the BIM acceleration plan follow the sequence for BIM implementation as suggested by the author (Figure 21). Following the acceleration plan as recommended guarantees that the organisation would conduct BIM implementation in a sequence encourage by the author, what he considers as an ideal progression. This represents a disruption on the way BIM implementation has been conducted at the organisation currently, as concluded from the case study.

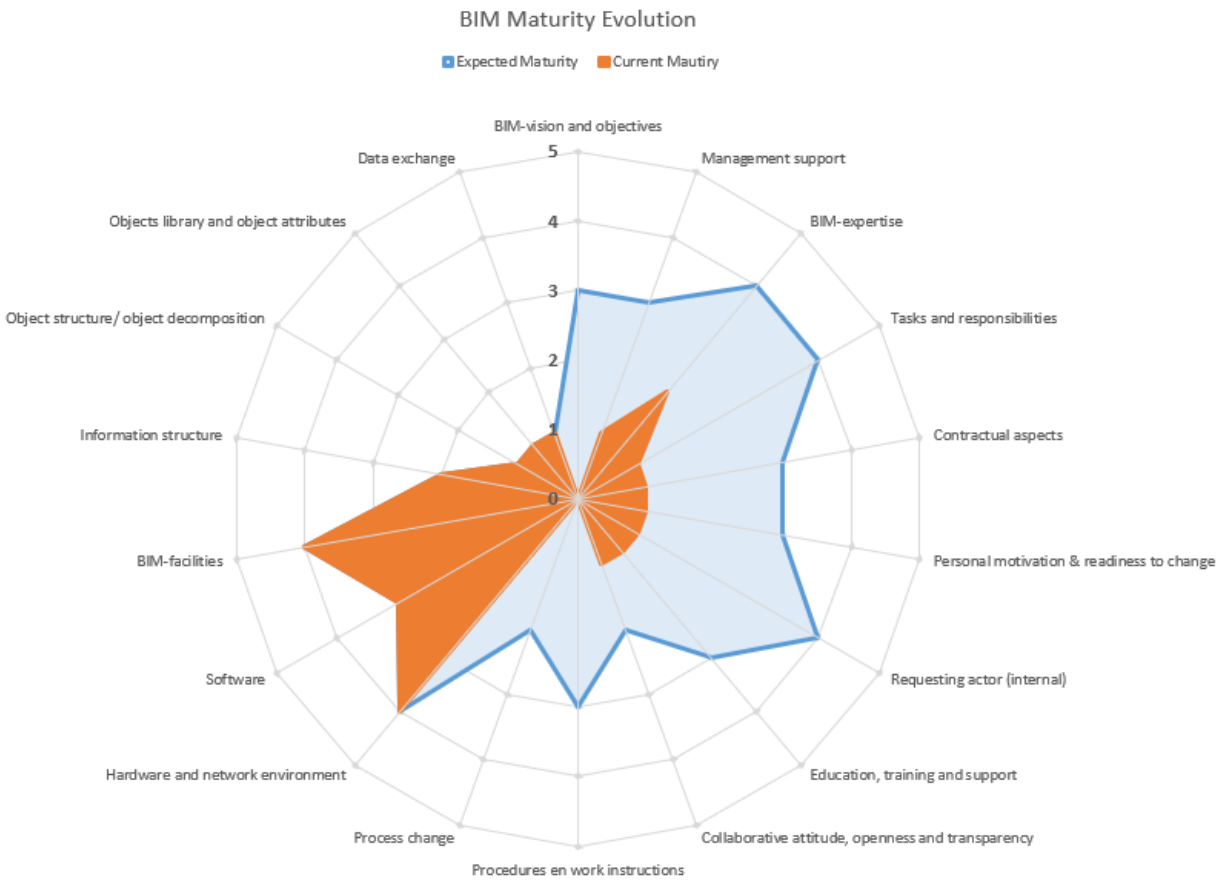


Figure 19 – Estimation of the gains of maturity according to subcategories from the maturity model

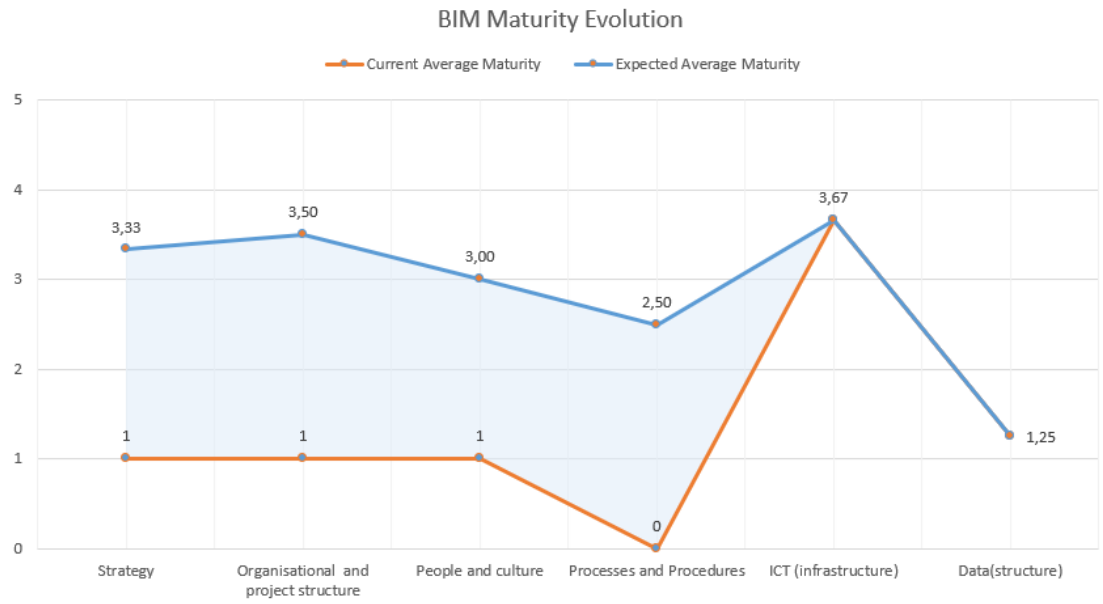


Figure 20 – Estimation of the gains of average maturity according to categories from the maturity model

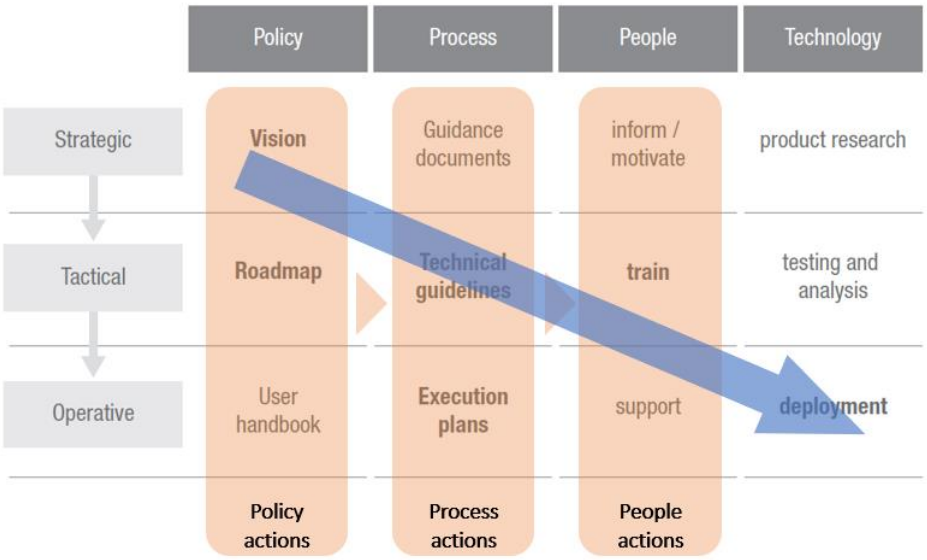


Figure 21 - The relation between the recommended actions and the BIM Implementation Matrix from Baldwin (2019)

SECTION IV

DISCUSSION, LIMITATIONS, CONCLUSION AND FUTURE RECOMMENDATIONS

5. DISCUSSION

This section aims to provide reflections by making parallels between the results achieved and previous studies and literature. In addition, a discussion will be made around the chosen research methodology. In the end of the chapter, the limitations of the research are discussed.

5.1. Reflection on the findings

The findings from this research pointed to a relevant aspect that is behind the problematics related to implementation of BIM for companies: the lack of strategic planning for organisational BIM implementation. This major finding that organisations fall quickly into a technical debate when it comes to BIM, making them focus unduly on the deployment of technology, and much less on strategic implementation, is in line with previous research (Demarchi, 2018; Panaitescu, 2014; Muñoz-La Rivera et al., 2019; Kharoubi, 2019). This was evidenced in the case study in which the category related to ICT infrastructure scored best in comparison with all the other criteria. In comparison with the publication from Siebelink, Voordijk and Adriaanse (2018) in which the authors applied the BIM Maturity Model in several companies in order to provide a sectoral analysis of the Dutch construction industry, some results obtained from this research deviate from the trends observed by the authors. In their study, for the sector of engineering firms, the sector in which the commissioning organisation from this study falls into, the category related to strategy scored the highest value. This implies that the engineering organisations interviewed attach value to BIM development by setting an organisational BIM vision, BIM goals and implementation plans. However, the case study from this research concluded the opposite. For the commissioning organisation, the category of strategy scored one of the lowest levels since a BIM vision, goals and implementation plans have not been set. On the other hand, the scores of the categories processes and procedures, IT infrastructure, and data structure for the case study follows the trend observed for engineering firms in the research from the authors. Even though an in-depth investigation needs to be conducted in order to explain the divergences, two possibilities can be pointed out:

I. the organisation has been tackling the strategy aspect of BIM implementation poorly as an exception among other organisations from the same sector;
II. The study from Siebelink, Voordijk and Adriaanse (2018) did not consider marine contractors for the sectoral analysis performed. In this case, the fact that there is a lack of BIM vision, goals and implementation plans could be a characteristic of the marine contractor sub sector, what would distinguish this sub sector from others.

While some studies focus on BIM adoption and maturity on national levels (Jung and Joo, 2011; Hardi and Pittard, 2014; Khosrowshahi and Arayici, 2012; Siebelink, Voordijk and Adriaanse, 2018) and others on specific engineering sectors (Kharoubi, 2019; Muñoz-La Rivera et al., 2019; Ghaffarianhoseini et al., 2016), literature on BIM adoption and maturity for the marine contractor

sector embedded in the Dutch and international markets is inexistent. This evidences that there is a need of conducting additional studies on organisational BIM implementation for the marine contractor sub sector.

In line with other studies on BIM implementation conducted with Dutch firms (Kharoubi, 2019; Prinsze, 2014; Panaitescu, 2014), the lack of BIM strategic planning as one of the reasons behind unsuccessful BIM implementation is not particular for the Dutch industry, but has been also detected in research conducted in other European countries, such as Germany (Baldwin, 2019; Both, 2012), Italy (Demarchi, 2018), and in the UK (Jung and Joo, 2011; Khosrowshahi and Arayici, 2012).

In addition to the lack of BIM strategic planning, it was detected in practice that even though BIM solutions are part of the company's practices to some extent, there is no widespread and common understanding of what BIM actually is throughout the organisation. This finding can be directly related to the fact that management support is unstructured and limited. During the conduction of the interviews for the case study, a relevant number of individuals from the management level admitted not to have a clear understanding of what BIM is, its benefits and why the organisation should apply its uses. Therefore, it is not an issue of lack of support resulting from a business decision in which it was concluded that BIM does not add value to the organisation, but it is a result of the lack of understanding about BIM. This is in line with Baldwin (2019), Panaitescu (2014), Hardi and Pittard (2014), Giel and Issa (2016) and Olugboyega and Windapo (2019).

The elaborated BIM implementation acceleration plan aims to provide the organisation with directions for enhancing its current level of BIM maturity by prioritizing the aspects that require special attention: policy, process and people. For the policy aspect, the actions addressed the alignment of a BIM vision to the corporate mission and the identification of current and future BIM model uses as first steps to build the foundation. Previous studies aimed to elaborate framework for BIM implementation for organisations, such as Saluja (2009), Demarchi (2018) and Khosrowshahi and Arayici (2012). However, for the present research, an aspect appeared relevant during the elaboration of the implementation framework that has not been approached by the studies mentioned: the consideration and inclusion of current digitalization initiatives. This was important for the implementation steps since initiatives such as VO.X Data have goals and relation to the corporate mission similar to a BIM initiative. In a scenario in which many owners feel uncertain about how and where to start with BIM implementation (McGraw-Hill Construction, 2012), the consideration of already established digitalization initiatives can be a good start.

Moreover, the research conducted and its findings highlight the importance of an organisation to carry out BIM implementation according to what is defined in norms and guidelines on organisational BIM implementation, such as the publications from Baldwin (2019), CIC (2013), the National Institute of Building Sciences (2017) and the International BIM Implementation Guide (RICS, 2014). By tackling the policy aspect, companies elaborate BIM vision and goals in order to orientate itself during BIM implementation, avoiding efforts to be misguided and uncoordinated.

By tackling the process aspect, guidelines and work instructions are elaborated in order to document the different uses of BIM, orienting the project teams toward a uniform and standardized way of working, and avoiding knowledge to get lost over time. By tackling the people aspect, companies address one of their most valuable assets: human resources. This is necessary in order to inform, motivate and train employees. By following this approach, organisations will be able to experience the promised BIM benefits of higher level of design and construction process integration, resulting in the increase of the quality of the constructions to be performed at lower cost and optimized project duration, orienting the sector towards a digital collaborative way of working. (Eastman, 2008; Bataw et al, 2016; Baldwin, 2019)

Another relevant aspect from this research to be discussed is the relation between BIM implementation and the financial resources that need to be allocated. One of the BIM promises is the reduction in costs for all project phases – design, construction and operation (Eastman, 2008; Miettinen and Paavola, 2014; Succar, 2009; Borrmann et al., 2018). However, organisations should consider that in order to achieve this reduction in practice, BIM has to be implemented accordingly and the adoption of new technologies and processes inevitably means short-term productivity loss and increase in costs (Eastman, 2008; Baldwin, 2019). One of the concerns of the interviewees considered for the case study was the limited allocation of resources for the creation of a BIM department or knowledge pool, as a result of the lack of management support for this potential business decision. The consideration of current digitalization initiatives into the implementation framework and the development of in-house human resources via courses and training on BIM have shown once again to be strategic since the incorporation of BIM and expansion of these initiatives would work around this resource allocation problematics. This approach is different from other studies on organisational BIM implementation, in which the creation of a BIM department and the acquisition of personnel specialized in BIM was part of the implementation frameworks (Panaitescu, 2014; Demarchi, 2018).

