MASTER THESIS

BIM maturity on project level

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Commissioned by:
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PREFACE

Submitted in partial fulfillment for the requirements of the degree of Master of Science, this thesis marks the end of my time as a student at the University of Twente.

I would like to take this opportunity to thank several people who have been very helpful before and during my thesis project. In the first place, I would like to thank Hans Voordijk and Sander Siebelink for their excellent supervision from the University of Twente. I would like to thank them for their adequate feedback and constructive comment and positive attitude. I also want to thank them for the weekly feedback moments during the writing of the thesis, so the graduation process went very smoothly, I experienced this method as very pleasant.

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I hope you enjoy reading my thesis.

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Ilse Meijer

SUMMARY

Digitization in the construction world is going prosperous and BIM is a central element in this development, it is favored topic in the construction industry (Succar, 2010).The benefits of using BIM are now widely recognized (Kushwaha, 2016; Li et al., 2014), although the speed of implementing BIM at different companies in the industry is low due to various hurdles. Transforming traditional approaches to a BIM approach is not an easy task, it requires collaborative efforts from all parties (Kushwaha, 2016). The use of BIM is currently applied to almost all parties, but not all parties in the construction sector are equally developed. Recent research (Siebelink, Voordijk, & Adriaanse, 2018) shows that Dutch organizations have also recognized that differing levels of BIM readiness within organizations representing the various disciplines within the Dutch construction industry is a serious implementation barrier to BIM supported collaboration between parties. Many companies still experience many differences in the level of working methods by different parties with regard to the use of BIM (Wolf, 2018). Since they have all differences in the level of working, the cooperation becomes difficult.
It appears that the inconsistent BIM maturity levels across collaborating parties in a project limit the degree to which BIM goals and accompanying expectations can be realized, especially regarding BIM uses with extensive data exchange between parties (Siebelink et al., 2018).

Various studies have been done on the BIM maturity levels at diverse levels. It is applied at the national level as well as to stakeholders, organizational and the renovation sector. Different tools are therefore applied at many levels, but specifically at project level is still a gap. Investigating the potential of the developed BIM maturity model on the project level is particularly relevant because cooperation aspects are expected to be particularly beneficial within a project context.

The aim of the research is to gain insight into the differences between the parties' perception of the BIM maturity of the project as a whole on the collaboration on this project. The framework used for this research is based on the maturity model of Siebelink et al. (2018) and linked to the approach of Eisenhardt (1989). The structure of the maturity model is divided into six main criteria namely strategy, organizational structure, people and culture, processes and procedures, IT (infrastructure, and data (structure). The framework was applied in four cases, the framework was used to gain insight into the differences between the parties' perception of BIM maturity and the project as a whole on the BIM collaboration.

The results show that the current BIM maturity level on the project differ in some cases by the perceptions of the parties. Some parties are closely connected to the project and do receive certain documentation, which results in a higher perception at the BIM level. Meantime, other parties are less involved in the project which resulted in unknowingness because they have not received information about certain aspects. From the case data, most of the differences in perception between the parties were observed in the following aspects; BIM processes, strategy and organizational and project structure. It is concluded that projects that use a DMS system have a higher maturity on data structure and experience better mutually cooperation because everything is shared with each other and agreements have been made. Some of the individual parties score low on strategy criteria. This is due to the fact the parties do not know anything about agreements or they have not received it because it is a party which is less involved in the project. Motivating the different parties is an important aspect in the success of a BIM project. In some case studies there is given resistance, it is also not clear to a number of parties

whether there is education and training. This is due to the fact that communication is lacking among/between the parties and score therefor low on the criteria people and culture.

The projects as a whole scored all relatively high on the following criterion; data, strategy and people and culture. The results show that the perceptions of parties of all cases differ sometimes from criteria compared to the project as a whole. Most of the times this is because the agreements are not known by the parties or not shared or set up sufficiently resulting in ignorance. The projects that have established these agreements since the first phase of the project score significantly higher in most aspects, and all parties are more aware of it. It is also turned out that projects with a lower maturity level, the cooperation is experienced as bad because it is unclear which agreements have been made. The parties are either insufficiently or not included in the agreements, which sometimes makes it unclear for the parties.

When the perceptions of the parties' match, the project has a higher maturity level and the cooperation on the project is better as well. The parties are all aligned, resulting in an integral whole. The consequences of differences in perceptions of BIM maturity between the parties are that they have poorer cooperation and experience more problems on the project. Another possible consequence of differences in maturity level is; it can pose a risk for good BIM use. When some people/parties are not aware of the agreements that have been made it will result in unknowingness about certain aspects resulting in a difference in maturity level. Also, the lack of communication during a project will result in bad collaboration and differences in maturity level. The consequence of bad collaboration is misunderstandings and even errors in the project. When the project has a higher maturity level, the experiences of collaboration is better. This is because the parties have coordinated agreements with each other and are all aligned. Projects with a higher maturity level experience fewer problems and the project runs smoothly, resulting in better cooperation.

The results also showed that no difference is seen between the type of project in relation to the maturity level. It also appears that the level of maturity could depend on the project phase and the maturity could still develop during the project. Finally, it appears that certain roles or parties score more often higher than other parties. Contractors and engineers often score higher than parties further up the chain; suppliers and subcontractors.

The projects can improve on many aspects, but it depends on agreements. It is advised to pay more attention to contractual agreements. By creating clarity through agreements, the motivation within a project can increase and the resistance can decrease. Collaboration can be improved by working at a joint project location, this also improves communication and makes it easier to ask for help which resulted in less errors.

TABLE OF CONTENT

1. INTRODUCTION

This introductory Chapter serves to outline the motivation for this research, to describe the state of the art in this research field and to demarcate the project. The first Section treats the project context and literature review. This leads to the formulation of the research aim in Section 1.2 and questions in Section 1.3. An outline of the remainder of this thesis can be found in Section 1.4.

1.1 PROJECT CONTEXT & LITERATURE REVIEW

Digitization in the construction world is going prosperous and BIM is a central element in this development, it is favored topic in the construction industry (Succar, 2010).The benefits of using BIM are now widely recognized (Kushwaha, 2016; Li et al., 2014), although the speed of implementing BIM at different companies in the industry is low due to various hurdles. Transforming traditional approaches to a BIM approach is not an easy task, it requires collaborative efforts from all parties (Kushwaha, 2016).

Since it requires collaborative efforts from all parties, BIM cooperation is an important driver for BIM adoption (Boeykens, De Somer, Klein, & Saey, 2013). Grilo and Jardim-Goncalves (2010) indicated that if higher levels of interactions between participants emerge (e.g., through full 3D BIM cooperation), companies in building projects will likely obtain differentiation value levels, where higher cost benefits and less risk are likely to be the outcome.

The use of BIM is currently applied to almost all parties, but not all parties in the construction sector are equally developed. Recent research (Siebelink et al., 2018) shows that Dutch organizations have also recognized that differing levels of BIM readiness within organizations representing the various disciplines within the Dutch construction industry is a serious implementation barrier to BIM supported collaboration between parties. Many companies still experience many differences in the level of working methods by different parties with regard to the use of BIM (Wolf, 2018). Since they have all differences in the level of working, the cooperation becomes difficult.

The challenge of implementing BIM is seamlessly integrating BIM into daily work processes and achieving continuous improvements. To meet this challenge, it is important to first evaluate the current circumstances in the company. The BIM maturity tool, assessing the maturity level of BIM adoption on a project or within the organization can provide insights to ways to improve processes and better take advantage of the benefits of BIM. The results of the BIM maturity tool can be used to set priorities for further acceptance and implementation of BIM within the firms.

The analysis of the BIM maturity level is applied at different levels. Previous research adopts a wide-angle approach to BIM maturity as applicable to countries rather than organizations, the BIM maturity level is assessed on a large scale and is supported by the BIM maturity tool (Kassem, Succar, & Dawood, 2013). This study focusses on the maturity levels of three different countries with similar construction cultures. This study also investigates at the maturity levels of different sectors within a certain country.

Furthermore, Yang and Chou (2019) focusses on the BIM maturity levels of different stakeholders. This study defines the level of different stakeholders who have little or no BIM project experience. After this, with the help of the research results and findings, the relevant stakeholders will be informed about how BIM can be further implemented within the company.

Joblot, Paviot, Deneux, and Lamouri (2019) focus on the BIM maturity level in the renovation sector. The three different case studies show that only one company actually uses BIM. The other companies work with either 2D drawings or 3D software and these are not yet able to integrate BIM into the company. This shows that the BIM maturity level in the renovation sector is quite low.

Siebelink et al. (2018) which focuses on BIM maturity at the organizational level, shows that there are differences in the level of maturity in different organizations. They concluded that; in addition to being motivated to work with BIM, the functioning of BIM is also determined by having the competence required to be able to work with it. Intensive education and training to all those who are part of the BIM process should be provide by the organization. The culture of the organization also affects the openness (to external partners) and the degree of collaborative attitude or orientation toward the supply chain. Achieving an integrated and multidisciplinary BIM approach requires a setting and an attitude that are aimed at cooperation. To this end, the organization needs to show a willingness to change its traditional culture, structure, and processes.
It appears that the inconsistent BIM maturity levels across collaborating parties in a project limit the degree to which BIM goals and accompanying expectations can be realized, especially regarding BIM uses with extensive data exchange between parties (Siebelink et al., 2018).
Investigating the potential of the developed BIM maturity model on the project level is particularly relevant because cooperation aspects are expected to be particularly beneficial within a project context.

During the literature study papers in the field of BIM maturity were examined, at diverse levels various studies have been done on the BIM maturity levels. It is applied at the national level as well as to stakeholders, organizational and the renovation sector. Different tools are therefore applied at many levels, but specifically at project level is still a gap. But here are challenges because within a project, parties have to collaborate together which differ a lot from each other. It is difficult to collaborate with people who has all different maturity levels, which can lead to difficulty cooperation. This is not the only effect which can occur due to the different maturity levels, it can also have an effect on the project as a whole or it may have other effects. Research on project level is necessary to fulfill this research gap and to gain insights in the effects of the different BIM maturity of parties involved in a project.

1.2 RESEARCH OBJECTIVE

This Section examines the goal of this study. The general background described in the first Section was the main reason for starting this study. The goal has been set in this research objective, this concerns the use of the knowledge that the research will produce.

The goal of the research represents the external goal of the research project, the practical value of this research for the construction firm. This research aims at helping the large construction firm to gain insights into the BIM maturity level of different parties at project level and therefor this research contributes to increase the knowledge on the different maturity levels in different project levels. In addition, knowing the possible effects on the project as a whole and what the possible consequences for the BIM cooperation are, is of value for the construction firm.

The aim of the research is to gain insight into the differences between the parties' perception of the BIM maturity of the project as a whole on the collaboration on this project.

1.3 RESEARCH QUESTIONS

In this Section the research questions are presented which together will collect the required knowledge to achieve the goal of the research. These questions are derived from the goal and from the background of this research. The central questions of the study are:

- What is the current BIM maturity level on the project by the perception of the parties?
- What is the overall assessment of the maturity level of the project as a whole?
- What are possible consequences of difference perceptions of the BIM project maturity for the BIM cooperation on project level?

1.4 THESIS OUTLINE

This thesis is further organized as follows. Chapter 2 describes the methodology employed to arrive at the research aim described. Results are presented in Chapter 3. Chapter 4 is dedicated to the discussion of this work. Finally, the conclusions and recommendations for further research and it treats this research's potential and limitations in detail in Chapter 5.

2. METHODOLOGY

This Chapter presents the methodology that was employed to achieve the research aim of this study. This Chapter deals with steps 3 (crafting instruments and protocols) of the Eisenhardt framework as mentioned in Section 2.1.3 research framework. Sections 2.1 describe the research steps and method taken to obtain the results for the four case studies the framework was applied to. Section 2.2 will give an overview of a couple of existing maturity models, hereafter the selected maturity tool is discussed in Section 2.3.

2.1 RESEARCH METHOD

This Section describes the technical research design. Here the interpretation of the research is discussed. First, Section one will elaborate on the research methodology. The second Section will give an overview of the research framework and deals with data collection strategy and the data analysis strategy. This describes the way the data will be gathered from the field and how the data will be analyzed.

2.1.1 RESEARCH METHOD

For the development of the research strategy decisions are made to determine how the research is conducted. Three decisions set the base for the rest of the strategy. These decisions are, if the research will be broad or in-depth perspective. The second decision is whether it is a qualitative or quantitative study. And the third decision is whether the research is empirical or non-empirical.

The first question addresses if the research perspective will be broad or in-depth. The research will have an in-depth perspective since it will focus on the building industry. The research will be qualitative, since the answers on the research questions will lead to results and conclusions. The interviews will focus on the maturity levels on project level. The basis of this research will be a multiple case study, to collect and analyze the required information of the interviews therefor, the research will be an empirical research.

The research will be a multiple case study, the cases that will be investigated are four building projects of the construction firm. The reasons for carrying out a multiple case study are to understand the differences and the similarities between the cases. Conducting a multiple case study, give the possibility to analyze the data both within each case and across the cases. The evidence created from a multiple case study is measured strong and reliable considering several cases have been investigated. Multiple case study allows to go in depth on every project and allow wider exploring of research questions.

2.1.2 RESEARCH FRAMEWORK

In this Section, the research framework is developed and explained. This framework is based on the maturity level of Siebelink et al. (2018) and linked to the approach of Eisenhardt (1989). Eisenhardt's method is based on case study research: multiple cases are used and literature is used to determine the focus of the study. Nevertheless, this method does not rely heavily on literature or preliminary research, which makes it appropriate for studying new fields where little literature is available. Eisenhardt (1989) distinguishes eight steps in her method, which are presented in Figure 1. These steps are placed in logical order and can only be executed consecutively and are needed to achieve the research objective. The steps are described in more detail below.

FIGURE 1. RESEARCH FRAMEWORK

(1) Getting started

This action addresses the start of the research. The BIM Maturity tool of Siebelink et al. (2018) will be used during this research. First the questions for the research must be properly formulated. These questions are formulated in Section 1.3.

(2) Selecting Cases

To find an answer on the research question, data from the case studies is needed. In accordance with the research framework, several cases are used to collect data.

This action aims at determining which projects can be used during the research, in consultation with a large construction company. For this research four projects will be used. The four projects will be derived from three different operating companies of the large construction company. From these three operating companies, projects are selected per company. During the research new cases may become more interesting or other cases might become less interesting. The interesting cases can be added and some can be removed from the planning. Depending on which projects are selected, approximately five important parties will be selected. This will mean that around 20 interviews will be conducted.

(3) Crafting instruments & protocols

The data should be approached in many ways to eliminate a biased view. This can be done by using multiple data collection methods, both qualitative and quantitative data, and by using multiple cases.
During this research the protocol which is going to be used during the interviews is the BIM maturity model. The qualitative data collection will take place with the help of several interviews, through a questionnaire the interviews will be conducted, which is a compressed version of the survey by Siebelink et al. (2018). This interview format is explained in Section 2.3. These interviews will give an answer to the first, second and third research question. The interviews are conducted, but from the perspective of how the project functions.

(4) Entering the field
When the data collection methods are defined, the field can be entered. Before starting the interviews, it is important to be well prepared. It is necessary to delve into the selected project, companies and respondents and to know them well and to know what their activities are within the project. Hereafter through a questionnaire the interviews will be conducted.

(5) Analyzing Data
When the interviews are conducted, the data collected from the interviews are not directly useable for drawing conclusions. During interviews the interviewee already interprets the data, by asking follow-up questions about interesting parts of the answers. After the interviews are conducted and everything has been digitally processed, the results can be analyzed. Firstly, the data will be elaborated in a predefined format and the BIM maturity level of each company within a project will be determined. The level of maturity will be determined based on the answers given by the interview.
Hereafter the analysis of the case data will be carried out in three dimensions: across different parties, within the cases and across the cases. When all maturity levels of different parties are determined, the different parties can be compared with each other. The analysis across parties aims to identify patterns or similarities/differences. It will be used to test whether the supposed causes of a problem are in line with the other parties and whether the designed solution is applicable in other parties as well. The interpretation of the single cases is used to get understanding of the case specific situation. First the case itself will be analyzed, the consequences of possible different maturity levels within the case will be identified. The problem and its consequences will be identified and the possible source will be investigated. When a case has been thoroughly explored, this case can be compared with other analyzed cases. The analysis across cases aims to identify patterns or similarities/differences. It will be used to test whether the supposed causes of a problem are in line with the other cases and whether the designed solution is applicable in other cases as well.

(6) Shaping Hypotheses
The findings of each case are used to define, sharp, or redefine the hypothetical answer on the research question. The findings are tested by the other cases, and the reasons behind the found relationships are examined in latter cases.

(7) Enfolding Literature
The findings will finally be compared to the literature, both conflicting and similar, which sharpens the results and conclusions.

(8) Reaching closure

After the data is analyzed and compared in the three dimensions, the research questions are answered, and conclusions are made, the research should be ended.

These steps are used to answer the research questions in order to reach the research goal. The three dimensions of analyses are used to determine the current state of BIM maturity level of various parties on a project. It also determined what the current state of BIM maturity level of a project as a whole, and what the possible consequence are for the BIM cooperation on project level. This draws conclusions and provides answers to the research questions.

2.2 Overview maturity models

The BIM maturity model describes levels of maturity with regards to the ability of the construction supply chain to operate and exchange information. Dozens of maturity measurement tools are available, several maturity models are discussed below and it is indicated why these are not suitable for project level analysis. The evaluated maturity models are the BIM maturity matrix (Succar, 2009), Penn State BIM assessment (program, 2013), the BIM Quickscan (van Berlo, Dijkmans, Hendriks, Spekkink, & Pel, 2012), the national BIM Standard Capability Maturity Model (NBIMS CMM) (Alliance, 2012) and BIM Maturity Model (Siebelink et al., 2018).