5.2. Reflection on chosen research methodology

In order to get insights on how BIM is currently being implemented in the organisation during the case study, the BIM Maturity Model developed by Siebelink, Voordijk and Adriaanse (2018) was applied due to the fit that this approach has in measuring organisational BIM implementation. The analysis of how BIM is being conducted was done, then, from the perspective of six main criteria and eighteen sub criteria, scored from 0 to 5. The chosen approach differs from recent studies in which the investigation was done from the perspective of BIM implementation challenges from literature, such as the research from Demarchi (2018) and Panaitescu (2014). Based on the similarities of the diagnosis found and on how they provide necessary insights for the elaboration of implementation strategies, this research indicates that applying the BIM maturity model is a viable option. In fact, maturity models facilitate the elaboration of implementation frameworks by

providing criteria and sub criteria that serve as input for the steps to be further elaborated. In addition, the evaluation of specific criteria and sub criterion already provide insights on BIM implementation challenges (Siebelink et al., 2020), such as for the case of management support. Therefore, this research also enriches literature by showing the viability of applying maturity models to evaluate organisational BIM implementation, especially if it is considered that there is a trend in choosing for methodologies that consider BIM implementation challenges only.

Moreover, as pointed out in the theoretical framework, the BIM Maturity Model from Siebelink, Voordijk and Adriaanse (2018) proposed to address the shortcomings from other BIM maturity measurement models from literature, such as the excessive focus on technological characteristics of BIM and on specific disciplines (e.g., clients) instead of organisational processes and collaboration. Based on that, the choice to apply the BIM Maturity Model was made for the case study. However, as pointed out by the authors, organisations with limited focus and experience on BIM were often unwilling to participate in the research. Having said that, the interviews that did take place tend to provide insight on BIM maturity of those companies that are leaders in the industry. This explains the significant gap between the maturity levels assigned to the commissioning company of this study and the maturity levels of the companies considered for the BIM Maturity Model. Additionally, in order to provide a sectoral analysis on BIM maturity of the Dutch construction industry, the authors have considered seven sub sectors of this industry. However, it is not clear if the marine contractor sector was considered for this selection, as discussed previously. The consequence of that for this research is that the BIM maturity measurement model chosen for the case study was not developed and tested considering the specific sector of the commissioning company. Therefore, it would be preferred to apply a measurement model that was developed and tested considering the specificities of the marine contractor sector as well in order to provide more realistic and representative results. However, such measurement model cannot be found in literature.

In addition, the BIM maturity model chosen does not deal with an aspect that appeared relevant for this research: the consideration of current digitalization initiatives. If it is considered that digitalization initiatives are, such as BIM, an information system result of the interaction between the system design features and the organisational context, as defined by the theory from Silver et al. (1995), it would be interesting for BIM maturity models to consider digitalization initiatives already in place. Therefore, approaching current digitalization initiatives in the framework of a BIM maturity measurement model would facilitate the definition and prioritization of measures to be taken in order to increase organisational maturity. This is relevant for organisations that do not count with a dedicated BIM department, but have digitalization initiatives already in place, such as for the case of the present study.

5.3. Limitations of the research

Initially, one of the aims of the research was to make a parallel between the state of BIM implementation at the organisation obtained via the case study and the maturity level of its sector. However, there is a knowledge gap in which literature on BIM maturity of the marine contractor sector is inexistent. In general, the studies considered for the literature review deal with BIM maturity for the civil engineering industry perspective as a whole, and go as far as dealing with maturity for the building contractors. Therefore, the analysis of BIM maturity could not be made considering the business specific context in which a marine contractor is embedded in. Another limitation related to BIM references is that most of the publications that deal with BIM implementation approach it from the national-level, industry-level or project-level perspectives. Publications and guides that deal with BIM implementation for the organisational level are scarce, especially for organisations that have already started with BIM implementation somehow, such as the case for the commissioning organisation from this study. Additionally, the lack of literature that approaches the impacts of considering current digitalization initiatives into BIM strategic implementation did not allow to predict the influence of this action on the sub criterion from the maturity model.

Another limitation of the study is related to the lack of literature on BIM organisational implementation considering the Data (structure) criterium of the BIM maturity model chosen for the case study, evidencing a knowledge gap. Even though this criterium was not considered as critical for the elaboration of the BIM acceleration plan due to the desire of the organisation to focus on the first four criteria of the maturity model, more attention could have been given to the Data (structure) criterium in case sufficient literature could be found.

Another limitation is related to the fact that the limited time available for the study to be conducted did not allow to follow the implementation of the framework steps recommended in the third phase of the study. This would be ideal to validate the recommended actions, and make necessary adjustments according to what would be observed in practice. Therefore, the scope of the research had to limit itself to provide recommendation steps, and not follow their implementation in practice in order to perform validation.

Even though the research counted with the abovementioned limitations, the objectives of the research were achieved, making the results and implementation framework here presented suitable to be used for future research.

6. CONCLUSION

The present research aimed to measure organisational BIM maturity of a Dutch marine contractor and elaborate a set of recommendations to be followed by the commissioning organisation in order to increase its level of BIM maturity. The research was successful in achieving its objectives, and this was enabled by answering the sub questions and the main question of the research, to be detailed in this chapter.

- Sub questions

I) What aspects should be considered during BIM implementation according to strategies from theory and how to measure this organisational implementation?

The aspects for organisational BIM implementation are defined by the theory from Baldwin (2019). The first aspect approached by the author is policy and it relates to how the BIM implementation affects business operations by promoting optimization of existing activities and enabling new opportunities of business to develop. The aspect of processes relates to the redefinition of work processes due to the change of business activities resulting from the introduction of BIM. The aspect of people consists of the impact that BIM implementation brings to the organisation's team, considering the organisational culture, the technical management and the social competencies of the team. The aspect of technology comprehends the biggest investment for BIM implementation and have implications on future resourcing, training and software interoperability.

In order to measure organisational BIM implementation, maturity models can be applied. Several maturity models have been developed over the years by diverse studies in which the analysis of several categories provide insight on how the organisation has been conducting BIM. For the present study, the BIM Maturity Model from Siebelink, Voordijk and Adriaanse (2018) was used due to the fit it has in measuring organisational BIM maturity. This maturity model consists of 6 categories and 18 sub categories in which different aspects of BIM implementation are analysed in order to measure organisational BIM maturity.

II) What is the current BIM level of maturity of the commissioning organisation according to the BIM Maturity Model?

During the case study, interviews were conducted with individuals from different levels of decision making of the organisation in which they were asked to grade the subcategories from the BIM Maturity Model, ranging from 0 to 5. Analysing the average values of the categories, three out of six categories scored 1 (strategy, organisational culture and project structure, and people and

culture), one category scored zero (processes and procedures), one category scored 1.26 (data structure), and the category of ICT infrastructure scored the maximum detected average value of 3.67. These results indicate that the organisation has been conducting BIM implementation in an unstructured and non-strategic way, focusing on the deployment and technology and disregarding the other aspects for successful BIM implementation.

III) What actions should be taken in order to increase BIM maturity of the commissioning organisation?

This sub question aims to bring together the theoretical and empirical parts of the research in order to formulate actions for the organisation to achieve higher levels of BIM maturity than what was verified in the case study. A parallel was made between the theoretical BIM implementation framework and the empirical data collected in the case study: the outcome of the BIM maturity model and the prioritization and company's specificities from the discussion meetings. The result obtained is a BIM implementation acceleration plan with concrete company-specific actions that consider not only the organisation's current level of BIM maturity but also other specificities such as other digitalization initiatives and corporate mission. The BIM implementation acceleration plan consists of three main categories, each one relating to a specific aspect for BIM implementation from Baldwin (2019) – policy, process and people -, and one preliminary category that addresses actions necessary to be taken primarily. Preliminary actions consist of articulating the benefits across management level, in order to increase BIM awareness of the higher level of decision making of the company's structure, and establishing a BIM planning committee, in order to structure several key individuals to guide BIM strategic implementation. Policy actions consist of aligning BIM with corporate mission, an important aspect for strategic implementation with the objective to link BIM to the organisational mission, defining current and future model uses, and integrate BIM to current digitalization initiatives. The last action mentioned presented to be relevant considering current initiatives related to digitalization present in the company, and has not been approached by BIM implementation guidelines. Process action consists of document BIM processes and work instructions with the objective to structure and document current BIM uses. People actions relate to the revision of organisational roles, in order to incorporate the changes in the job functions required by BIM, and establish BIM skills, in order to elaborate a structure BIM education and training programme with the objective to spread awareness and educate individuals on BIM.

- Main research question

By answering the three sub questions, the main research question could be answered.

What recommendations can be proposed in order to assist a marine contractor in achieving higher levels of BIM maturity?

By first investigating the topics of organisational BIM implementation, how to measure this implementation via BIM maturity models and how to elaborate an implementation strategy, and thereafter making a parallel with current BIM implementation of the commissioning organisation, the researcher was able to provide recommendations in the form of a BIM implementation acceleration plan. The theoretical framework for BIM implementation was further refined via discussion meetings with key individuals from the organisation in order to provide tailor-made recommendations that consider the company's specificities. These recommendations followed the structure recommended by Baldwin (2019) – therefore, considering the aspects of policy, processes, people and technology – and considered the prioritized categories for BIM implementation resulting from the case study. This provided the organisation with a set of tailor-made recommendations that promise to allow the company to achieve higher levels of BIM maturity.

7. FUTURE RECOMMENDATIONS

This section aims to present two different sets of recommendations. The first consists of practical recommendations in order to orient the commissioning organisation on aspects that have not been approached during previous discussions. That way, the organisation can take the best benefit of the results from the research. The second set describes scientific recommendations for future research in the field, highlighting the limitations of the present conducted research.

Practical recommendations

- It is recommended for the organisation not only to implement the acceleration plan, but also to maintain consistent evaluation of its performance by observing the impact of the steps on the maturity model in practice. This will provide necessary insights that enable the organisation to measure the proposed model's efficiency and make necessary adjustments on the proposed steps.

- The actions recommended provide general information on what they consist of, the processes related, and the associated subcategories from the maturity model. For further details on the recommended actions, it is highly recommended for the organisation to consult the references included in this study.
- The organisation should give priority on the inclusion of current digitalization initiatives into the BIM process. The VO.X Data initiative represents an opportunity for the organisation to form a BIM working group. This inclusion would allow skip the bureaucratic steps necessary to establish a new department within a complex organisation such as Van Oord, facilitating allocation of resources and personnel via a digitalization initiative already in place. However, the organisation should provide training necessary to the personnel currently part of VO.X Data on BIM processes and standards due to the current lack of BIM expertise. Another option would be acquiring new personnel with prior BIM knowledge and experience for this initiative.
- Other initiatives and working groups linked to digitalization should be investigated further and considered in order to facilitate the execution of current and future BIM uses. This is the case, for example, of the integration of Estimating Landscape working group in assist in the process of 4D and 5D modelling, as discussed in this study. Therefore, facilitating BIM execution via collaboration with current digitalization initiatives.

Further research recommendations

- This research was conducted in cooperation with one company from the marine contractor sector, and used its data to measure BIM maturity and elaborate a recommendation framework. In order to improve external validity of the results and to verify if they are representative of the sector, the methods applied in this research should be replicated at other marine contractors embedded in the same context;
- Within BIM literature and scientific research, little attention was given so far on how to increase organisational BIM maturity based on maturity models outcome. Literature on BIM maturity models mainly focus on how to measure BIM maturity, but do not go further toward how to develop an implementation framework based on the model outcome. Therefore, further research on the topic should be developed;
- The evaluation of the implementation is necessary in order to verify if the recommendations elaborated do in fact have direct impact on the subcategories from the BIM maturity model. This is crucial in order to verify and improve the validity of the recommendations proposed;

REFERENCES

Alaghbandrad, A. & Forgues, D. (2013). Development of a model to select BIM implementation strategy with respect to the BIM maturity level of an organization. In: Bedard, C. & Katsanis, C.J. (Eds.). Montreal: Canadian Society for Civil Engineering, pp. 1149-1159

AEC UK Initiative. (2015). BIM Technology Protocol. Retrieved from https://aecuk.files.wordpress.com/2015/06/aecukbimtechnologyprotocol-v2-1-1-201506022.pdf

Baldwin, M. (2019). The BIM-Manager. Weinheim, Duitsland: Beltz Verlag.

Bataw, A., Kirkham, R., & Lou, E. (2016). The Issues and Considerations Associated with BIM Integration. MATEC Web of Conferences, 66, 00005. *https://doi.org/10.1051/matecconf/20166600005*

Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). Building Information Modeling: Why? What? How? Building Information Modeling, 1–24. https://doi.org/10.1007/978-3-319-92862-3_1

Both, P. (2012). Potentials and Barriers for Implementing BIM in the German AEC Market: Results of a Current Market Analysis.

Bryman, A. (2012). Social Research Methods (4th Edition). Oxford, United Kingdom: Oxford University Press.

Building and Construction Authority. (2013). BIM Essential Guide: for BIM adoption in an organisation. Retrieved from https://corenet.gov.sg/media/586143/Essential-Guide-Adoption.pdf

BuildingSMART Finland. (2012). Common BIM Requirements 2012. Retrieved from https://buildingsmart.fi/en/common-bim-requirements-2012/

Computer Integrated Construction Research Program (CIC). (2013). BIM planning guide for facility owners – Version 2.0. USA: The Pennsylvania State University.

Construction Industry Council. (2018). Building Information Modeling (BIM) protocol. Retrieved from http://cic.org.uk/admin/resources/bim-protocol-2nd-edition-2.pdf

Demarchi, R. (2018) Stimulating the digital transition in the Italian construction industry. University of Twente. Available at: https://essay.utwente.nl/76848/.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors. New Jersey: Wiley.

Fisher, J. (2011). BIM Technology Briefing Steering Committee. BIM Execution Plans. Retrieved From: http://www.advsolinc.com/pdf/events/StLouis_BIMExecutionPlan.pdf. Accessed April 2020.

Ghaffarianhoseini, A.; Doan, D.T.; Zhang, T.; Ur Rehman, A.; Amirhosein, G.; Nicola, N.; John, T. A BIMreadiness & implementation strategy for SME construction companies in the UK. In Proceedings of the 33rdCIB W78 Conference 2016, Brisbane, Australia, 31 October–2 November 2016

(20) (PDF) Effects of BIM-Based Construction of Prefabricated Steel Framework from the Perspective of SMEs. Available from: https://www.researchgate.net/publication/332686206_Effects_of_BIM-Based_Construction_of_Prefabricated_Steel_Framework_from_the_Perspective_of_SMEs [accessed Oct 28 2020].

Giel, B., & Issa, R. R. A. (2016). Framework for Evaluating the BIM Competencies of Facility Owners. Journal of Management in Engineering, 32(1), 04015024-1-04015024–15. https://doi.org/10.1061/(asce)me.1943-5479.0000378.

Häkkinen, T., and Belloni, K. (2011). Barriers and drivers for sustainable building. Build. Res. Inf., 39(3), 239–255.

Hardi, J., Pittard, S. (2014). If BIM is the solution, what is the problem? A review of the benefits, challenges and key drivers in BIM implementation within the UK construction industry. Building Survey, Appraisal & Valuation.

Hartmann, A. (2017). Research Methodology and Academic Skills. University of Twente.

Hartmann, T., Van Meerveld, H., Vossebeld, N., & Adriaanse, A. (2012). Aligning building information model tools and construction management methods. Automation in construction, 22, 605-613.

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. Automation in Construction, 20(2), 126–133.

Kharoubi, Y. (2019). Towards 5D BIM: A Process Map for Effective Design and Cost Estimation Integration [unpublished master's thesis]. Delft University of Technology. Available at: http://resolver.tudelft.nl/uuid:b5539dcb-358b-410a-a3cb-21043a9228ce .

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. Engineering, Construction and Architectural Management, 19(6), 610–635.

Kjartansdóttir, I. B., Mordue, S., Nowak, P., Philp, D., Snæbjörnsson, J. T., & Politechnika Warszawska. Wydział Inżynierii Lądowej. (2017). Building Information Modelling - BIM. Amsterdam, Nederland: Amsterdam University Press.

McGraw-Hill Construction. (2012). The business value of BIM in North America: Multi-year trend analysis and user ratings (2007–2012). SmartMarket Rep., New York.

Messner, J., Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Leicht, R., Saluja, C., and Zikic, N. (2019). BIM Project Execution Planning Guide, Version 2.2. Computer Integrated Construction Research Program. The Pennsylvania State University, University Park, PA, USA. Available at http://bim.psu.edu.

Miettinen, R., and S. Paavola. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. Autom. Constr. 43 (Jul): 84–91.

Muñoz-La Rivera, F., Vielma, J. C., Herrera, R. F., & Carvallo, J. (2019). Methodology for Building Information Modeling (BIM) Implementation in Structural Engineering Companies (SECs). Advances in Civil Engineering, 2019, 1–16. https://doi.org/10.1155/2019/8452461.

National Institute of Building Sciences. (2012). National BIM standard: United States version 2, buildingSMART alliance. Washington, DC: National Institute of Building Sciences.

National Institute of Building Sciences. (2017). National BIM Guide for Owners, buildingSMART alliance. Washington, DC: National Institute of Building Sciences.

Olugboyega, O. (2017). Framework for Creating a Building Information Modelling Environment in Architectural, Engineering and Construction Firms and Projects. PM World Journal, 4(4).

Olugboyega, O., Windapo, A. (2019). Comprehensive BIM Implementation Model For Developing Countries. Journal of Construction Project Management and Innovation. 9 (2): 83-104.

Panaitescu, R. (2014). Building Information Modeling: towards a structured implementation process in an engineering organisation. Master thesis, TU Delft, The Netherlands.

Parkes, A. (2016). A critical success factors model for business process implementation. Taylor's Business Review, 6, 15-37

Prinsze, R. (2014). Transformation from 3D modelling to building information modelling: The implementation of BIM in an engineering organization. Master thesis, TU Delft, The Netherlands.

Royal Institution of Chartered Surveyors (RICS). (2014). International BIM Implementation Guide. Amsterdam, Nederland: Adfo Books.

Saluja, C. (2009). A process mapping procedure for planning building information modeling (BIM) execution on a building construction project. Master thesis, Pennsylvania State Univ., University Park, PA.

Sebastian, R., van Berlo, L. (2010). Tool for Benchmarking BIM Performance of Design, Engineering and Construction Firms in The Netherlands. Architectural Engineering and Design Management, 6, 254 – 263.

Silver, M. S., Markus, M. L., & Beath, C. M. (1995). The Information technology interaction model: A Foundation for the MBA Core Course. MIS Quarterly, 19(3), 361. https://doi.org/10.2307/249600

Siebelink, S., Voordijk, J. T., & Adriaanse, A. (2018). Developing and Testing a Tool to Evaluate BIM Maturity: Sectoral Analysis in the Dutch Construction Industry. Journal of construction engineering and management, 144(8).

Siebelink, S., Voordijk, H., Endedijk, M., & Adriaanse, A. (2020). Understanding barriers to BIM implementation: Their impact across organizational levels in relation to BIM maturity. Frontiers of Engineering Management, 1–22. https://doi.org/10.1007/s42524-019-0088-2.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Autom. Constr. 18 (3): 357–375.

Van Nederveen, S., Beheshti, R., Gielingh, W. (2010). "Modelling Concepts for BIM" in J. Underwoord and U. Isikdag (eds.) Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies, IGI Global.

Verschuren, P., & Doorewaard, H. (2010). Designing a Research Project: Second Edition (2nd Revised ed.). The Hague, The Netherlands: Eleven International Publishing.

Wieringa, R. J. (2014). Design Science Methodology for Information Systems and Software Engineering. New York, United States: Springer Publishing.

Wu, W., Issa, R. R. A. (2015). BIM Execution Planning in Green Building Projects: LEED as a Use Case. Journal of Management in Engineering, 31(1). https://doi.org/10.1061/(asce)me.1943-5479.0000314

Wu, C., Xu, B., Mao, C., Li, X. (2017). Overview of BIM maturity measurement tools. ITcon Vol. 22, pg. 34-62.

Yin, R. K. (2014). Case Study Research. Thousand Oaks, Canada: SAGE Publications.

APPENDIX I – Interview protocol

This appendix covers the interview questions applied for the interviews made during the case study phase of the research, together with the referred concepts from different theories from literature. This interview protocol was provided by the authors of the BIM Maturity Model (Siebelink, Voordijk and Adriaanse, 2018) under request from the researcher.

Strategy

BIM vision and goals

a) Is there a BIM vision formulated on organizational level?
b) And has the organization formulated BIM goals?
c) To what extent do the vision and goals fit within the broader strategy of the organization?
d) Are goals SMART and monitored?
e) Do you also align vision and goals with (strategic) partners?

Management support

a) To what extent is BIM supported from the management of the organization?
b) Does it include both support in spoken words and by management committing financial and other resources?
c) Are sufficient budgets being allocated to adoption and implementation of BIM?
d) Do you have a plan of how to allocate the resources for specific applications?
e) To what extent is the support ensured?
f) Is there a long-term investment plan in place?

BIM expertise

a) Are one or more BIM experts, a BIM working group or a dedicated BIM department appointed to guide the BIM implementation process centrally?
b) Is their support dependent on the time they have left besides other activities or is their support structured?
c) Do BIM expert(s), a working group or department have sufficient time and capacity for BIM guidance/support? Are they in touch with operational teams?
d) From what parts of the organization do the experts originate? Is senior management represented? And are they influential?

Organizational and project structure

Tasks and responsibilities

a) Are tasks and responsibilities with regard to the use of BIM documented/formalized in job descriptions or role descriptions?
b) Is this documentation laid down on the organizational level or established on projects?
c) Are traditional functions adapted such that they support the BIM use?

Contractual aspects

a) Are hard agreements being made with other parties regarding BIM?
b) Organizational guidelines for these contract agreements or established on projects individually?
c) Is the BIM collaboration explicitly laid down in contracts? Are those agreements specific and measurable (SMART)?
d) Are protocols updated regularly?

People and culture

Personal motivation and willingness to change

a) Is there motivation within your organization to make the transition toward working with BIM?
b) Is BIM sufficiently embedded within the entire organization culture or is it very much dependent on motivation of individual project members?
c) To what extent are people in the organization willing to adapt their way of working to the benefit of BIM? Does this allow the organization to adapt quickly to a changing environment?

Requesting actor

a) Does the organization have one or more BIM champions who function as a driver of the implementation process by steering and stimulating others? If yes, do they have sufficient time/capacity for this task?
b) From which part of the organization do (does) the BIM champion(s) originate? Does this suit different departments / perspectives on BIM?
c) Is there a champion from senior management?
d) Are champions involved in a network with other organizations/authorities? (Tick where appropriate)

Education, training and support

a) How is organizational education and specific training for BIM set up? Is there a programme?
b) Who is de target group / who is under consideration?
c) What is the content of the education/training (general information and/or specific training and guidance)?
d) Are good/bad practices taught?
e) Are persons available to provide guidance in practice?
f) Are experiences from practice used to improve the education and training?

Collaborative attitude, openness and transparency

a) To what extent is your organization focused on collaboration with partners? (oriented internally or externally)?
b) Is collaboration part of the strategy?
c) Are you structurally working together with other parties, for example to align BIM-related tasks and responsibilities?
d) Do you have joint activities with supply chain partners in order to extend and/or improve BIM use?
e) Does the collaboration affect the mutual trust and transparency between parties?
f) To what extent is your organization dependent on collaboration with regard to performance/competitiveness?

Processes

Procedures and job descriptions

a) Is the use of BIM standardized in procedures and job instructions? To what extent? Are these available for the most important BIM uses?
b) How are the available procedures and job instructions set up? Are they based on good practices? Do they include external processes? Do they focus on quality of processes?
c) Are instructions commonly used? How is that ensured? Are they being updated?

Process change

a) Is BIM considered to be a driving force for improving processes? If yes, is that change organization-wide or dependent on specific individuals/teams?
b) And to what extent is this change affected by traditional structures and habits?
c) Are process changes from projects shared to other projects / parts of the organization? What is the result of the BIM-driven process improvement?

IT (infrastructure)

Hardware and network environment

a) To what degree is the available hardware in the organization capable for supporting BIM use?
b) Consider the physical systems, including the network environment, do they support the desired/required BIM uses?
c) Is appropriate hardware available on all workplaces or just at dedicated workstations or for advanced users?
d) Does the network environment sufficiently support the data exchange with other parties?
e) Does maintenance of hardware ensure continuous development of BIM?

Software

a) To what extent is BIM supported by available software?
b) Does the available software facilitate further implementation and future use of BIM?
c) Does available software sufficiently support collaboration?
d) Does the organization ensure that software supports future needs of BIM?

BIM Facilities

a) Has the organization spaces or rooms available to facilitate the BIM use, for example for visualization of 3D models or for joint reviewing?
b) Do the available rooms/spaces support collaboration of coordination through BIM?
c) Can meeting and coordination sessions sufficiently be accommodated? Are large screens / smartboards available?
d) How does the organization ensure that rooms and equipment stay future proof?

Data (structure)

Information (structure)

a) Does the organization make use of a system for structured storage of project data, for example a DMS (Document Management System)?
b) If yes, is use of this system part of the standard practices (procedures) of the organization? Is it being used consistently / consequently?
c) Are documents linked directly to objects in the BIM environment? Are documents accessible to / adjustable by other persons/parties?
d) Is project data managed from a multi-organizational perspective? Who manages the consistency of that overarching system? (Tick where appropriate)

Object structure / object decomposition

a) Does the organization make use of a methodology for decomposition / structure of building object parts? Is it being used consistently?
b) Is this methodology or standard established on project level or do you have an organizational standard for this?
c) To what extent are object structure methods aligned and shared with other parties (on project level)? Do you make agreement with other parties?
d) To what extent are sector wide standards or guidelines followed?
e) How do you act on new sector wide developments in this field?

Object libraries / object attributes

a) While creating Building Information Models, does the organization make use of object libraries?
b) Is there a uniform approach for building and using an object library?
c) To what extent are different object libraries aligned and centrally managed?
d) How do you make use of object attributes, non-geometric data?
e) Is the object library set up in a structured way and is it in line with industry standards?
f) How are object libraries managed, updated and reused over time?
g) To what extent does your organization make use of objects and attributes from external online (product) libraries and open standards?

Data exchange

a) How and to what extent is data exchanged from or via the building model?
b) Is data exchange with external parties / other disciplines well-defined? Or is data exchange merely taking place internally between teams / departments of the organization?
c) Is data exchange set up in such a way that your organization or others can continue working based on the exchanged models/information?
d) Is data exchange laid down in contracts/protocols?
e) Do you make use of information exchange standards, such as IFC?
f) Is data exchange also focused on measuring and improving the performance, e.g. by exchanging KPIs?

APPENDIX II – BIM maturity levels

BIM Maturity Level	Internal Definition	External Definition
0	Processes related to the criterion are not present in the organization and no related goals are formulated.	-
1	Internal BIM processes are not defined or limited and ad hoc. Good practices are not shared or laid down in procedures (no multiproject integration). Performance of BIM-related processes and projects is unpredictable and completely dependent on skills in the project team.	Cooperation between companies within a project is ad hoc and reactive rather than proactive. The organizational structure and functions are not geared to collaboration within the supply chain (no multifirm integration). Performance of BIM-related external processes and projects is unpredictable and targets are often not met.
2	BIM policies and procedures have been established for the management of major project-specific BIM processes, whereby good practices can be repeated and processes become more predictable. The structure of the organization is traditional and has not adapted to the BIM process. BIM processes are followed, adjusted, and evaluated to a limited extent during the project.	The importance of cooperation in the supply chain is recognized through the definition of objectives and external fundamental processes. However, the organization has changed insufficiently to reflect supply chain processes. Although external BIM processes are better able to predict, objectives are often still not met.
3	BIM goals are formulated by management with strategic intention, and there is a good overview of the performance and progress of BIM projects. Organizational structures, job profiles, and working methods are defined in accordance with BIM-related tasks, providing greater understanding of the delivered quality of projects. Good BIM practices are documented and applied as standard processes throughout the organization. Based on trust and motivation, there is increasing unity regarding joint BIM targets, which outweigh possible frustrations.	At this level, a breakthrough takes place with regard to cooperation in the supply chain: organizational structures and functions are partly focused on supply chain management, whereby joint supply chain goals and activities can be set. Clients/partners in the chain are involved in efforts to process improvements, leading also to greater mutual satisfaction.
4	Measurable quality targets (quality programs) are made with regard to the outcome and progress of processes. BIM processes are controlled objectively, enabling adjustment and helping to keep targeted performance	Cooperation with chain partners is part of the business strategy and takes place on the process level, including joint efforts on process improvement. Traditional functions disappear at the expense of functions and procedures focusing on external

	within acceptable limits. Risks associated with new, more advanced BIM applications can be controlled due to the strong process discipline and the acquired skills. Both the internal culture (in which confidence in the BIM approach and method is present) and the satisfaction of the project partners strengthen the competitive position/authority of the organization.	processes in the supply chain. This enables more-advanced applications to be set up together with supply chain partners, such as joint planning for both the short and the longer term. This cooperation, with shared confidence in the objectives, becomes a competitive advantage.
5	Effective evaluation of processes and projects contributes to continuous learning and improvement. Internal processes are aligned with the collaboration within the supply chain. Data on the effectiveness of processes are used to analyse new technologies and proposed changes in organizational processes. Through this increased understanding of the processes, organizations are able to assess and implement large-scale process changes. The corporate culture stands for openness and transparency for the sake of intensive collaboration.	An organization operates as part of a multifirm supply chain. This is characterized by intensive cooperation with supply chain partners in which BIM processes are continually improved. This cooperation is ensured by the strong mutual trust and financial dependence. The exchange of performance data makes it possible to anticipate problems and to implement new BIM applications/technologies. Evaluation of processes and projects contributes to coordinated learning across projects.