The BIM maturity matrix (Succar, 2009) has been developed in order to measure the BIM maturity level, it defines three BIM fields namely technology, process, and policy. Although this model can be used at sector, corporate and project levels and it can be applied in organizations of different sizes. The different BIM maturity levels are not clearly defined and it also don't cover different phases in the life cycle of a construction work and the parties involved.

Pennsylvania State University published a guideline of key components and steps that facility owners need to integrate in their businesses, which include the BIM assessment profile. It is composed of 6 areas, 20 measures, and 5 maturity levels to evaluate the BIM maturity of facility owners. This model can be partly used at sector, corporate and project levels even as in organizations of different sizes. The five maturity levels are available but could be more defined. The model doesn't cover different phases of life cycle of a construction work and BIM supported cooperation between parties.

BIM Quick scan (van Berlo et al., 2012) consists of almost 50 measures and four main categories :Organization and Management; Mentality and Culture; Information structure and Information flow; Tools and Applications, that are organized in the form of a multiple choice questionnaire. After filling out the complete questionnaire, the results will be received which indicates the level of BIM in their company. Even though the BIM quick scan is a model to measure the BIM maturity level, the focus is business oriented and couldn't be used at project levels also the different BIM maturity levels are not distinctly defined.

The NBIMS CMM is proposed by the national institute of Building Science. The model evaluates BIM implementation in 11 areas using a 10-level scale. This model has only a small number of measures, which are limited to technical aspects. The model could be applied in organizations of different sizes but the model is not suitable for application at project level. Also, the BIM maturity levels are not specific and distinctly defined.

2.3 EVALUATION AND SELECTION

The maturity model was chosen because it is better than the other models. Almost all of the existing maturity models tend to focus on technological characteristics of BIM. These models are not or difficult applicable on project level. Also, collaborative aspects receive little attention in the current tools, complex frameworks are often applied making the results unclear or not transparent, the different maturity levels are poorly defined, insufficient attention is paid to organizational processes and often focused on the evaluation of a specific disciplines (Siebelink et al., 2018). These tools are developed separately, with unique advantages but also specific disadvantages. This makes selecting one of these tools confusing for BIM users (Wu, Xu, Mao, & Li, 2017). Siebelink et al. (2018) developed a BIM maturity model that is able to asses BIM maturity of organizations in the various subsectors of the construction industry. This BIM maturity model is used because the tool can support individual organizations in determining priorities for improving their BIM implementation process. There is more attention for people and culture, aspects of cooperation and strategy and processes. These aspects are important on project level. The maturity levels of the BIM maturity model were specified. A distinction is made between internal and external processes. The description of the five maturity levels used in this model are shown in Table 1 below.

TABLE 1. DEFINTION BIM MATURITY LEVELS. (ADAPTED FROM SIEBELINK ET AL. 2018)

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 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.	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 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 analyze 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.

The structure of the model is divided into six main criteria namely strategy, organizational structure, people and culture, processes and procedures, IT (infrastructure, and data (structure). Most criteria include several sub criteria (Figure 2. Criteria and sub criteria of the BIM maturity model.). The BIM maturity model is visualized as a matrix, the horizontal axis of the matrix consists of the maturity levels and the vertical axis consists of the criteria and sub criteria. The data collection methods are interviews,

the interview is divided in the six main criteria, each main criterion consists of several questions. According to the answers given by the respondent, the level of BIM maturity can be determined, they received scores on 6 main criteria of the maturity model: strategy, organizational structure, people and culture, processes and procedures, IT (infrastructure), and data (structure). The level is determined on the basis of different characteristics of levels. The criteria 'Strategy' is divided in three sub criteria: BIM vision and goals, management support and BIM expertise. The criteria 'Organizational structure' is divided into two sub criteria: tasks and responsibilities and contractual aspects. The criteria 'People and culture' is divided in four sub criteria namely: personal motivation and willingness to change, requesting actor, education and training support and collaborative attitude and transparency. The main criteria 'Processes and procedures' is divided in two sub criteria: procedures and job instructions and process change. The criteria 'IT' is divided in three sub criteria: hardware, software and BIM facilities. The criteria 'Data' is divided in four sub criteria: information structure, object structure, object libraries and data exchange. The four selected cases are discussed on these criteria in Chapter 3.

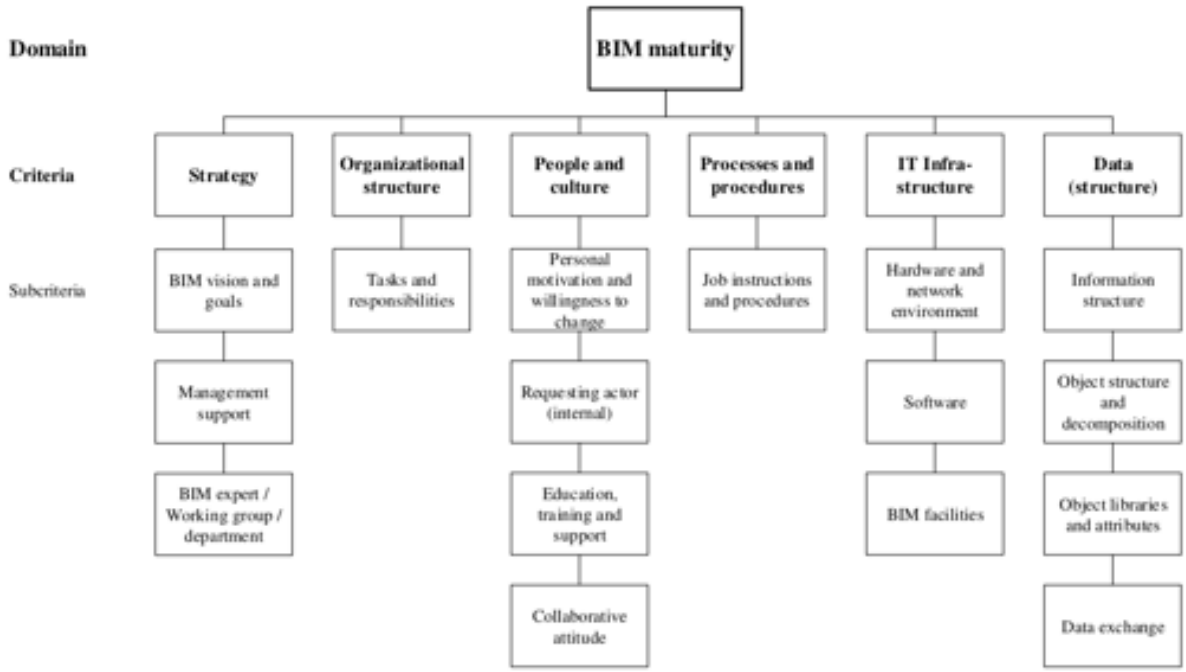


FIGURE 2. CRITERIA AND SUBCRITERIA OF THE BIM MATURITY MODEL (ADAPTED FROM SIEBELINK ET AL. 2018)

3. RESULTS CASES

This Chapter is dedicated to the results of this study. This Chapter deals with step 5 (analyzing data) of the Eisenhardt framework as mentioned in Section 2.1.3 research framework. First the results of the four cases are described and discussed in Section 3.1, 3.2, 3.3 and 3.4. The results for these cases are then compared in Section 3.5. The four projects are derived from three different operating companies of the large construction company. From each project there are important parties selected to interview, which resulted in a total of 22 interviews.

3.1 CASE 1 PROJECT A.

Project A is an office development (6500m2) in the heart of the European quarter in Brussel (Belgium), surrounded by all major European institutions and is executed by the large construction company. This project contains 10 levels with workplaces. The location is on one of the most important central roads in Brussel (see picture below). This project is about to move towards the executive phase. The parties involved work from their own office during the preparation (the design phase). This has been a long process which has now been going on for two years, because they had problems with permits. A coordinated design will be released soon where after the contractor can make a price for the client. The interviews with the various parties were conducted during the design phase.

Four different dominant parties have been chosen to conduct an interview for this case (Appendix A). The four parties chosen are: the architect, engineering firm for stability, client and the contractor himself.

The results for the BIM maturity level per party for this project are depicted in Figures 3-6 and the overall result of the project in Figure 7. These show the scores in graphical manner on the 6 main criteria and the sub criteria on project level. Below the results of the parties will be discussed per criteria.

(1) Strategy

The scores on BIM vision and goals differ per party, but they all scored relatively low. The client and contractor indicate that the goals and vision have been formulated, but they are obsolete because they were drawn up two years ago. They also indicate that the vision and goals must be adapted to the current goals. The initial vision was to coordinate the works and reduce failure costs by using BIM, but nowadays they want to have quantity take offs and use all the information they have so it becomes an

all in one model for maintenance. The architect and engineering firm indicates that they do not know whether any BIM goals and visions have been formulated. The engineering firm thinks this is a pilot project for the contractor, and therefore no goals have been formulated. He thinks this project is meant to see what is possible and what BIM will give.

Also scored all parties differently on the support of the management. The client and contractor indicate that the project is well supported by management, specific people have been assigned to support everyone and to teach programs. The architect and engineering firm indicate that too little attention has been paid to BIM, so it is important that management supports BIM and that this is not the case right now. In terms of BIM expertise, there is almost a clear consensus, all parties indicate that a BIM expert is present who looks at optimizing processes and who supervises this project which is part of the function. It is indicated that the person does not have enough time and capacity for this, because the process and project are not running smoothly, however the client indicates that the capacity and time is sufficient and could not complain about it.

(2) Organizational structure

The tasks and responsibilities are scored differently by the four different parties. The client indicates that tasks and responsibilities regarding BIM are formalized in job profiles and role descriptions, but this is also done two years ago because of this they have deviated from it because there is a turnover of people. All these agreements are recorded in Bricsys. The contractor, architect and engineering firm didn't know whether this is documented or formulized and if it is documented they do not know anything about it, for this reason they scored low on this aspect. In terms of the contractual aspects, the client indicates that there are agreements about what information is provided when and how. They have one week for the clashes and thereafter two weeks to adjust the model. The contractor, architect and engineering firm indicate that BIM is not explicitly included in contracts, protocols or formalized in agreements. They will exchange the models if requested, so no agreements for when to provide what information, and therefore scored low on this aspect.

(3) People and culture

There is a clear overall consensus on the aspect personal motivation, the contractor, architect, client and engineering firm all experience resistance and notice that the motivation depends on individual project members, they all scored low on this aspect. Some project members are demotivated to such an extent that they did not want to adapt the working method. This is due to insufficient knowledge and too little experience, as a result of which the modeler's appointments are not observed and extra work emerges. In terms of requesting actor the four parties score low because for this project no BIM champion is present. For the sub criteria education and training support, the parties all scored different. The architect and engineering firm indicate that there is no education or specific training for BIM available, where the contractor and client agree that it is offered at individual request, if there are specific questions there is someone who supports them.

In terms of collaborative attitude, openness and transparency the BIM maturity results of the parties are different. The architect and engineering firm indicate that the project organization is a collection of individual parties and not a collaborative whole, because everyone works for themselves. The client and contractor are trying to integrate the collaboration, and they form building teams. It is now more of a whole because they are now accelerating again. That influences trust and transparency, a year ago everyone works for themselves, confidence was less present and the processes went less smoothly, which

has been improved. The parties therefore individually have a different view of this aspect, as a result of which they differ in maturity level on this aspect.

(4) Processes and procedures

The first sub criteria, the procedures and job descriptions are scored differently by the parties. The architect indicates that no procedures or work instructions for the use of BIM are documented. The engineering firm and contractor indicate BIM processes are limited laid down in procedures or work instruction. They try to follow the ISO procedures but they are not enforceable, because these instructions were not there before. The client indicates that work instructions and/or procedures have been established for important uses of BIM. The instructions are about everything and are very broad, modeling, exporting, clashes, names, who has which roles and which platforms they have to use. These instructions are certainly used on the project. The parties therefore individually have a different view of this aspect, as a result of which they differ in maturity level on this aspect. They also differ on the aspect process change, the contractor and engineering firm scored very low because BIM is considered to be a tool for specific activities like improving the design but does not lead to fundamental process change. The client and architect agreed that BIM is a driving force for process improvement throughout the project, and process changes are well shared with other parties, resulting from now using quantity take offs.

(5) It (infrastructure)

The four parties scored equal on hardware and BIM facilities, because there is not a joint project location where the parties work together but work individually in their own office, therefor all parties score low on hardware and BIM facilities. They also score the same on the sub criteria software, because everyone is satisfied with the software and the cooperation with other parties, including the exchange of information, is well facilitated by the available software. Agreements have been made about which software to use, which version and whether the exchange is in IFC.

(6) Data (structure)

In terms of information structure, the parties scored all low on this aspect except the client. This discipline indicate that project data are made accessible to other parties within this project by using Bricsys and is a standard procedure on this project, it is also used consistently. They do notice that sometimes it gets too much, and there must be someone who is liable, the BIM manager only manage this. For this project the documents are not directly linked in the BIM environment. The contractor, architect and engineering firm scored equal on this aspect, they indicate that they use Bricsys but are not used consistently, data is still sent by email. There is resistance because they send the model by email because it is not seen as their job to upload the model on Bricsys, therefor these three parties score low on this aspect. The object structure and decomposition are scored differently, the client and contractor agree that there is an object structure for this project and is aligned with other parties the same for the coding agreements, where the architect and engineering firm indicate that it is not present and there is no agreement about coding and therefor the parties differ in level on this aspect. For the object libraries the client, contractor, architect and engineering firm scored equal because within the project different unaligned object libraries are used, there is no uniform approach and naming is inconsistent. There is also a clear consensus about the sub criteria data exchange, the data exchange with other parties is well-defined and according to the project standard, exchange of BIM data take place via open standards, e.g. IFC. The data exchange take place on Bricsys as indicated earlier, the engineering firm does not adhere to this and send it by email.

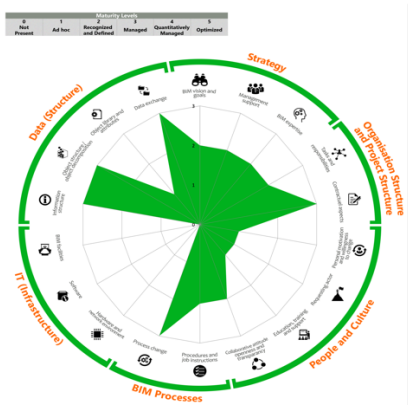


FIGURE 3- CLIENT

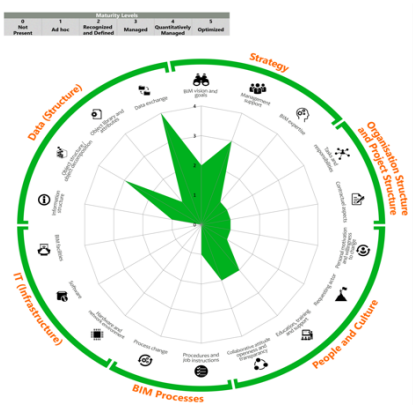


FIGURE 4- CONTRACTOR

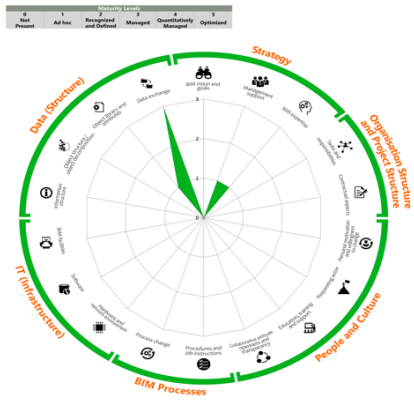


FIGURE 5- ARCHITECT

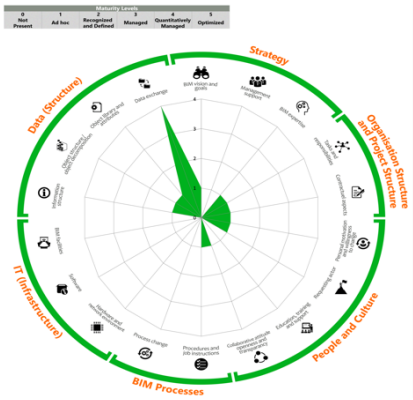


FIGURE 6- ENGINEERING FIRM FOR STABILITY

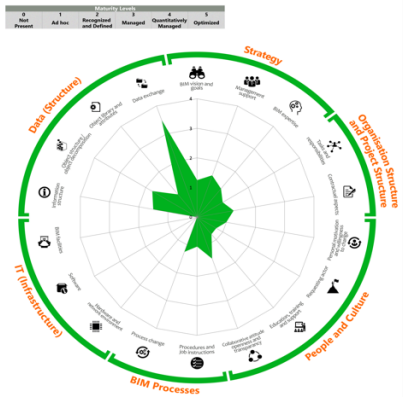


FIGURE 7- PROJECT OVERALL PROJECT A

RADAR CHARTS

As the radar diagrams show, the client and contractor score relatively higher than the architect and engineering firm for stability on this project. The contractor and client were both the most informative interviews. These two parties work closely together, the client is partly part of the construction firm, but they are separate business units. This explains why these two parties scored higher than the architect and engineering firm for stability. This also explains why the contractor and client scored high on management support, these two parties have significantly more insights in this aspect, and the architect and engineering firm for stability not. The architect and engineering firm for stability couldn't give much information, such as how certain matters were arranged, whether any contractual arrangements have been made on the project because they were not informed about it. The interviewee was unaware of all of this. Even if the contractual arrangements not being shared with the parties, the agreements about

data exchange are clear to them and discussed. This is also reflected in the radar diagram, and regardless of whether two parties generally score higher than the other two, they all score the same on data exchange. Here it also appears that the agreements are clear to everyone how and when data should be exchanged.

Notwithstanding the contractor and client had a high score, they were also very critical about the progress of the project. They are both not satisfied with the collaboration because it is a longer-term project. They notice little cooperation from the designers, because it has already been completed for them, which is a difficult relationship. Also, not everyone adheres to the working method and the agreements, because they started without BIM. The architect and engineering firm for stability also indicate that cooperation on this project can be improved and are not satisfied with it.