APPENDIX III – BIM maturity levels according to subcategories

Criteria / sub criterion	Description	Description maturity level					
Strategy		**0**	**1**	**2**	**3**	**4**	**5**
BIM-vision and objectives	To direct the implementation process of BIM within an organization, a BIM-vision and BIM-objectives can be used.	No vision or objectives for BIM formulated.	A (basic) vision for BIM is defined, but there are no concrete objectives associated with it.	There are general BIM-objectives. A BIM-vision is missing or is not kept in line with the broader strategy.	The BIM vision fits within the broader organizational vision/ strategy and is aligned with partners.	BIM-goals are defined. SMART	BIM-vision and goals are actively monitored (e.g. by means of a periodic reporting) and if necessary updated.
Management support	The extent to which the management supports the implementation and further development of BIM by making budgets available and through communicating the relevance of BIM.	No BIM support from the management.	Limited, unstructured support for BIM. Budgets are ad hoc available	The importance of BIM is expressed in words, but budgets are limited.	BIM is supported with sufficient/appropria te budgets.	There are focused resources are to develop BIM further and to implement new applications.	Support for ongoing efforts to implement and further develop BIM in the future guaranteed.
BIM-expertise	Dependent on the organization size, a BIM-expert, a BIM working group and/or BIM-related department can be appointed. This play often a leading, advisory and supporting role in the implementation process of BIM.	No BIM- expert, BIM-working group or BIM supporting department.	There is a BIM expert with little time for BIM initiatives. A BIM-working group or group core users on an irregular basis comes together to discuss BIM implementation.	BIM-expert (s) with enough time/ capacity for introduction of BIM.	BIM expert works in close cooperation with relevant parts of the organization. All (relevant) business units are represented in a BIM-working group or group of core users.	Among the BIM-expert (s) or members of the working group/core group is representation from senior management. There is close cooperation with parts/teams responsible for BIM-tasks.	BIM-related decision making of the expert/group is taken seriously to adjust the BIM-strategy of the organization based on knowledge, experiences and new developments.
Organisational structure and project structure		**0**	**1**	**2**	**3**	**4**	**5**

Tasks and responsibilities	The extent to which the tasks and responsibilities related to BIM processes are formalized and the way in which they are filled in.	No tasks and responsibilities for BIM-related processes documented.	BIM-duties and responsibilities are only partially or on insufficient level documented.	Tasks and responsibilities for BIM processes are sufficiently documented, but limited integrated into the regular job descriptions.	At the project level roles and responsibilities for BIM processes are documented. Project teams use (standard) task or role descriptions.	At the organization level roles and responsibilities are adapted to the extent that they fit with current BIM-use.	Documented BIM-related tasks and responsibilities are regularly evaluated, so that they remain properly tuned to the changing (BIM) environment.
Contractual aspects	The extent to which tough arrangements are made with other parties related to BIM. This includes agreements by means of a contract, a BIM-protocol or another type of formalization.	BIM will not be included in contracts, protocols or otherwise be formalized in agreements.	On a project basis or depending on project teams is BIM (partly) included in contracts or protocols. Within the organization, however, there is no standard or directive available.	There are clear guidelines from the organization for the anchoring of BIM in contracts or protocols, but these are not yet sufficiently used in practice.	The cooperation through BIM is explicitly laid down in contracts or protocols with other parties. The organization is able to take the lead in this formalization and/or to act proactively.	BIM-related agreements are specific and measurable laid down in contracts or protocols. This provides clarity about what information when and how it should be provided.	Changing BIM-use, new BIM insights and potential changes in legal terms are carefully monitored, so that contracts or protocols can be adapted accordingly.
People and culture		**0**	**1**	**2**	**3**	**4**	**5**
Personal motivation & readiness to change	Individual drivers to accept and support BIM implementation. This motivation will determine the willingness of people to adjust their way of working to the BIM-use. The prevailing organizational culture has great influence on the extent and speed of change processes.	There is a lot of repulsion against the use and implementation of BIM.	Personal drivers determine if BIM can be applied on a project basis. There is no organization-wide culture that motivates the transition to BIM.	Despite the motivation from the top of the organization and of (a small group) early adopters, there is still too little enthusiasm for BIM in the majority of the organization.	There is a widely supported enthusiasm within the Organization to work with BIM. This results in an increasing willingness to change the way of working in favor of BIM.	The prevailing culture in the organization has a stimulating effect on the implementation of BIM. This ensures that traditional functions and processes are adapted to the BIM-use.	The strong motivation to apply and improve BIM allows the organization to respond and adapt quickly to new BIM-developments.

Requesting actor (internal)	A requesting actor acts as driver for the BIM implementation process. These so called BIM champion steers and stimulates other people in the organization to use BIM.	No requesting actor (BIM champion) present	A BIM champion is present, but does not have sufficient time and capacity to fulfill this role.	The BIM champion has limited time for the drive on BIM, but is nevertheless able to get BIM to a higher level.	The number of BIM champions and the background of these actors is appropriate to adapt BIM to the perspectives of different individuals, target groups and/or departments.	There is a BIM champion within the management/executives of the organization. He is in close contact with the people (and/or teams) who are responsible for the operational BIM-tasks.	One or more champions within the organization work closely with BIM champions from other organizations or bodies.
Education, training and support	Education, training and support for BIM include both the general information at organization level as specific instructions and guidance for particular people/target groups. Also meant is the development of competences to execute BIM-related tasks.	No education or specific training for BIM.	Education and training for BIM is unstructured and ad hoc. It is offered when individuals insist on this.	There is a structured program for education and training for BIM. This is offered to people who (soon) frequently have to work with BIM.	General information on BIM is organization-wide given to motivate and to create awareness. Extensive training sessions for persons and/or target groups with specific attention to BIM applications.	The education and training program for BIM is tailored to the needs of people and target groups, partly because of the important place for guidance and support in practice: "training on the job".	Education and training for BIM is kept up to date and constantly improved based pm practical experiences, with good/bad practices from projects.
Cooperation focus, openness and transparency	The extent to which the attitudes and people is aimed at cooperation. Important related aspects include openness and transparency with parties worked with.	The organization is internally oriented. This also applies to BIM-use.	Collaboration with other parties is ad hoc and more reactive than proactive. A lack of openness and transparency hampers joint activities.	The effort to structurally work together with other parties are partly successful. Significant improvement in collaboration with other parties is possible if the organization culture would support this more.	Breakthrough in terms of the extent to which organizations are focused on collaboration within the supply chain. BIM-tasks and processes are successful aligned with other parties.	External cooperation is part of the organizational strategy and is considered competitive advantage. The mutual trust between (chain) partners grows, allowing to increase openness and transparency.	A joint functioning network in the construction chain transcends the interests of individual organizations. The interdependence is large, so cooperation is critical to the competitiveness and joint performance.
Processes and Procedures		**0**	**1**	**2**	**3**	**4**	**5**

Procedures en work instructions	The extent to which organizational and project-based processes are documented, e.g. in procedures and work instructions. This affects the consistency and performance of processes.	No documented procedures or work instructions for the BIM-use.	BIM processes are limited laid down in procedures or work instructions. As a result, BIM processes are unpredictable and largely dependent on personal competences.	Work instructions and/or procedures have been established for important applications of BIM. Although work instructions/procedures are still partly present, often older/traditional approaches are continued to be used.	The BIM-use of the organization is (largely) documented in work instructions and/or procedures. This includes good practices and attention to cooperation with other parties (external processes).	The detailed process documentation is intended to ensure the quality of BIM processes. This makes the predictability of processes large and performance remains within acceptable limits.	Process documentation is kept up to date and improved based pm evaluations and new (BIM) developments. This will ensure that the drafted instructions remain relevant for the current BIM-use.
Process change	The driving role BIM can fulfill for change and improving organizational processes.	BIM is considered as a tool for (certain) activities, but does not lead to basic process improvement.	BIM is to a limited extent a driving force for change and improvement of processes. This is highly dependent on the skills and motivations of specific individuals/teams.	BIM is a driving force for improving processes, but traditional structures and habits slowing down this transition for the time being. Adjustments on projects are limited rolled out to other parts of the organization.	BIM is considered effective driver of process improvement. Changes are well shared with other departments/teams and have a positive influence on both internal and external processes.	The BIM-driven change and improvement of processes promotes monitoring and adjusting processes is.	BIM supports continually optimized processes, including intensive cooperation with other parties and disciplines.
ICT (infrastructure)		**0**	**1**	**2**	**3**	**4**	**5**
Hardware and network environment	The physical elements and systems required to use and to store software and data. The quality of the network environment determines the ease with which a construction model and associated data can be exchanged internally and externally. Also working simultaneously within the BIM-environment depends on the network environment.	The hardware is on an insufficient level to let the BIM software function properly.	The hardware supports applications of BIM to a limited extent; the processing of large volumes of data gives problems. The infrastructure for the network environment hinders the external data traffic.	People who work with BIM have suitable hardware at their disposal. The infrastructure for the network environment is of a sufficient level to exchange BIM data with other parties.	Powerful hardware systems are partially present within the organization. The allocation of these systems depends on the need and the BIM application.	The hardware can execute advanced BIM software applications organization-wide. The network environment supports working simultaneously on a building model by multiple parties.	Current and future needs with respect to BIM are actively monitored to identify necessary changes in time and to keep hardware systems up to date.

Software	Operating and application tools that facilitate BIM applications.	There is no BIM software available.	BIM software is available, but this software supports the required current BIM-use to a limited extent.	The necessary BIM-use is sufficiently supported by the available software. Further implementation of BIM (the intended future use) is prohibited.	The cooperation with other parties, including the exchange of information, is well facilitated by the available software.	All necessary and desired (intended) BIM applications are supported by the available software packages. The BIM software acts as a catalyst for a further implementation of the BIM-use.	Future needs for BIM are regularly mapped to keep the used software aligned with these needs.
BIM-facilities	The extent project and meeting rooms with associated facilities are present and available. This includes what function these spaces have to support BIM-use.	There is no project space or meeting rooms available to support BIM-use.	Project area (s) and/or meeting room (s) available, but a lack of facilities (e.g. for projection) ensures that these spaces contribute in a limited way to BIM-use.	The available space (s) are sufficiently equipped to facilitate collaboration with BIM. This allows a number of people to work together through a joint screen/monitor.	There are one or more spaces available which teams can use for a long period of time. This promotes multidisciplinary and integral cooperation.	One or more existing spaces are sufficiently equipped for meeting/coordination sessions with BIM supported by large projection screens or smart boards.	The needs of BIM-related utilities are actively monitored to identify necessary adjustments and to be able to make these adjustments.
Data(structure)		**0**	**1**	**2**	**3**	**4**	**5**
Information structure	Use of a document management system (DMS), such as SharePoint, in order to save project data in a structured way and to make it accessible.	No document management system is used.	The use of a document management system is unstructured and highly dependent on needs and competencies of project teams.	The use of a document management system is part of the standard practices of the organization. However, there is no link between this system and the BIM-environment.	The information within the DMS are (partly) made accessible to other parties within projects (e.g. via the BIM-environment). There can also be granted rights to add/ change documents.	The DMS is fully integrated in the BIM-environment. In this way DMS acts the as a primary source of information during (and after) projects and forms an effective way of communication between parties.	The project-based data is managed from an organizational wide system. A central person is appointed to ensure the consistency and quality of this information.

Object structure/ object decomposition	The decomposition / breakdown of a construction work, where physical or functional elements at different levels of detail of a building are defined. The structure that this creates can be used to provide insights in different parts of the construction work, to draw up and manage work packages, or to link information to certain elements.	There is no methodology used for the object structure/decomposition of a construction work.	The object structure is used on project basis. There is no uniform methodology at the organization level for the object structure defined.	The object structure is an organization-wide uniform methodology.	The organizational methods for the object structure is aligned with and shared with other parties on project level.	The methodology for the object structure is consistently aligned with guidelines/standards in the sector. There are agreements with project exceeding (chain) partners made about the methodology.	Developments at sector level in order to improve the methodology for object decomposition and align themselves are meticulously monitored, so that the organization can adapt itself to this.
Objects library and object attributes	In the construction of a building model standardized objects from an object library (a database of objects) can be used. The object attributes are an addition of non-graphical information to objects in the building model, including characteristics and properties of an object are defined.	There is no use of an object library.	Within the organization different objects-libraries are used which are not aligned to each other: there is no organization standard. Attributes are randomly added.	On an organizational level an object library is managed. Non-geometric data is linked to objects.	The applied object library is set up in a structured way and the naming of objects is consistent. The object library is in line with industry standards.	In creating building models and object libraries available objects and their attributes from external (product) libraries and open standards are.	Object libraries are continuously kept up to date with additional data from projects. Object attributes are added to support other parties in the chain and to be able to reuse information.
Data exchange	The exchange and sharing of data via or from the building model with other parties. In this way e.g. One can work on the basis of data (part models) of partners.	There will be no exchange of data via or from the building model.	Exchange of data via or from the building model is limited and unstructured. This exchange is largely dependent on competencies of project teams.	Data exchange takes place between mainly internal teams/departments. External data exchange is complicated by the lack of mutual agreements and/or data standards.	Data exchange with other parties is well defined in contracts or BIM- protocols. This forms the basis for successful data exchange and supports working based on (parts of) the construction model of other parties.	The exchange of BIM-data takes place via open standards as much as possible. The interoperability (interoperability) of construction models/BIM-data increases.	The exchange of BIM-data includes indicators for the success of BIM applications. This makes continuously monitoring and adjusting possible.

APPENDIX IV – Summaries of the interviews conducted during the case study

Interviewee 1 – Engineering Specialist 1

BIM vision and goals

At Van Oord, we do some strategic thinking that can be related to BIM. Our strategic goals are aligned to BIM but they are not called BIM. There are some initiatives BIM-related, but the term of BIM is still quite vague at Van Oord. We do not say we need to call it BIM in order to make it BIM. There are BIM related objectives without the overarching vision of "This is BIM for Van Oord". There is no conflict between BIM-related vision and goals and the broader strategy of the organisation. There are no SMART goals are they are not monitored. I'm not quite aware of our level of strategic partners.

Management support

The support for BIM from the management is limited due to the lack of understanding that the managers have on BIM and the lack of clearly defined benefits of BIM for the company. The support they provide is more passive than active. For now, allocation of resources is very ad hoc. Resources are not allocated specifically to further develop BIM. Financial support is given according to the departments and the departments, then, decide on how to spend it according to the BIM uses. Financial depends on the economic context and now it this context is not very positive (market crisis).

BIM expertise

There is no formal BIM department. There are individuals that can be considered as experts of BIM, but they are located in different departments (plan & risk department, GDD department, etc). On paper, it is structured. But my impression is that time is more and more taken away by making BIM experts involved on the operational activities of BIM in projects. They are in touch with other operational teams, but I think their time is quite limited to make a real impact within Van Oord. There are people that work for our subsidiary Mackley, a number of people in our business unit Netherlands. Senior management is not represented on the concept of BIM – they do not recognize as being BIM.

Tasks and responsibilities

On an organisational level, no tasks and responsibilities are formalized and documented. There are no BIM formalized and documented job descriptions. But on a project level, yes.

Documentation that relates to tasks and responsibilities of BIM functions are laid down on the project level in the form of BIM Execution Plans (BEPs).

Contractual aspects

No formal organisational guidelines or templates on how to integrate BIM in contracts are available. Collaboration through BIM is explicitly laid down in contracts/protocols. However, these agreements are not specific and measurable. Protocols are not updated regularly.

Personal motivation and willingness to change

People are very open to use the tools and get very enthusiastic with the use of digital tools. But everybody hates processes. Time constraint also plays a role on this aspect. Motivation from the management level is still missing. A lot of unknown factors related to BIM bring resistance to the use of the tools and processes on an organisational level. It is very much dependent on motivation of individual project members. It is very clear to them what it's in it for them. People find it difficult to adapt the way of working. The only difficulty is that we are not so used to a very disciplined and structure way of working. This very "hands on", "go for it" attitude within Van Oord makes more difficult to move to a very structure way of working. But in general, the organisation is quite open to doing things in a new way. We are aware that we need to adapt change, but we still have a long way to go.

Requesting actor

(Interviewee sees the term BIM champion as someone from the management level of the organisation, so the description of this question relates to this vision). BIM champions outside the management level can be identified, but not on the management level. More present lower on the hierarchy and less visible higher on the hierarchy. They come from the engineering and estimating department. It is not driven from the Operations. When it comes to level of decision making, it comes from below (shakes the tree from below).

Education, training and support

There is no specific BIM related in house training program. Training provided limits to individual development plans. The focus is then the competences that individuals need to acquire in order to fulfill their role. An example is the Synchro 4D training (external).

Collaborative attitude, openness and transparency

It is opening up to a more external way. But in general, Van Oord is quite closed in sharing information, especially when it comes to sharing financial information and production information. We are aiming to get there, to collaborate but external collaboration with partners is not part of the organisational strategy of the company. There is no joint network with the supply chain partners when it comes to the use of BIM.

Procedures and work instructions

BIM is barely explicitly mentioned. So there are really no work instructions related to BIM. It is limited to some applications of BIM, such as for design activities. There are some mentions on BIM, but very limited. We are working on this. But it is not completely absent. Work instructions are limited to some applications of BIM, such as for design activities. There are some mentions on BIM, but very limited. We are working on this. But it is not completely absent.

Process change

I do not think BIM is being perceived as a change on the way we work. It is still more perceived as tools. BIM is considered to be a tool for specific activities, but does not lead to fundamental process change.

Hardware and network environment

Saying that this criterion would score the highest grade would be to a certain extent questionable. There are some limitations when it comes to the network availability due to the construction site locations. At the office we have a very good network, but it is not perfect. The available physical systems provided organisation-wide is able to run advanced BIM software applications. I am not sure if current and future needs with respect to BIM are actively monitored to identify necessary changes in time and to keep hardware systems up-to-date.

Software

The required actual BIM use is sufficiently supported by the available software. I do not think future needs for BIM are mapped regularly to keep the used software aligned with these needs.

BIM facilities

There are several meeting rooms available that support collaboration and coordination through BIM. Meetings can be sufficiently accommodated. By making sure the rooms always contain the most recent necessary features, the organisation ensures that rooms and equipment stay future proof.

Information (structure)

The organisation makes use of a system for structured storage of project data, for example a DMS (Document Management System). Structured storage and (re)use of project data is part of the standard practices of the organization. Information and documents associated with building objects are not integrated in the BIM environment. It is not common practice. Project data are

(partly) made accessible to other parties within projects by providing rights to read, add or change data. This is true for project that use joint ventures (SharePoint).

Object structure/object decomposition

A methodology for decomposition of building object parts is not used in a companywide perspective. But yes if considered the project level. The used object structure is established on project basis. There is no uniform approach for the object structure defined at the organization level (under development). Sector wide standards and guidelines are followed according to the client's requirements.

Object libraries / object attributes

Object libraries are used more in the CAD/design department. An organisation wide object library is still under development. There is no uniform approach. Object libraries are not managed on organisational level.

Data exchange

Exchange of data via or from the building model is limited and unstructured. This exchange is highly dependent on the project. Depending on the project contract, data exchange with other parties is well-defined in contracts. Depending on the project contract, data exchange with other parties is defined in contracts or protocols, to a limited level. There is space for improvement. IFC is rarely used. Data exchange does not focus on measuring and improving the performance.

Interviewee 2 – Engineering Specialist 2

BIM vision and goals

The company has been busy for the last 5 years trying to determine what the vision and goals are when it comes to BIM. Only a basic vision has been determined, but no concrete objectives have been associated with it.

Management support

The support for BIM from the management is limited. Financial support is provided when requested for specific applications of BIM, such as purchasing of software. At this moment, before the management makes a decision about committing budgets, they need to know "why do we need it?", "what do we get from it?" and that has not been done extensively so far. They are, then, involved in this process of trying to understand what BIM is and how the company can benefit from it. Right now, they only see costs, since the benefits are not clearly defined and vague. The decision has not been made. If the decision has been made, then the support will be there.

BIM expertise

There is BIM expertise, but it is limited. The BIM Manager that left last month was the BIM lead, but an engineering specialist is being assigned to take upon his role. I do not know how big that department is and what are their levels of expertise.

Tasks and responsibilities

On an organisational level, no tasks and responsibilities are formalized, only on the project level. For the Dutch tenders, yes. For the international tenders, no.

Contractual aspects

No formal organisational guidelines or templates on how to integrate BIM in contracts are available.

Personal motivation and willingness to change

In general, there is motivation but it is mostly dependent on the individual motivation. There is a strong willingness from people when it comes to adaption. In general. But we really need to show that there are concrete benefits when it comes to BIM.

Requesting actor

There are individuals that can be identified as BIM Champions. However, one left the company and there is only the other one left. So at this moment, this situation is a bit unclear. At this point, I can only locate him in one department (Netherlands). BIM Champions cannot be identified within the management/executives of the organisation.

Education, training and support

There is no specific BIM related in house training program. The training provided is very individualistic and project-related.

Collaborative attitude, openness and transparency

Collaboration is a very important aspect at the organisation. We always maintain a good collaboration with partners – clients and sub-contractors – during a project life cycle. I consider collaboration as part of the strategy. I consider collaboration collaboration affect the mutual trust and transparency between parties

Procedures and work instructions

In the international department, the use of BIM is not standardized in procedures and job instructions. No job instructions are used.

Process change

BIM is not considered to be a driving force for improving processes. In fact, BIM should be seen as a tool/method that would help the organisation on achieving the intended goals. BIM is considered to be a tool for specific activities, but does not lead to fundamental process change.

Hardware and network environment

For the limited BIM uses that we do at the International department, the hardware and network environment are suitable.

Software

(answers similar to previous sub criteria. Since the international department does not make extend use of BIM, the hardware and software are suitable so far)

BIM facilities

(does not apply for the international department)

Information (structure)

The organisation makes use of a system for structured storage of project data, for example a DMS (Document Management System). Structured storage and (re)use of project data is part of the standard practices of the organization. Documents are not linked to objects in the BIM environment.

Object structure/object decomposition

A methodology for decomposition of building object parts is not used in a companywide perspective. But yes if considered the project level.

Object libraries / object attributes

These questions do not apply to the international department due to the limited use of BIM, according to the interviewee.

Data exchange

Exchange of data via or from the building model is limited and unstructured. This exchange is highly dependent on competences of project teams. Data exchange is mainly limited to internal teams/ departments. Depending on the project contract, data exchange with other parties is well-defined in contracts or protocols, e.g. via a BIM Execution Plan or Employer's Information Requirements. Depending on the project contract, data exchange with other parties is well-defined in contracts or protocols, e.g. via a BIM Execution Plan or Employer's Information Requirements. IFC is used only when required by the client. Data exchange does not focus on measuring and improving the performance.

Interviewee 3 – Technical service manager Van Oord UK (Mackley)

BIM vision and goals

The definition of specific BIM vision and goals is a process that has not been initiated, at least for Mackley. What drove Mackley's vision was the government requirement. There is no vision driven by the company.

Management support

Management is not driving BIM as a whole, but they are more focused on certain applications of BIM. They like the fact that we are doing it, but they are not driving it. It is driven by the business/market needs, and not by management. Budgets are allocated to BIM according to what is required by clients during a tender procedure. Besides that, I have to fight for other resource allocation when it comes to BIM. They are not financing BIM.

BIM expertise

There are some BIM experts, but it is limited. There are in practice individuals that accumulate functions and are partially occupied with BIM developments, but there is no structured working group. We have someone that manages the CDE and is a bit more involved in the BIM role. In my case, BIM is just a fraction of what I do. But in terms of BIM expertise, there is nobody else at Mackley. Dependent on the time they have left besides other activities. BIM gets done when it gets done. Senior management is not represented.

Tasks and responsibilities

Roles are not documented or formalized. Besides the requirements for the accreditation level 2, we do not formalize these tasks and responsibilities.

Contractual aspects

Agreements have been made between Mackley and consultants. This is the case for the design of the construction. There is a contract that stipulates the exchange of project data. It is more ad hoc on Projects individually. This is the case for the BIM Execution Plan (BEP), for example.

Personal motivation and willingness to change

Very few individuals actually want to deliver BIM. Dependent on motivation of individual project members. What we do at Mackley is that we push people to use BIM platforms, such as the BC platform, by storing organisational processes and procedures in it. So if individuals want to have access to these files, they have to use the CDE.

Requesting actor

Yes, but very few individuals. Me and someone else, to a certain extent. The "BIM manager" from Rotterdam was not really involved with Mackley, except for the Lincshore project. BIM Champions cannot be identified within the management/executives of the organisation.

Education, training and support

There is no specific organisational programme setup. We provide training for specific applications of BIM, such as the use of the CDE, but it is not part of a BIM programme. Good/bad practices are only taught for the use of CDE.

Collaborative attitude, openness and transparency

I think that Mackley is doing better than most. In general, we do collaborate and work quite closely with our partners. We are quite open on knowledge. This is not an issue. I would consider that our collaboration is externally oriented. Collaboration is not part of the strategy. We are part of EA's BIM Group. The discussions brought to the table are good/bad experiences when it comes to the BIM use. This can be considered as a joint activity for the use of BIM.

Procedures and work instructions

The use of BIM is not standardized in procedures and job instructions. No job instructions are used.

Process change

BIM is not considered to be a driving force for improving processes. BIM is considered to be a tool for specific activities, but does not lead to fundamental process change.

Hardware and network environment

The hardware available is capable for supporting BIM use. The network environment sufficiently support the data exchange with other parties.

Software

The software available is capable for supporting BIM use. When it comes to keeping the software up to date, we are entitled to receive always the latest version of the software packages that we have. This is the case of, for example, BC Enterprise (the Common Data Environment used by Mackley).

BIM facilities

Question does not apply since BIM review sessions (for example) are not being done at Mackley. However, the available spaces would support collaboration or coordination through BIM if it was necessary.

Information (structure)

The organisation makes use of a system for structured storage of project data, for example a DMS (Document Management System). every individual that joins our team is obliged to use our CDE (BC Enterprise. We do not link documents to the BIM environment because we do not make use of BIM models, but we do link documents to the GIS system. So, if you consider a GIS model as a BIM environment, then yes, we make that link. A future possibility is to link other BIM models (3D, 4D…) to the GIS environment.

Object structure/object decomposition

A methodology for decomposition of building object parts is not used in a companywide perspective. Mackley will be using their object standards in the future.

Object libraries / object attributes

The organisation does not make use of object libraries.

Data exchange

Exchange of data via or from the building model is inexistent. Every contract we have with the EA has got a MIDP (Master Information Delivery Plan). The use of MIDPs has been adopted extensively since the client sees the benefit of using such a system very clear. IFC is used only when required by the client. Data exchange does not focus on measuring and improving the performance.

Interviewee 4 – Lead project planning & risk

BIM vision and goals

BIM vision and goals have not been formulated. At least not explicitly. We have in our company strategy something about digitization, which is part of BIM.

Management support

The support for BIM from the management is limited due to the lack of understanding that the managers have on what BIM is and what is comprehends in the company. Budget is made available on specific initiatives, not for explicitly for BIM as a whole. For example, the case of Estimating Landscape. Considering that BIM is not explicitly identified, we can consider the budgets are ad hoc available. If considered BIM, we again have the problem of lack of identification what is BIM and what is not BIM. But for specific initiatives that are BIM-related, then support is ensured.

BIM expertise

For some business units/departments you can identify BIM experts, but for others not. Counting with the presence of a BIM expert is more an exception than a rule. There is no general Van Oord BIM working group. Basically dependent on the time they have left besides other activities on a non-structured way. I do not think it is sufficient. We do not have a BIM expert assigned, so it is difficult to answer this question. And this is a result of a lack of BIM vision within the company. For some business units/departments you can identify BIM experts, but for others not. Senior management is not represented

Tasks and responsibilities

BIM roles are not sufficiently documented and formalized, only partially, such as Document Management/Information Management roles. Documentation that relates to tasks and responsibilities of BIM functions are laid down on the project level.