PROJECT AS A WHOLE

By going through all criteria, it has been determined what the BIM maturity level of the project really is (Figure 8). This was done by studying the documentation etc., the complete data set has been considered for determining the maturity level on the project as a whole.

(1) Strategy

For this project an implementation plan has been created, however no BIM vision and goals have been formulated here, so its level 0 on the criteria BIM vision and goals. The architect and engineering firm scored the same on this aspect. However, the client and contractor scored higher, they indicate that the goals and vision have been formulated in the implementation plan. But when examining and studying the documentation, this turns out to be incorrect. This may have been discussed orally and has not been documented. Because opinions differ about management support, it is clear that it is limited and/or unstructured support from top management, so its level 1. The architect and engineering firm scored the same on this aspect. But the client and contractor indicate the project is well supported by management, these two parties have a different view because they probably have more overview of the financial support. The BIM expert is described in the implementation plan, along with a description of his function and duties. His task is to steer the overarching BIM process in the right direction and to assist the project partners so, its level 1 on the criteria BIM expertise because it appears this person don't have enough capacity and time for BIM guidance. The client scored higher and stated the capacity and time is sufficient, as a researcher this impression is not received because it has been repeatedly stated that there is too little capacity and time for it.

(2) Organizational structure

In the implementation plan, tasks and responsibilities with regard to BIM have been integrated in regular function descriptions to limited extent so, its level 2 on tasks and responsibilities. The client scored the same except for the contractor, architect and engineering firm they scored lower on this aspect. They didn't know whether this is documented or formulized, so it can be concluded that these parties have either not read the implementation plan properly or have not received it. BIM related agreements are laid down specifically and measurably in the implementation plan, and clarity about what information is provided when and how is described so, its level 4 on contractual aspects. The client scores the same on this aspect as well, and the contractor, architect and engineering firm scored lower and indicate that there are no agreements for when to provide what information, and therefore scored low on this aspect. Also, here it can be concluded that these parties have either not read the implementation plan properly

or have not received the implementation plan and therefor score low on this aspect. Because during the study of the documentation it emerged that these agreements have been formulized and documented.

(3) People and culture

Because personal drivers within project teams determine if and to what extend BIM can be applied on the project, this project scored level 1 on personal motivation and willingness to change. All parties scored level 1 on this aspect, they experience sometime resistance and notice that the motivation depends on individual project members. A BIM champion who functions as a driver of the implementation process by steering and stimulating others is present as can been seen in the implementation plan. Because of limited capacity, the BIM champion is hindered to push harder for BIM so, its level 2 on the criteria requesting actor. The parties scored lower on this aspect because they don't experience someone has this task on the project however, the documentation shows that it is present. Education and training for BIM is unstructured and ad hoc; it is offered at individual request and therefore the project scores level 1 on this aspect. The architect and engineering firm indicate that there is no education or specific training for BIM available and therefore scored lower. Where the contractor and client agree that it is offered at individual request, and scored also 1 on this aspect.

Only basic processes are defined to foster collaboration with other parties, a lack of openness and transparency hinders joint activities so, its level 2 on collaborative attitude, openness and transparency. The parties all have different perceptions of this aspect, the architect and engineering firm scored lower and agreed that everyone works for themselves, whereas the client and contractor agreed on it functioned as a whole and therefore scored also level 2 on this aspect.

(4) Processes and procedures

In the implementation plan, work instructions and procedures have been established for important uses of BIM, it is not very detailed so it is level 2. The client scored the same, for the architect it is not clear whether any procedures or work instructions for the use of BIM are documented and therefore scored lower. The engineering firm and contractor also scored lower because it is not clear for them. They are not sufficiently informed about this and therefore score lower. However, this is all formulated in the implementation plan, and scored the project as a whole higher on this aspect. Because the extent to which BIM is a driving force for change and improvement of processes is highly depended on individual skill and motivation, the level of the sub-criteria process change is level 1. The client and architect scored higher because they see BIM as a driving force for process improvement throughout the project. And the contractor and engineering firm scored lower, they consider BIM to be a tool for specific activities like improving the design. Because BIM is seen differently on this project, the project as a whole scored therefore 1, it is depended on individual skill and motivation.

(5) It (infrastructure)

This project has no joint project location and therefore no joint hardware and network environment, this project as a whole scored level 0 on hardware and network environment and BIM facilities. All parties have also achieved this score on both aspects. The cooperation with other parties, including the exchange of information, is well facilitated by the available software, so its level 3 on software. All parties also indicate that in the aspect of software the cooperation with other parties, including the exchange of information, is well facilitated by the available software.

(6) Data (structure)

The Bricsys platform is used 24/7 in this project. This platform is managed by the contractor who is responsible for setting up, configuring and making available access to the central data environment for other project partners. For the information structure its level 3. The client scored the same on this aspect, but the contractor, architect and engineering firm score lower on this aspect because according to them the structured storage is limited. Also, the method for the object structure and decomposition is aligned with the parties on project level and described in the implementation plan. On this aspect the project's level is 3. The client and contractor scored the same as the project as a whole, but the architect and engineering firm scored lower because they indicate there are no agreements about coding and object structure. The implementation plan shows that it is present, so the parties which score low on this aspect are not properly informed. Within the project different unaligned object libraries are used and no uniform approach, the project as a whole scored low and its level 1. The perception of the parties does not deviate from this and they all have the same level as the project as a whole.
The data exchange with other parties is according to the organizational standard, exchange of BIM data takes place via open standards, e.g. IFC and therefore its level 4. In this aspect too, the perception of the parties is the same as the project as a whole, and the level here is also the same.

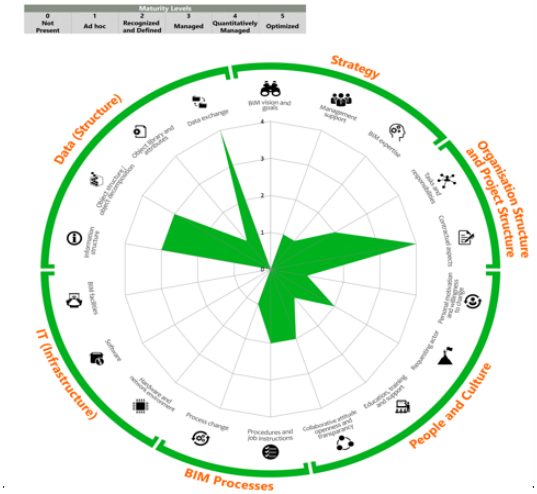
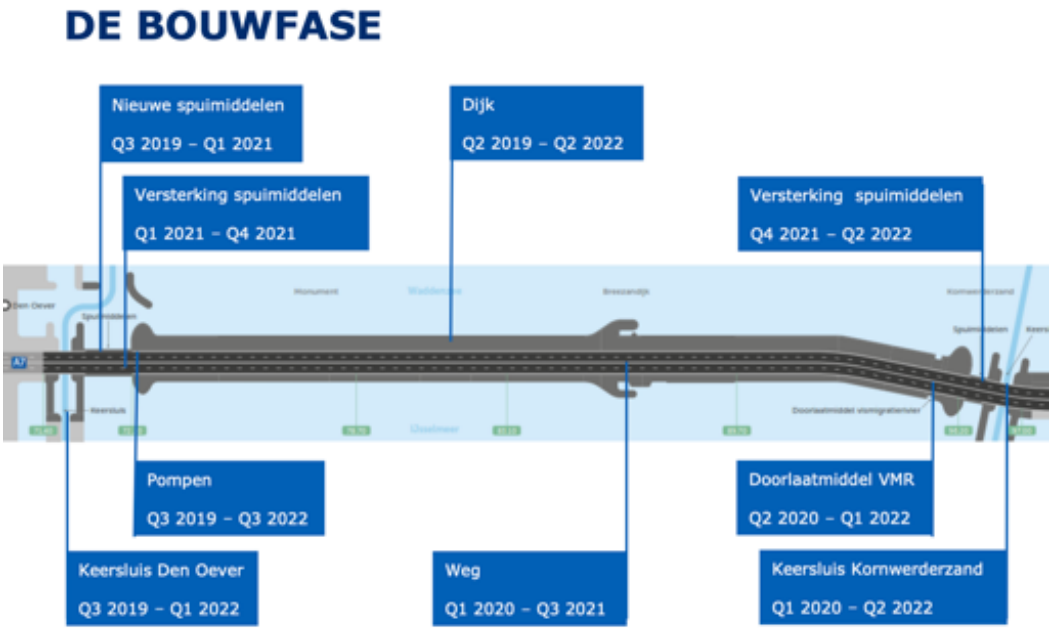


FIGURE 8- PROJECT A

3.2 Case 2 Project B

This project has been awarded to the project B consortium. This joint venture is formed by a couple of firms and will be responsible for design, build, finance and 25 years maintenance of the project. Construction works has been started in the autumn of 2018. In 2023, the project will be completed. The activities will be: 32 km protective top layer against overtopping water, strengthening the locks, construction of new storm surge barriers and installation of large pumps.
The project has been started in April 2018, from 2019 to 2022 the project is in the executive phase, the project will be completed by the end of 2022, the management and maintenance period will end at the end of 2047. The interviews with the various parties were conducted during the executive phase.



Five different dominant parties have been chosen to conduct an interview for this case (Appendix B). The five parties chosen are: two engineering firms, two project partners and the contractor himself.
The results for the BIM maturity level per party for this project are depicted in Figures 9-13 and the overall result of the project in Figure 14. These show the scores in graphical manner on the 6 main criteria and the sub criteria on project level. Below the results of the parties will be discussed per criteria.

(1) Strategy

The scores on BIM vision and goals didn't differ that much, for the engineering firm (two), it is not clear whether any goals or visions have been established and therefor scored low on this aspect. It is clear to the other parties that there are BIM goals, these have been established in the "BIM plan van aanpak". The goals for this project are formulated as follows: higher quality, reduction of failure costs, better cooperation, significant reduction of the total lead time and transparency of information. These four parties score all high on this aspect. There is a clear overall consensus on the aspect of management support, the parties scored all high on this aspect. In terms of management support, all parties indicate that BIM is well supported by the management of the project. BIM coordinators and directors are appointed to support BIM, there are sufficient budgets for this support, follow-up actions are also taken if certain aspects didn't go well. The parties differ a bit on the aspect BIM expertise, they all indicate that a BIM expert is present, and agreed that this BIM expert has sufficient capacity and time to help where necessary. However, the project partner (1) has insufficient view to say whether this BIM expert has sufficient capacity and time to fulfill his role. Therefore, this party has a slightly lower score than the other parties.

(2) Organizational structure

The tasks and responsibilities are formalized in job and role descriptions in the "BIM plan van aanpak". The BIM action plan describes the project roles and the responsibilities of a role. There is also a folder structure created per role description. All parties know about this role descriptions and therefore score high on this aspect, except for the engineering firm (2) who scored low because he does not know anything about the documentation of these tasks and responsibilities. In terms of contractual aspects, the BIM related agreements are laid down in the "BIM plan van aanpak", which have been coordinated. Gradually more and more agreements are made. There is also clarity about what information is provided when and how, this is also laid down in the "BIM plan van aanpak". For subcontractors, this is shortened on how they want to achieve files and is part of their contract. Therefore, they all scored equal on contractual aspects.

(3) People and culture

The personal motivation and willingness to change are score equal on this project, all parties generally experience sufficient motivation within the project. They notice, the people working with BIM push as hard as possible. They also all agreed that a number of people are still traditional, especially the older generation, because it is hard for them to switch from 2D to BIM because learning the new software is harder for them. They also scored all the same on requesting actor, they all agreed that the BIM champions are successful in getting BIM to a higher level, they also push/stimulate the use of BIM360 and provides training and people with questions can come along. These BIM champions come from different parties, from the large construction company and another firm which are linked to the different teams. In terms of education and training, these are offered to people who work within this project. In various aspects training and supervision takes place on this project; environment platform, use of

BIM360, getting quantities from models, synchro, it is all project related. Everyone is familiar with these training and education and therefore all score the same on this aspect. Because of project related focus on collaboration, BIM related processes are successfully aligned with partners. In terms of collaborative attitude, in this project they work with four large teams, which is also considered as four separate teams, but within the team everyone works as a whole. Everyone has almost the same view within this project and therefore score the same.

(4) Processes and procedures

The five parties scored all the same on procedures and job descriptions, they all indicate that these have been laid down in the "BIM plan van aanpak", such as a Revit work instruction, PMI standard process. These have been drawn up and are flexible and are continuously adjusted if there is a better way. Everyone indicates that this is actually used in practice, although the engineering firm (2) deviates from this and indicates it is not always applied when there is time pressure, for this their score is lower on this aspect. In terms of process change, the parties score differently. For the contractor BIM is considered to be a tool for specific activities, but does not lead to fundamental process change. The engineering firms (both) agreed on the extent to which BIM is a driving force for change and improvement of processes is highly dependent on individual skill and motivation. For the project partners (both) BIM is seen as a driving force for process improvement throughout the whole project organization. They all have a different view of the process change and therefore all score differently on this aspect.

(5) IT (infrastructure)

Hardware and network environment are scored equal by the disciplines. All parties agreed that quality of the network environment on project location allows cloud-based working on a building model by multiple parties. Therefore, all parties scored equal on this aspect and is here a clear overall consensus. The cooperation with other parties, including the exchange of information, is well facilitated by the available software. Agreements are made about which software to use within this project and which versions, all these agreements are laid down in the "BIM plan van aanpak". Almost all parties scored the same at the sub criteria software except for one party, the project partner (one) indicates the software support the required current BIM use to a limited extend. The exchange is sometimes difficult in Revit, which causes obstruction. He does indicate that agreements have been made about the software and which type. Therefore, this party scores slightly lower than the others. There is a clear overall consensus on BIM facilities and therefore all parties score the same, there is enough capacity of spaces that are well equipped to accommodate meetings and coordination session with BIM.

(6) Data (structure)

The five parties have a clear overall consensus on all four sub criteria and score therefore all the same. Project data are made accessible to other parties within the project by providing rights to read, add or change data. For this project, a number of DMS systems are used, namely shared published, BIM 360, Volt and think project. There is someone present who manages these platforms and carry the responsibility, a document inspector is also present therefor they score equal on the information structure. In terms of object structure and decomposition, there are agreements about coding. Also, there is a decomposition list within Relatix, which contains a complete structure of the project, where the individual elements are coded underneath. This structure is used throughout the project. Also, object libraries are set up in a structured way and the naming of objects and data is consistent. The NLSB structure has been applied by the large construction company to create a library specifically for Revit.

These are managed at project level and are now distributed and shared via BIM 360. The last sub criteria data exchange is also scored equal, all parties agreed that data exchange with other parties is well defined in the "BIM plan van aanpak" and shared via BIM360.

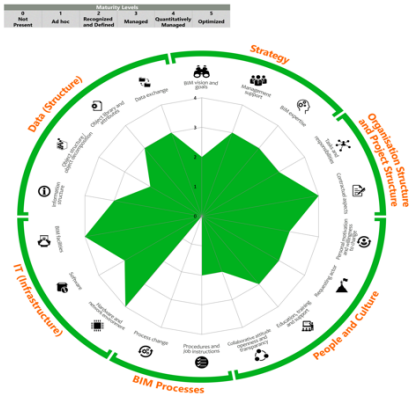


FIGURE 9- CONTRACTOR

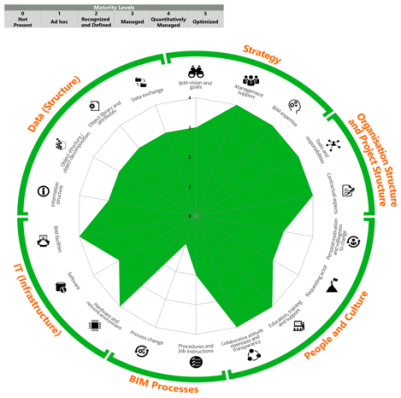


FIGURE 10- ENGINEERING FIRM

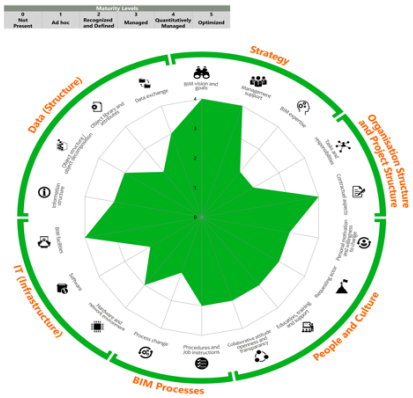


FIGURE 11- PROJECT PARTNES

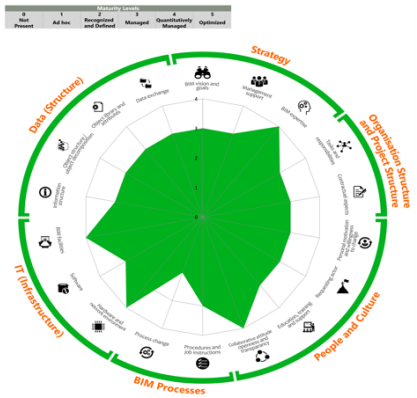


FIGURE 12- PROJECT PARTNER

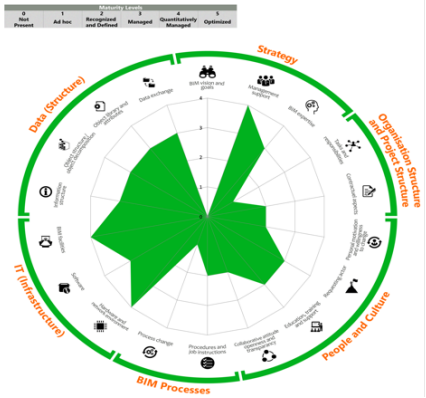


FIGURE 13- ENGINEERING FIRM

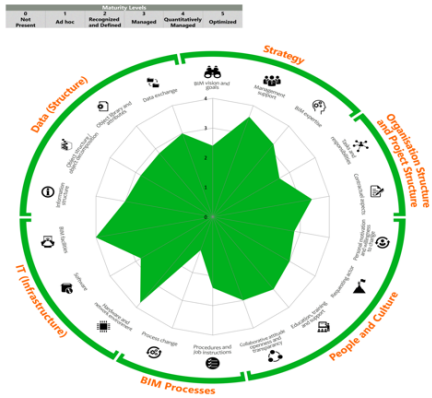


FIGURE 14- PROJECT OVERALL PROJECT B

RADAR CHARTS

The radar diagram clearly indicates that this project scores high at maturity level. All parties score high and no one scores significantly lower on the project as a whole. Although everyone scores high, there are deviations on some dimensions where the maturity level is very poor, which is reflected in the notch at process change. For the contractor and engineering firm, BIM is considered to be a tool for specific activities, but does not lead to fundamental process change. Where BIM is also seen as a driving force for process improvement throughout the whole project organization for the other parties.