Contractual aspects

Hard agreements being made with other parties regarding BIM only when requested by the client. It is not from our own desire. They are not included in organisational guidelines. BIM collaboration is not laid down in contracts.

Personal motivation and willingness to change

I do not think that there is a repulsion to BIM. I see the desire to collaborate. There discussions on how do we should do it. It is very much dependent on motivation of individuals, since the

enthusiasm is not widely supported. However, for some aspects that we can consider as BIM – but are not explicitly recognized as BIM – I see a support that goes beyond the personal driver. For example, the offshore organisation is embracing the concept of Estimating Landscape, what can be linked to BIM. This also changes according to department. Dredging is different than offshore wind. If the members from our organisation see exactly what BIM is and its benefits, they are also willing to adapt their way of working. But getting to the point in which they see the benefits, that is where the challenge relies on.

Requesting actor

There are some champions distributed in different departments of you consider specific applications of BIM. My reading is that BIM champions are those with enthusiasm about BIM. However, these champions do not have a BIM stamp on their forehead, they do not participate in any BIM discussion or compose a BIM group. Therefore, considering the whole BIM concept, we cannot identify one specific BIM champion. But if you consider more specific parts of BIM, then we find individuals. BIM Champions cannot be identified within the management/executives of the organisation.

Education, training and support

The training provided is not BIM training considering the aspect as a whole, but more a specific software training with relation to BIM. Training provided limits to individual development plans. The focus is then the competences that individuals need to acquire in order to fulfill their role. An example is the Synchro 4D training (external).

Collaborative attitude, openness and transparency

Currently, collaboration and openness are quite internally oriented, but it is changing. We are aiming to get there, to collaborate but external collaboration with partners is not part of the organisational strategy of the company. Working together with other parties has been taking place partially by connecting different sectors of the company such as modelling with planning (internal perspective). Internally, during this process of enhancing collaboration, people sometimes ask “why are you interfering with my work?”, “why do you need this?”. But this has to be seen as a result of multi-disciplinary collaboration. Therefore, internally speaking we can collaborate better. Externally, we can be more efficient by collaborating in a sort of partnership. However, I do not see that happening a lot. It is still the traditional contractor-employer relationship.

Procedures and work instructions

The use of BIM is not standardized in procedures and job instructions. No job instructions are used.

Process change

BIM is not considered to be a driving force for improving processes. More because the issue relies on the fact that there is a lack in identifying what BIM is and what aspects does it include in our organisation.

Hardware and network environment

The hardware available is capable for supporting BIM use. The network environment sufficiently support the data exchange with other parties. The reason why this sub category does not score level 4 is that our database is not configured in such a way that supports working simultaneously on a building model by multiple parties. For example, we do not have a network in place that would allow us to work with partner companies during a joint venture. The exchangeability of data is poor. The system has been set up for internal use only and working with external partners is a deviation to that.

Software

The software available is capable for supporting BIM use. Up to 4D we have everything in the company to make it happen.

BIM facilities

There are several meeting rooms available that support collaboration and coordination through BIM. Meetings can be sufficiently accommodated.

Information (structure)

The organisation makes use of a system for structured storage of project data, for example a DMS (Document Management System). Linking documents to objects in the BIM environment is not standardized and it is not a common practice. We are not doing well on managing project data from a multi-organisational perspective. For example, the documentary is not managed. We have a Van Oord management plan (included in the VOMS) together with sub plans, that we do not know how do they relate to the central management plan. If we have a risk management plan, why do we need the sub plans? Or does the management plan cover it all, or it serves as a table of contents that relates the sub plans.

Object structure/object decomposition

A methodology for decomposition of building object parts is not used in a companywide perspective. But yes if considered the project level. There is no organisational standard. The company tries to keep updated on the new sector wide developments. In the dredging department, it is easier to follow the sector developments than a specific country development.

Object libraries / object attributes

Object libraries are partially used, only in some departments. I know that supply chain has their own object categories and structure, like rock and steel. Now we have object types only and we look at “how do we use these object types?”, “Do we have standards for that?”, “do we have standard models?”. But currently there is no uniform approach. Object libraries are not managed on organisational level.

Data exchange

I do not think data exchange happens via the building model. We apply an old school data sharing (PDF files). We do not use a BIM model for that. The data exchange is not really defined.

Interviewee 5 – Project Manager VOX.Data

Due to the limited time available for the interview and the limited knowledge of the interviewee on BIM aspects, he only responded questions related to Data (structure).

Information (structure)

Interviewee claimed not to have knowledge on this matter.

Object structure/object decomposition

A methodology for decomposition of building object parts is not used in a companywide perspective, but partially. The department most advanced on this is Offshore Wind. Estimating Landscape has created an CBS structure that is now being used by Offshore Wind. WBS (work breakdown structure) has been under development. We have never had a OBS (object breakdown structure). Organisational methodology has been under development. For now, these methodologies are defined project base. Right now, some developments are being done in merging WBS with CBS (cost breakdown structure). When you develop these common languages, you cannot start with all Van Oord. You always have to start small. Non uniformity is inevitable. The CBS was developed for tendering and now it is being expanded to project and execution. Cleopatra translates the structure of the Bill of Quantities from the client. Each client has its own BoQ, so it is very difficult to match them with the way we estimate. To overcome this difficulty, we make use of Cleopatra (provides flexible conversion). In a nutshell: there is no OBS defined on an organisational level, but there is a CBS well defined (Cost Breakdown Structure), at least for 1,5 business units (out of 4): Offshore Wind and Offshore. Dredging and Netherlands do not have CBS.

Object libraries / object attributes

Object libraries are partially used, only in some departments. For my work at Estimating Landscape there were 2 components: cost and time. For those, we had a library (fixed master data), which

we would use to verify consistency (costs and activities). In offshore wind as well (for the production). – opinion not related to BIM models. E&E, Procurement and Finance. Now we have object types only and we look at "how do we use these object types?", "Do we have standards for that?", "do we have standard models?". But currently there is no uniform approach.

Data exchange

The data exchange is not really defined. We share information in the form of signed off PDF on project basis (DBR – Data B. Reports). Conversations with clients around this process are starting to be made. It is providing the client with our database, but to discuss the client the need for certain information – why they need certain information from us. IFC is used only when required by the client. Data exchange does not focus on measuring and improving the performance.

Interviewee 6 – Director department Engineering & Estimating

Due to the limited time available for the interview and the limited knowledge of the interviewee on BIM aspects, he did not provide answers to questions from all sub categories.

BIM vision and goals

BIM vision and goals have not been formulated.

Management support

At this moment BIM is not supported because it has not been explained clearly what is BIM for us. Considering that BIM is not explicitly identified, we never discussed it in a conscious way. There has never been a request to specifically allocate budgets for BIM.

BIM expertise

The BIM experts identified in the company steer BIM from their own, but it has never been a company decision to implement BIM and structure a BIM working group.

Tasks and responsibilities

BIM roles are not sufficiently documented and formalized, only if it is part of the client's requirements. But not on an organisational level.

Contractual aspects

Hard agreements being made with other parties regarding BIM only when requested by the client, especially in the UK.

Personal motivation and willingness to change

There is not personal motivation because so far awareness has not been provided on the advantages of the use of BIM.

Requesting actor

The BIM experts identified in the company steer BIM from their own, but it has never been a company decision to implement BIM and structure a BIM working group.

Education, training and support

No BIM education is provided.

Collaborative attitude, openness and transparency

Currently, collaboration and openness are quite internally oriented, because we are most of the time acting as a main contractor. Sometimes we are in complex joint ventures, but most of the cases we are not in charge of the design process. Our collaboration is not reactive.

Interviewee 7 – Manager Tendering & Estimating

BIM vision and goals

BIM vision and goals have not been formulated.

Management support

The support for BIM from the management is minimal. Mainly because there is a lack of awareness on what BIM is, why do we need to do it and its benefits. Without the business support, there is no point on developing BIM. The only business support we have for now comes from the UK, because the Level 2 accreditation level is a client requirement. “We need business pool to get things going”. This work could help us map what it could mean so we can explain to the other managers and departments why BIM is necessary. We do commit financial and other resources. We have individuals assigned to spend time on BIM, but it is still quite limited. If considered BIM, we again have the problem of lack of identification what is BIM and what is not BIM. But for specific initiatives that are BIM-related, then support is ensured

BIM expertise

There is no general Van Oord BIM working group, only one individual is currently ahead of BIM developments. Senior management is not represented.

Tasks and responsibilities

BIM roles are not sufficiently documented and formalized.

Contractual aspects

Hard agreements being made with other parties regarding BIM only when requested by the client. This is the case for the Accreditation Level 2 in the UK

Personal motivation and willingness to change

If BIM becomes part of our strategic goals (business driver), then the motivation will be there eventually. It is dependent on who has a clear definition and understanding of what BIM is and what it means to our organisation. For now, these individuals are quite limited. People are willing to adapt their way of working to the benefit of BIM if we can define and provide a good understanding of what BIM is and what it can add. As soon as we show that BIM cooperates with our success (winning a tender, for example), then motivation would not be an issue.

Requesting actor

You can identify some BIM champions, especially in our department. The lead project planning & risk and I would could be considered BIM champions. There is no BIM champion from the senior management level.

Education, training and support

No education on BIM is provided.

Collaborative attitude, openness and transparency

Currently, collaboration and openness are quite internally oriented, and collaboration is not part of the strategy.

Procedures and work instructions

The use of BIM is not standardized in procedures and job instructions. No job instructions are used.

Process change

BIM is not considered to be a driving force for improving processes.

Information (structure)

The organisation makes use of a system for structured storage of project data, for example a DMS (Document Management System). We have a DMS for tenders and projects. Our next step is to align the tender DMS structure to all business units. The next step is also expanding it to all departments. We do not link project information to BIM models.

Object structure/object decomposition

A methodology for decomposition of building object parts is partially used. For example, Open Earth where we link measurement results to project locations via a geographic model. But we do not do that structurally across the company. There is no organisational standard. It is only on the project level. With external parties, our object structure methods are not aligned and shared. But we are getting there, such as the case for Activity Logging, in which a vessel describes in real time what it is doing. The next step is to extract the information and provide it to the client. It is on the horizon, but not there yet.

Data exchange

Data exchange does not happen via the building model. Data exchange is well defined but only between teams/departments. We extract the information from the model and pass it on to the client.

Interviewee 8 – Director business unit Netherlands

BIM vision and goals

BIM vision and goals have not been formulated as part of the company's strategy. But we know the importance of it.

Management support

I am almost 5 years at Van Oord. In the company I was working before, the use of BIM was very common. Since I started here, I have been trying to support BIM development within Van Oord. The current situation is that there is not a good plan on how efficiently implement it. I am a big supporter of BIM and I know its importance, but I lack in in-depth knowledge on it. For the other areas, I can identify some other managers that support BIM. Financial support is provided but not sufficient enough to make big steps. I associate that with the lack of awareness and importance given to BIM.

BIM expertise

We have a small group in charge of BIM. These individuals are located in different departments and have different roles. However, one important member of this working group recently left. They do it as a side job. Senior management is not represented in the working group.

Tasks and responsibilities

Interviewee claims not to have knowledge on this matter.

Contractual aspects

Hard agreements being made with other parties regarding BIM only when requested by the client. They are not included in organisational guidelines.

Personal motivation and willingness to change

There will be motivation as soon as we understand more about BIM. If you don't know what it is, you don't know what to want. It is more individual, instead of embedded in the company's culture.

Requesting actor

I do not think we have BIM champions at this point. The engineer that left was a BIM champion that was trying to make some change, but no one was listening to him.

Collaborative attitude, openness and transparency

Currently, collaboration and openness are quite internally oriented, but it is becoming more external as well. I consider that collaboration with other companies is going very good. We are looking especially at companies to work with us considering capabilities we do not have, such as for BIM (integrated contracts). For BIM, the problem is that we build knowledge during joint activities but we do not know how to bring this knowledge and set it up for Van Oord.

Procedures and work instructions

We are aware of its importance, but this has not been done yet.

Process change

BIM is not considered to be a driving force for improving processes in general, only for some specific individuals. People are willing to change the way they work as soon as they know what BIM is and its benefits.

Hardware and network environment

The hardware available is capable for supporting BIM use.

Software

The software available is capable for supporting BIM use.

BIM facilities

There are several meeting rooms available that support collaboration and coordination through BIM.

Information (structure)

The organisation makes use of a system for structured storage of project data, for example a DMS (Document Management System). Linking documents to objects in the BIM environment is not standardized and it is not a common practice.

Object structure/object decomposition

Interviewee claims not to have knowledge on this matter.

Object libraries / object attributes

Interviewee claims not to have knowledge on this matter.

Data exchange

Data exchange does not happen via the building model. We do not use a BIM model for that. The data exchange is not really defined.