Also striking in the radar diagram is that the engineering firm scores low on the BIM vision and goals in relation to the other parties. This may be due to the fact that this person has not been working on this project for a long time, and is therefore not yet properly integrated. Another explanation may be because they are not all on the same team or division of this project, it is possible that this party therefore scores lower on this aspect. The project is in fact divided into several teams / division per part of the project. The engineering firm is part of the flood barrier Coenwederzand and the other parties are on new blowing agents.

On the project, cooperation is perceived as positive by everyone, especially among the parties that belong to the inner skin of the project. The hired parties / freelancers experience a lot of diversity in the field of BIM maturity, which sometimes makes it difficult to work together. It is also stated that freelancers are difficult to manage and still searching how to work with BIM, which requires coordination. In general, the cooperation is perceived as positive and the parties works together as one project organization. Cooperation is also fostering on this project because they often work on one project location.

PROJECT AS A WHOLE

By going through all criteria, it has been determined what the BIM maturity level of the project really is (Figure 15). This was done by studying the documentation etc., the complete data set has been considered for determining the maturity level on the project as a whole.

(1) Strategy

There is an "plan van aanpak" with clear descriptions of goals and vision. These objectives are formulated as follows: The use of BIM aims to: Higher quality; Reduction of failure costs; Better cooperation; Significant reduction of the total lead time; and Transparency of information. So, the project as a whole score level 3 on this aspect. There is one party which is not aware of these objectives and therefore scores lower in this aspect, for the engineering firm it is not clear whether any goal or visions have been established. This project is well supported by the management, BIM coordinators and directors are appointed to support BIM and also sufficient budget are allocated. This project scored therefore level 4 on this aspect. This is in line with the perception of the parties who score the same on this aspect.
In the "BIM plan van aanpak" is formulated that people who can support implementation of BIM is present. During the interviews it became clear that this person has appropriate and dedicated time for this support and therefore the project as a whole scored level 3 on this aspect. The project partner has insufficient view to say whether this BIM expert has sufficient capacity and therefor scored lower on this aspect.

(2) Organizational structure

The tasks and responsibilities are formalized in job and role descriptions in the "BIM plan van aanpak". The "BIM plan van aanpak" describes the project roles and the responsibilities of a role. There is also a folder structure created per role description so its level 3 on this aspect. The engineering firm scored lower because he does not know anything about the documentation of these tasks and responsibilities. Also, BIM related agreements are laid down in the "BIM plan van aanpak", there is clarity about what information is provided when and how so, its level 4 on the criteria contractual aspects. The perception of the parties does not deviate from this and scores the same on this.

(3) People and culture

Within the project, because of the enthusiasm to work with BIM, there is an increasing willingness to change the way of working for the benefit of BIM and therefore the project as a whole scored level 3. This is also consistent with the perception of the parties, which scored also level 3 on this aspect.
The BIM champions described in the "BIM plan van aanpak" are successful in getting BIM to a higher level and all have enough capacity and time to fulfill their role so, its level 3. The parties all have the same perception on this aspect and also score the same here. In terms of education and training, these are offered to people who work within this project and all laid down in the "BIM plan van aanpak". The project as a whole scored level 3 on the criteria education, training and support, the perception of the parties is the same. Looking at the complete data set of this project, it emerges that the focus is on collaboration. Because of project related focus on collaboration, BIM related processes are successfully aligned with partners so, its level 3 for the project as a whole. This is also reflected in all perceptions of the parties.

(4) Processes and procedures

For this project work instructions have been established for important uses of BIM and are laid down in the "BIM plan van aanpak", such as Revit work instruction, BIM 360 work instruction and PMI standard processes. So, its level 3, the perception of the parties does not differ from this except for one party and indicate it is not always applied when there is time pressure and scored lower on this aspect. In terms of process change, the extent to which BIM is a driving force for change and improvement is depended on individual skill and motivation so, its level 1. The engineering firms scored the same on this aspect. For the project partners (both) BIM is seen as a driving force for process improvement throughout the whole project organization and scored higher. And for the contractor BIM is considered to be a tool for specific activities, but does not lead to fundamental process change and scored therefore lower. They all have a different perception of how BIM is considered.

(5) IT (infrastructure)

For this project, the quality of the network environment allows cloud-based working on a building model by multiple parties and scored therefore level 4 on this aspect. All parties have the same perception and scored equal on this. Also, the cooperation with other parties including the exchange of information, is well facilitated by the available software. What is agreed by the parties, the score of both the perception of the parties and the project as a whole is therefore 3. In terms of BIM facilities, the project as a whole scored the same as the perceptions of the parties. There is enough capacity of spaces that are well-equipped to accommodate meetings and coordination sessions with BIM so, its level 4.

(6) Data (structure)

Project data are made accessible to other parties within the project by providing rights to read, add or change data. For this project, a number of DMS systems are used, namely shared published, BIM 360, Volt and think project so, its level 3 on the criteria information structure. The perception of the parties is the same. In terms of object structure and decomposition, the project as a whole scored level 3. There are clear agreements about coding and a decomposition list is present and is used throughout the whole project. Also, here the parties scored the same and have the same perception on this aspect.
For this project, object libraries are set up in a structured way and the naming of objects and data is consistent. The NLSB structure has been applied by the large construction company to create a library specifically for Revit and therefore the level is 3 for the project as a whole as for the individual parties.

Data exchange with other parties is well defined in the "BIM plan van aanpak" and supports working based on models of other parties so, its level 3. The scores of the parties do not deviate here either.

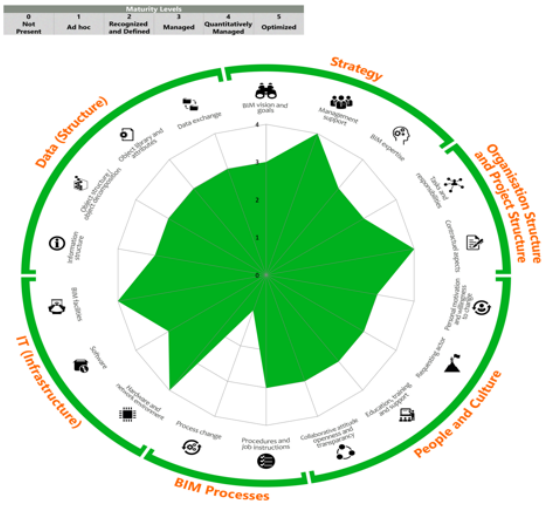
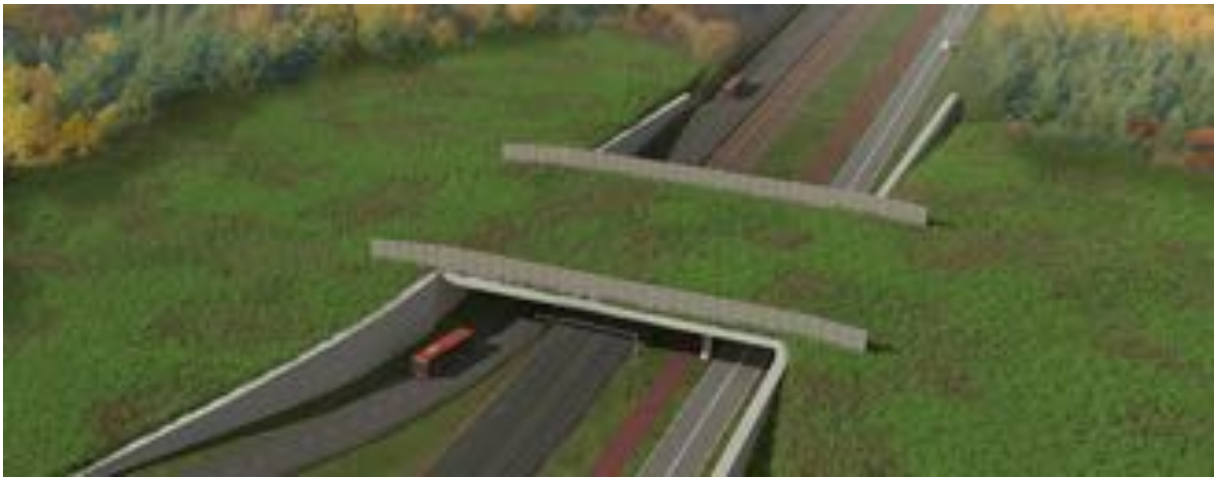


FIGURE 15- PROJECT B

3.3 CASE 3 PROJECT C

This project is a joint project of different municipalities, the project is the construction of a 3 km long bus lane along the track with artworks: a natural bridge, ecoduct and fly over. The plan for fitting in a bus lane became irrevocable in October 2017. In June 2019, the large construction company was contracted to construct a free bus lane, a nature bridge and a railway. The main contractor is the large construction company and indicates according to the planning, the road will be accessible for fast traffic again in August 2021. The interviews with the various parties were conducted during the executive phase.