APPENDIX V – BIM model uses identification

	Not applied
	Under development
	Applied to some extent

	Model Uses	Process description	Relation with corporate mission
	Monitor System Performance	Using analytical models (BIM models for analysis) and sensor data of a facility to evaluate and model the overall system performance of building structure (walls, floors, roof, etc) and equipment serving the building (mechanical, electrical, plumbing, security, etc).	Innovation Sustainability
	Monitor Space Utilization	A process in which BIM is utilized to effectively distribute, manage, and track appropriate spaces and related resources within a facility. A facility building information model allows the facility management team to analyze the existing use of the space and effectively apply transition planning management towards any applicable changes	Innovation
	Monitor assets	Link between an organized management system and a record model to efficiently aid in the **maintenance and operation** of a facility and its assets. Asset Management utilizes the data contained in a record model to populate an asset management system.	Innovation Collaboration Safety
	Monitor Maintenance	Using facility information models to monitor facility status and schedule maintenance activities for a facility.	Innovation Collaboration Safety
	Compile Record Model	A process to obtain information regarding the facility elements, surrounding conditions, and assets of a facility. The record model should, at a minimum, contain information relating to the architectural, structural, and MEP systems.	Innovation Safety
	Layout Construction Work	Using model information to layout facility assemblies or automate control of automated equipment on a construction project	Innovation
	Fabricate Product	Using information from a model to fabricate of construction materials, assemblies or modules. Examples include sheet metal / pipe fabrication, structural steel fabrication, wall panel fabrication, and wall assembly fabrication.	Innovation Safety

	Author Temporary Construction Systems Model	Using BIM to author the design of the temporary systems required for the construction of the permanent building systems. These temporary systems can include concrete formwork, scaffolding, support of excavation systems, temporary shoring, temporary heating, temporary lighting, or other engineered temporary construction systems.	Innovation Collaboration Safety
	Author Construction Site Logistics Model	Authoring a model of both permanent and temporary facilities on a site during multiple phases of the construction process to communicate the physical site conditions and plan the overall logistics. It may also be linked with the construction activity schedule to convey space and sequencing requirements - 4D	Innovation Collaboration Safety
	Draw Construction Documents	Using BIM to develop the documentation necessary to communicate the facility design to the construction personnel. This may include plans, elevations, sections, renderings, data schedules, 3D diagrams, or specifications.	Innovation Collaboration
	Analyze Sustainability Performance	A process in which a BIM project is evaluated based on LEED or other sustainable criteria. This process should occur during all stages of a facilities life including planning, design, construction, and operation.	Innovation Collaboration Sustainability
	Review Design Model(s)	A process in which stakeholders view a 3D model and provide their feedbacks to validate multiple design aspects. This BIM use can be done by using computer software only or with special virtual mock-up facilities, such as CAVE (Computer Assisted Virtual Environment) and immersive lab.	Innovation Collaboration Safety
	Coordinate Design Model(s)	Using 3D coordination software to compile a federated model of design models for performing automated 3D collision detection to identify potential coordination issues along with performing a visual analysis to identify potential spatial design issues.	Innovation Collaboration
	Analyze Lighting Performance	Leveraging the model to perform a quantitative and aesthetic review of the lighting conditions within a space or on a surface or series of surfaces. This can include daylighting analysis or artificial lighting analysis.	Innovation
	Analyze Structural Performance	A process in which analytical modeling software utilizes the BIM design authoring model so to determine the behavior of a given structural system.	Innovation Safety
	Analyze Energy Performance	The BIM Use of Facility Energy Analysis is a process in the facility **design phase** which one or more building energy simulation programs use a properly adjusted BIM model to conduct energy assessments for the current building design	Innovation

	Author 4D Model	A process in which a 4D model (3D models with the added dimension of time) is utilized to effectively plan the phased occupancy or to show the construction sequence and space requirements on a building site	Innovation Collaboration
	Author Cost Estimate	A process in which BIM can be used to assist in the generation of accurate quantity take-offs and cost estimates throughout the lifecycle of a project. 5D planning.	Innovation Collaboration
	Analyze Program Requirements	A process in which a spatial program is used to efficiently and accurately assess design performance in regard to spatial requirements. The developed BIM model allows the project team to analyze space and understand the complexity of space standards and regulations.	Innovation Collaboration
	Author Design Model	Using BIM authoring software to develop a model with 3D and additional attribute information for a facility design leveraging a library of parametric design elements.	Innovation Collaboration
	Capture Existing Conditions	A process in which a project team develops a 3D model of the existing conditions for a site, facilities on a site, or a specific area within a facility. This model can be developed in multiple ways: including laser scanning and conventional surveying techniques.	Innovation Safety
	Analyze Site Selection Criteria	A process in which BIM/GIS tools are used to evaluate properties in a given area to determine the most optimal site location for a future project. The site data collected is used to first select the site and then position the building based on other criteria.	Innovation Sustainability Safety
	Analyze Engineering Performance	A process in which intelligent modeling software uses the BIM model to determine the most effective engineering method based on design specifications. These analysis tools and performance simulations can significantly improve the design.	Innovation Sustainability
	Validate Code Compliance	A process in which code validation software is utilized to check the model parameters against project-specific codes. Validate that building design is in compliance with specific codes, e.g., IBC International Building Code, ADA Americans with Disabilities Act guidelines and other project related codes using the 3D BIM model.	Innovation Collaboration
	Analyze Emergency Management	A process in which emergency responders would have access to critical building information in the form of a model and information system. The BIM would provide critical building information to the responders that would improve the efficiency of the response and minimize the safety risks	Innovation Collaboration Safety

APPENDIX VI – Selection of steps to compose the BIM acceleration plan

Category	Action	Description from theory	Data from case study	Action included in the BIM acceleration plan
Preliminary	**Articulate BIM benefits across management level**	Management buy-in and support in essential in order to ensure effective BIM implementation and sufficient allocation of resources	Some members from the management level do not possess adequate awareness on BIM, its process and its benefits for the organisation. Management support is unstructured and budgets are made ad hoc available	Yes
	Establish BIM planning committee	A BIM planning committee reunites members from all levels of decision making and facilitates effective allocation of organisational resources for key BIM competencies and priorities	Individuals with prior knowledge and experience on BIM are scattered among different departments and decision-making levels but do not form a BIM planning committee	Yes
Policy	**Conduct current BIM implementation assessment**	BIM maturity measurement enables the identification of critical aspects for BIM implementation that require improvement	A BIM maturity assessment has been conducted in the present research	No
	Align BIM with corporate mission	Identifying corporate vision implies in understanding the organisation's definition on how it has acted and how it projects itself towards the future for the use of BIM, defining current and desired business processes	A BIM vision aligned with the corporate mission has not been defined part of BIM strategic planning	Yes
	Define current and future BIM Model Uses	A BIM use is defined as method of applying BIM during a facility's lifecycle in order to achieve one or more BIM-specific objectives.	The identification of current BIM model uses and definition of future uses has not been conducted as part of BIM strategic planning	Yes
Process	**Document BIM processes and work instructions**	BIM integrated processes associated with each BIM use should be mapped, documented and included along with the different activities from the organisation in order to provide a basic understanding of the activity to be performed	Formalization of current BIM processes and work instructions is inexistent	Yes
People	**Revise organisational roles**	Traditional roles and responsibilities within an organisation are required to change once the organisation decides to	BIM-related tasks and responsibilities are on insufficient level documented on the organisational level.	Yes

		apply the BIM approach and initiate BIM implementation		
	Establish BIM skills	The objective of a establishing BIM skills via an education program is to spread awareness on BIM, how it can be used and how it influences organisational roles and processes. It can be provided internally via workshops, or externally	education and training for BIM within Van Oord is unstructured and ad hoc. In practice, no extensive training sessions are provided to project team members focused on BIM applications. In addition, no general information on BIM is provided organisation-wide to motivate and raise awareness	Yes
Technology	**Mobilize supporting software solutions**	The definition of the necessary software part of the BIM implementation depend on the establishment of the BIM goals and uses. Once this has been defined, it is possible to identify and mobilize BIM software that meets the organisation's specific needs	Software availability is not a barrier for BIM implementation at Van Oord. It has been a consensus that the available BIM software is appropriate for the intended BIM uses	No
	Mobilize supporting hardware and network	The definition of the necessary hardware and network requirements part of the BIM implementation depend on the establishment of the BIM goals and uses. Once this has been defined, it is possible to identify and mobilize BIM hardware and software that meet the organisation's specific needs	The available hardware provided organisation-wide is able to run advanced BIM software applications and the quality of the network environment allows cloud-based working on building model by multiple parties, being sufficient to support the required BIM uses	No
	Adapt BIM facilities to support BIM uses	In order to achieve greater and better interaction essential for a collaborative environment such as BIM, workspaces within the company should be adapted	There is enough capacity of spaces that are well-equipped to accommodate meetings and coordination sessions with BIM	No

APPENDIX VII – Influence of proposed actions on subcategories from the BIM maturity model

In the first part of this appendix, a table that includes the relation between the proposed actions from the BIM implementation acceleration plan and the sub criterion from the BIM maturity model is presented. In the second part, the rationale behind the positive expected influence is presented according to findings from literature. In the last part, the expected impacts on the maturity levels, as shown in Figure 19, will be discussed considering the proposed steps.

I. Influence of proposed actions on categories and subcategories of the maturity model

		Strategy			**Organisational and project structure**		**Processes and procedures**		**People and culture**			
		BIM-vision and objectives	Management support	BIM-expertise	Tasks and responsibilities	Contractual aspects	Procedures and work instructions	Process change	Personal motivation	Requesting actor	Education, training and support	Collaborative attitude
Preliminary	1- Articulate BIM benefits across management level	o	+	+	o	o	o	+	+	+	o	o
	2- Establish BIM planning committee	o	o	+	o	o	o	o	o	+	o	o
	3 - Integrate BIM to current digitalization initiatives	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Policy	4- Align BIM with corporate mission	+	o	o	o	o	o	o	o	o	o	o
	5- Define current and future BIM Model Uses	+	o	o	o	o	+	o	o	o	o	o
Process	6 - Document BIM processes and work instructions	o	o	o	o	+	+	o	o	o	o	o
People	7 - Revise organisational roles	o	o	+	+	o	o	o	o	o	o	o
	8 - Establish BIM skills	o	+	+	o	o	o	+	+	o	+	+

+ indicates positive influence, o indicates neutral influence, n/a indicates not applicable

II. Rationale behind the relations

In this item, the rationale behind the relations indicated in the previous item will be further elaborated considering findings from the literature approached in the theoretical framework. This will provide the evidence necessary for the maturity gains to be presented in the next item. It is important to highlight that the proposed step "Integrate BIM into current digitalization initiatives" will not be approached since no theoretical evidence was found that would allow to draw any relation.

Proposed action 1: Articulate BIM benefits across management level		
Expected positive influence	**Justification**	**References**
Management support	Seminars and marketing meetings on BIM, its applications and benefits can increase the perception individuals have on BIM and facilitate a common understanding of BIM	*(Hartmann et al., 2012; Baldwin, 2019; Panaitescu, 2014; Muñoz-La Rivera et al., 2019)*
BIM-expertise	Managers, once aware and convinced on the applications and benefits of BIM can play a leading, advisory and supporting role in the BIM implementation process	
Process change	Managers actively involved in the implementation of BIM have enough influence to change the way BIM is perceived by the project teams	
Personal motivation	The motivation from the top of the organisation is essential to increase the project team member's willingness to change the way of working in favour of BIM	
Requesting actor	Managers fully aware on BIM and its benefits act as a driver for the implementation process, steering and stimulating other people in the organisation to use BIM	

Proposed action 2: Establish BIM planning committee		
Expected positive influence	**Justification**	**References**
BIM-expertise	An established BIM planning committee plays a leading, advisory and supporting role for the implementation of BIM	*(Baldwin, 2019; CIC, 2013; Panaitescu, 2014)*
Requesting actor	An established BIM planning committee acts as a driver for the implementation process, steering and stimulating other people in the organisation to use BIM	

Proposed action 3: Align BIM with corporate mission		
Expected positive influence	**Justification**	**References**
BIM-vision and objectives	The elaboration of a BIM vision aligned with the corporate mission is essential for the organisation to project itself towards the future for the use of BIM, defining current and desired business processes	*(Muñoz-La Rivera et al., 2019; CIC, 2013; Baldwin, 2019; Panaitescu, 2014)*

Proposed action 4: Define current and future BIM model uses		
Expected positive influence	**Justification**	**References**
BIM-vision and objectives	The identification model uses already in place in line with the BIM vision facilitates the elaboration of BIM objectives, necessary for defining future uses	*(Muñoz-La Rivera et al., 2019; CIC, 2013; Baldwin, 2019; Panaitescu, 2014)*
Procedures and work instructions	BIM uses should be mapped, documented and included along with the different activities from the organisation in order to provide a basic understanding of the activity to be performed, in the form of work instructions and process maps	

Proposed action 5: Document BIM processes and work instructions		
Expected positive influence	**Justification**	**References**
Contractual aspects	The definition and documentation of BIM processes provide the organisation with clear guidelines for anchoring BIM in contracts and protocols with other parties	*(Muñoz-La Rivera et al., 2019; CIC, 2013; Baldwin, 2019; Panaitescu, 2014; Siebelink, Voordijk and Adriaanse, 2018; Messner et al., 2019)*
Procedures and work instructions	The documentation of work instructions and procedures established for important applications of BIM ensures the quality of BIM processes	

Proposed action 6: Revise organisational roles		
Expected positive influence	**Justification**	**References**
BIM-expertise	The revision of organisational roles in order to incorporate BIM and bring them together facilitates the formation of BIM working groups, playing a supporting role for BIM implementation	*(Muñoz-La Rivera et al., 2019; CIC, 2013; Baldwin, 2019; Panaitescu, 2014)*
Tasks and responsibilities	The revision of organisational roles is necessary in order to incorporate BIM and define BIM-related tasks and responsibilities	

Proposed action 7: Establish BIM skills		
Expected positive influence	**Justification**	**References**
Management support	Educate members from the management level aims to help them in better understanding BIM and the organisation's purpose for using it, in order to guarantee sufficient support and allocation of resources	*(CIC, 2013; Baldwin, 2019; Panaitescu, 2014; Siebelink, Voordijk and Adriaanse, 2018; Muñoz-La Rivera et al., 2019)*
BIM-expertise	In order to establish a BIM working group, members might need additional training on BIM and its processes, especially considering members from initiatives already in place	
Process change	Training and education sessions facilitate in changing the way BIM is perceived by the project team members, supporting these individuals in replacing traditional habits for the new way of working	

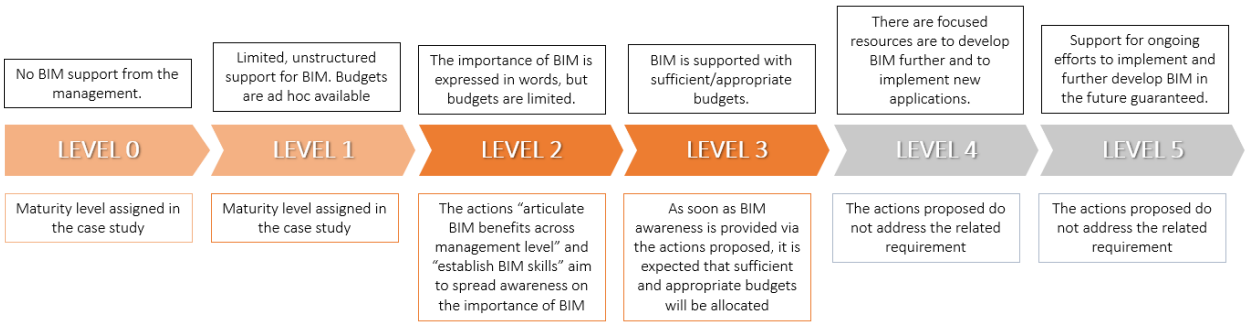
Personal motivation	Training and education sessions encourage individuals in accepting and supporting BIM, supporting these individuals in replacing traditional habits for the new way of working
Education, training and support	The establishment of BIM skills that consider general BIM information and specific instructions for particular target groups in executing BIM aim form an education, training and support programme
Collaborative attitude, openness and transparency	A BIM training and education programme can focus on the importance of structurally working together with other parties as a necessary factor for successful BIM implementation.

III. Expected impacts on the maturity levels

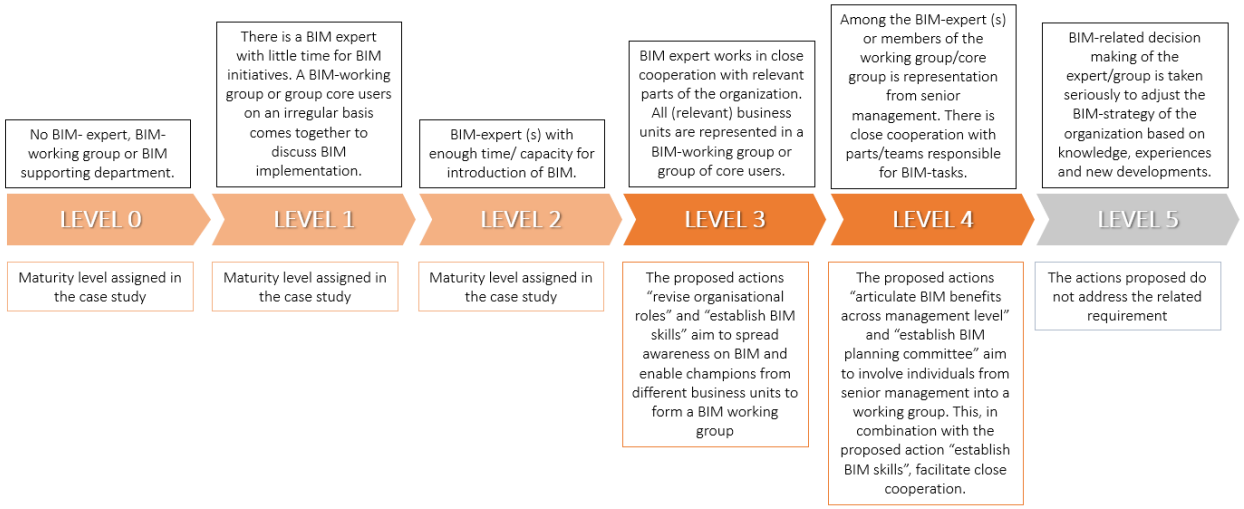
In this item, the impacts on the maturity levels of each sub criterion will be detailed considering the theory highlighted in the previous item. The text boxes located above each level refer to the descriptions of the levels, as presented in Appendix III.

<u>Sub criterion: BIM vision and objectives</u>

<u>Sub criterion: Management support</u>

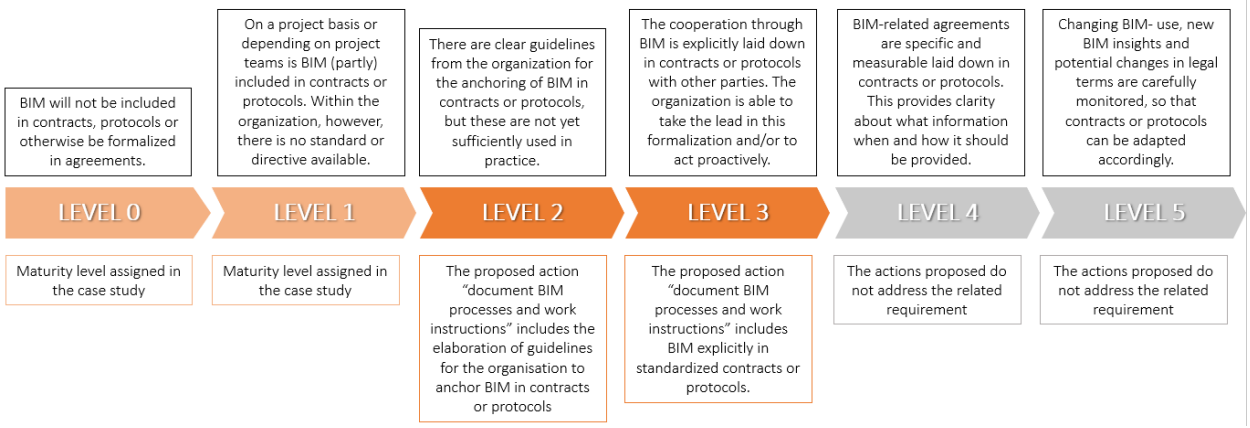


Sub criterion: BIM expertise

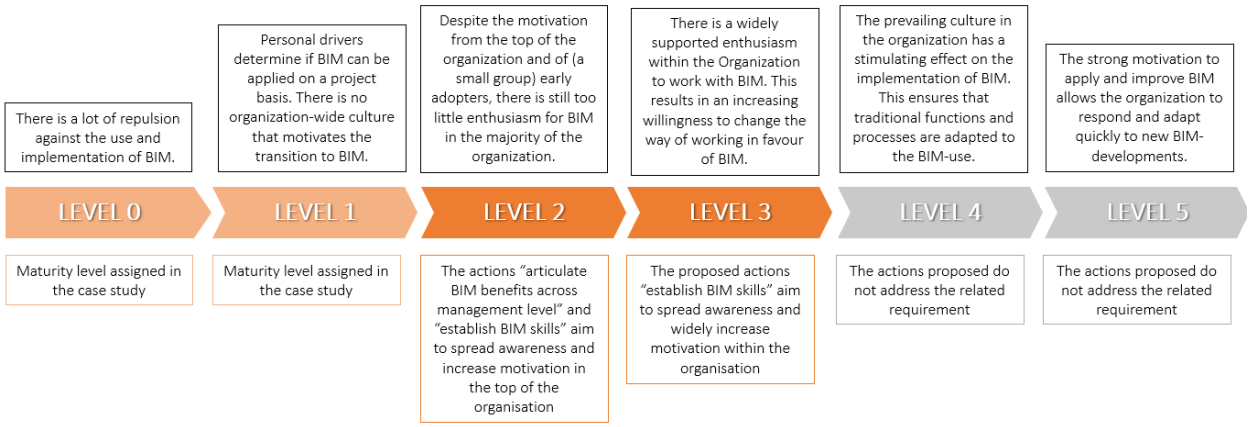


Sub criterion: Tasks and responsibilities

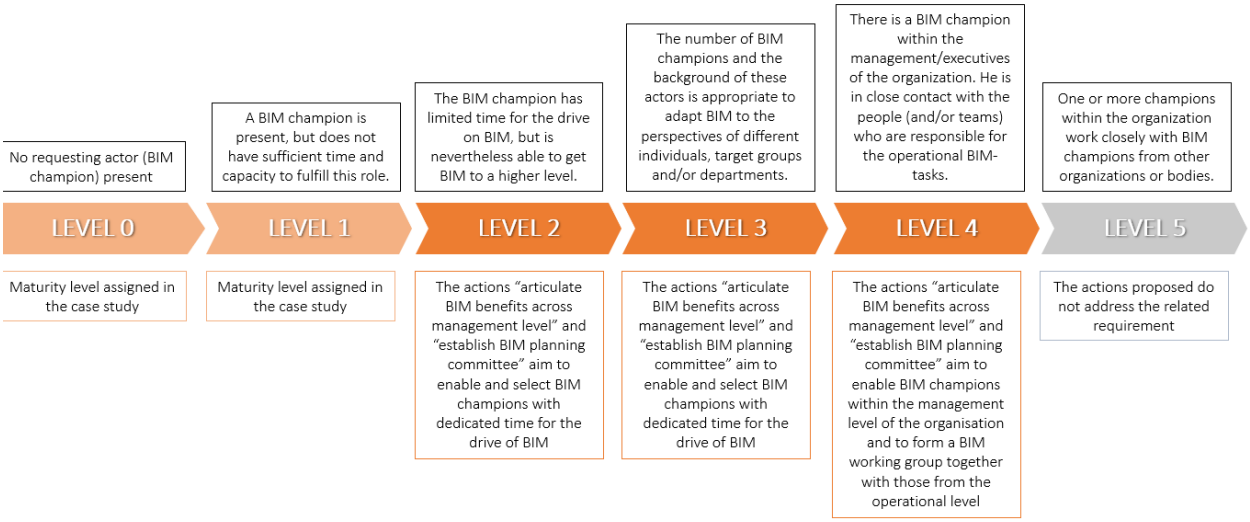
Sub criterion: Contractual aspects



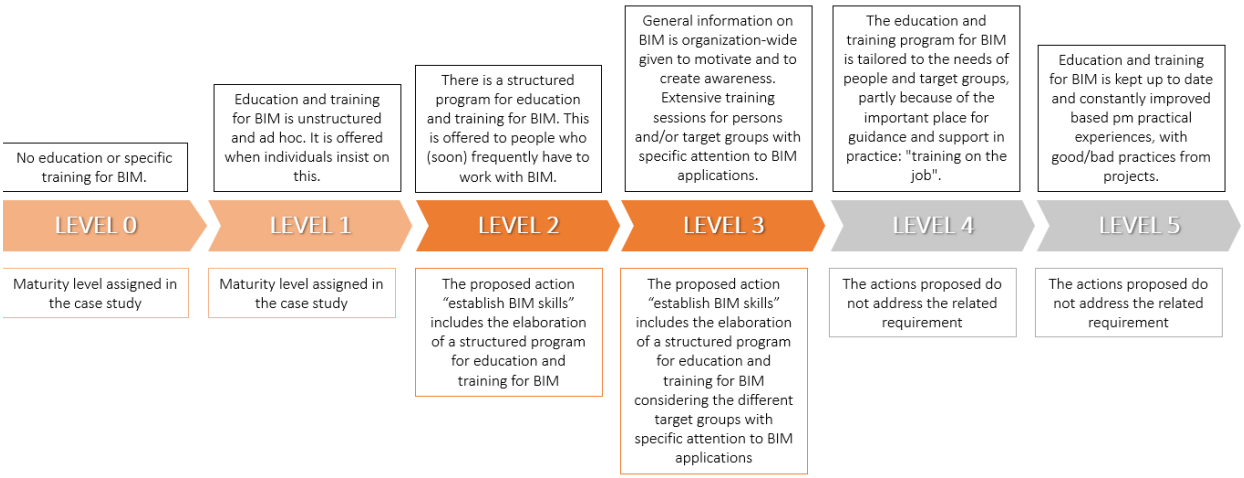
Sub criterion: Personal motivation and readiness to change



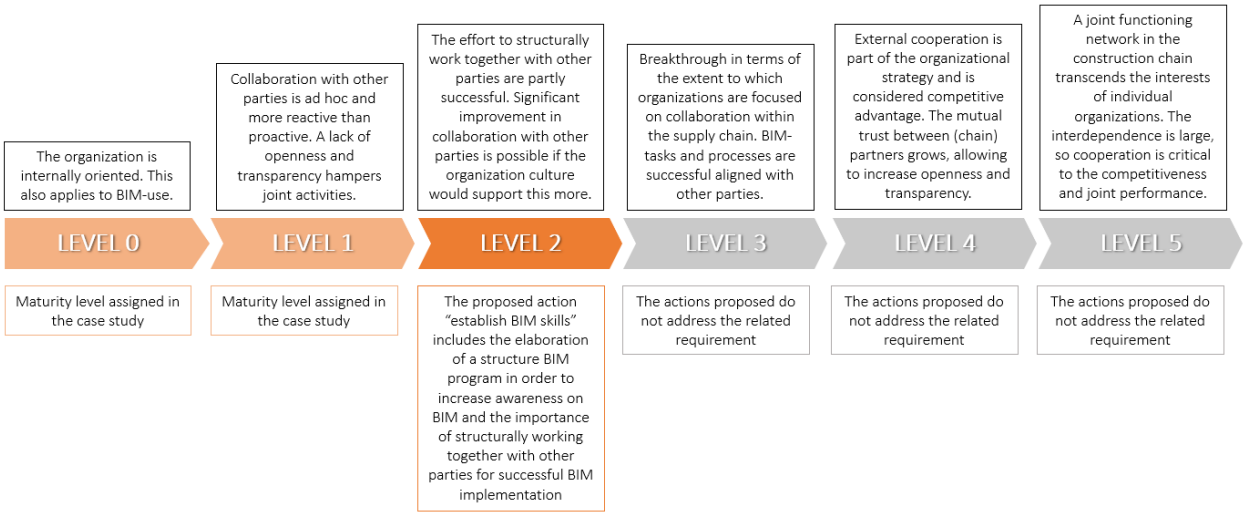
Sub criterion: Requesting actor (internal)



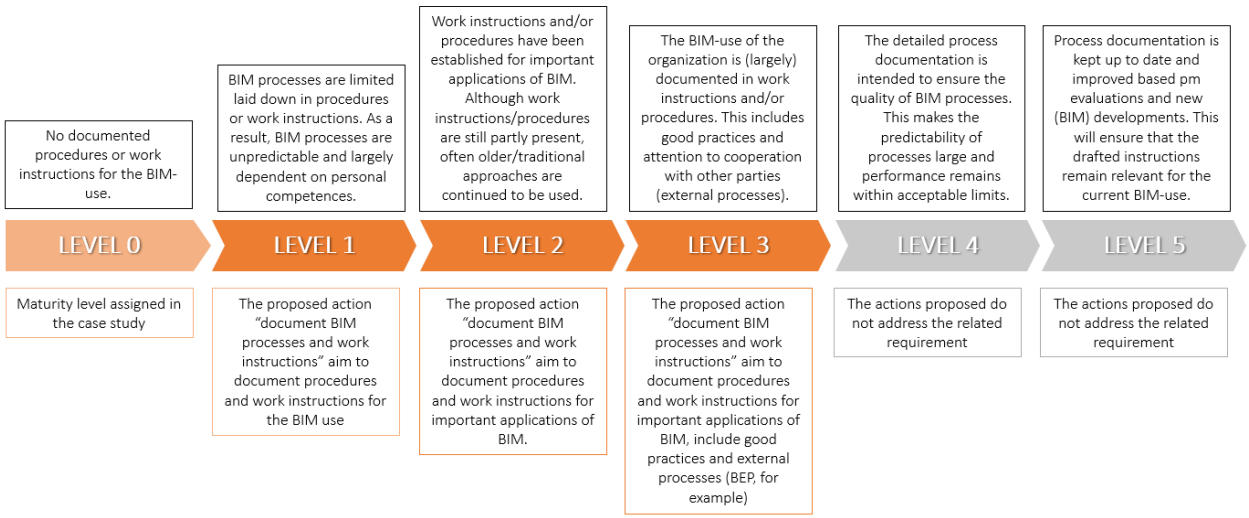
Sub criterion: Education, training and support



Sub criterion: Collaborative attitude, openness and transparency



Sub criterion: Procedures and work instructions



Sub criterion: Process change