Six different dominant parties have been chosen to conduct an interview for this case (Appendix C). The five parties chosen are: Engineering firm for concrete, concrete supplier, engineering consultancy firm, architectural firm, project leader, and the contractor himself.
The results for the BIM maturity level per party for this project are depicted in Figures 16-21 and the overall result of the project in Figure 22. These show the scores in graphical manner on the 6 main criteria and the sub criteria on project level. Below the results of the parties will be discussed per criteria.

(1) Strategy

The scores on BIM vision and goals differ per party, but they all scored relatively low except for the contractor which scored high on this aspect. This party indicates that all main goals are described in the "BIM plan van aanpak". The most important goal is to limit the failure costs. The applications that are used for this are also specifically mentioned in this document, these are coordinated with the other parties however, these are not always read. The engineering firm for concrete, engineering consultancy firm and the project leader indicate that this is described in the "BIM plan van aanpak", for them it is not clear what the ultimate goal should be. The architectural firm and concrete supplier indicate that no vision or goals for BIM are formulated.
Five parties scored relatively the same on the support of the management. The concrete supplier deviates extremely, and scored low on this aspect. This party indicates that no resources are released, the project is the same as for projects where no BIM is used and they do not notice the construction firm is extra committed to BIM. The engineering firm for concrete, engineering consultancy firm, architectural firm, project leader, and the contractor agree that it is fully supported by the management, and scored higher on this aspect. There is a BIM manager on this project and support from autodesk, they work with applications which are set up for BIM, so there is sufficient and appropriate budget. They do notice when deadlines arrived, sometimes BIM will be left behind for a while because the production is more important, this means that BIM is not a top priority. The aspect of BIM expertise differs a bit, the

engineering firm for concrete, engineering consultancy firm, project leader, and the contractor indicate there is structured support for BIM by experts and have appropriate and dedicated time for BIM guidance. For this project there are two BIM manager, who master the coordination model. However, they indicate that there should be more control over the models. The concrete supplier and architectural firm indicate there is no BIM expert on this project and therefor score low on this aspect.

(2) Organizational structure

On the tasks and responsibilities aspect all parties scored different, the project leader and the contractor agreed that these are sufficiently formalized in job profiles and role descriptions. This is noted in the "BIM plan van aanpak", which is specifically aimed at the design team, the modelers and design leaders are described here. The engineering consultancy firm and engineering firm for concrete indicate that there is information about it in the "BIM plan van aanpak", but this it is not clear for all parties. The concrete supplier and architectural firm indicate that tasks and responsibilities regarding BIM are not formalized. In terms of contractual aspects, the parties also differ. The concrete supplier, project leader and architectural firm agreed that BIM is not explicitly included in contracts, protocols or formalized in agreements. The engineering consultancy firm, engineering firm for concrete and the contractor indicate that this is formalized with some of the parties for example how they should cooperate and how they should exchange files. There are also parties that are less involved in this, they have a more limited role in this. This has been laid down in a contract with the parties to the design process, for this reason the parties scored differently on this aspect.

(3) People and culture

The first aspect personal motivation and willingness to change is scored almost equally, five parties agreed that there is a project wide motivation to work with BIM. They indicate that on this project everyone is positive/ enthusiastic and the benefits are seen. The concrete supplier indicates that he sees no resistance or motivation for BIM on this project, it is not really known exactly what BIM is. A BIM champion who functions as a driver of the implementation process by steering and stimulating other is not present on this project, therefor they score low on requesting actor. The architectural firm indicates that he thinks someone has these tasks, but he is not sure. In terms of education and training support, they all score low because no education or specific training for BIM is available, education is given internally but not specifically for this project. They also score equally high on collaborative attitude and transparency, because collaboration is part of the project strategy and mutual trust between partners is growing, openness and transparency is increasing.

(4) Processes and procedures

On the first aspect procedures and job descriptions the parties scored different, four parties scored higher than the other two parties. The engineering consultancy firm, engineering firm for concrete, the contractor and project leader indicated that work instructions and procedures have been established for important uses of BIM and laid down in the "BIM plan van aanpak". However, there is variation in whether they actually apply it to the project. The architectural firm and concrete supplier scored lower on this aspect because they agreed procedures or work instructions are not documented. The second aspect is process change, here the parties scored all equal and BIM is considered to be a tool for specific activities but does not lead to fundamental process change. They indicate that the processes are still traditionally structured. The engineering firm for concrete disagrees and considers BIM to be a driving force for

process improvement, because it is clear to everyone in which process phase the project is at that moment. Therefore, this party scored a bit higher on this aspect.

(5) IT (infrastructure)

On the IT criteria, the parties score almost equal, there are a few inequalities. There is a project location in Hilversum, and all resources are available there to view the model. It supports the desired from BIM and the network environment is good. The concrete supplier works from its own location, and therefore cannot give its opinion here and differ a bit on the aspect hardware and network environment. In terms of BIM facilities everyone scores the same there are project rooms available to support BIM use but it is approaching its maximum, if parties want to plan something in between, the spaces are usually full. The facilities are not technically sufficient, if you arrive on time, you have a place with a screen or else in the back with your own laptop. The interior of the smart screens could have been better equipped. Everyone agreed that the available software supports the intended future use of BIM and scored the same on the sub criteria software. In the "BIM plan van aanpak", agreements have been made about which software is used and in which versions.

(6) Data (structure)

Except for the concrete supplier they all scored equal on information structure. Project data are made accessible to other parties within the project by providing rights to read, add or change data. They use BIM 360 and is used consistently; the models are checked for actuality and agreements have been made about this. Tink project and teams are also used for the working environment. The concrete supplier does not use these systems and send the models via mail or we transfer and therefore score low on this aspect. The object structure and decomposition are aligned with other parties on project level. Here too the concrete supplier indicates that these are not present, as well as agreements for coding and scored low again on this aspect. The scores on object libraries are equal by all parties. Within this project different unaligned object libraries are used, there is no uniform approach and naming is inconsistent. In terms of data exchange these are almost scored equal, the data exchange with other parties is well defined and is mainly limited to internal teams. The supplier of concrete scores low on this aspect because the exchange of data is not via or from the building model but via email or we transfer.

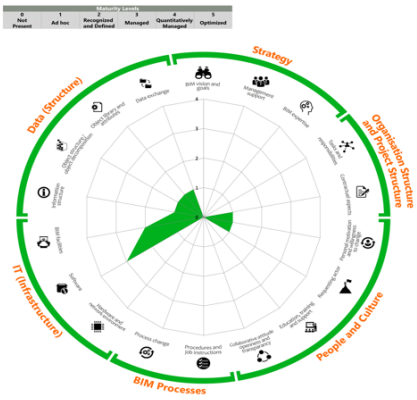


FIGURE 16- CONCRETE SUPPLIER

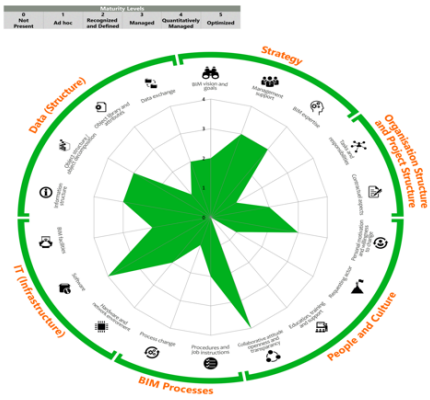


FIGURE 17- ENGINEERING CONSULTANCY

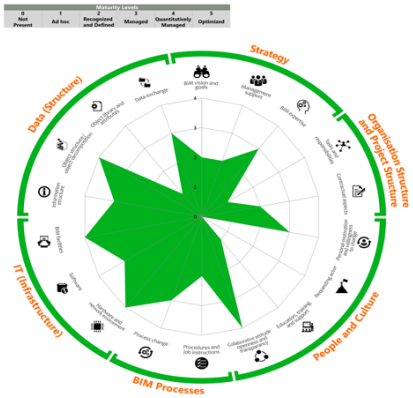


FIGURE 18- ENGINEERING FIRM FOR CONCRETE

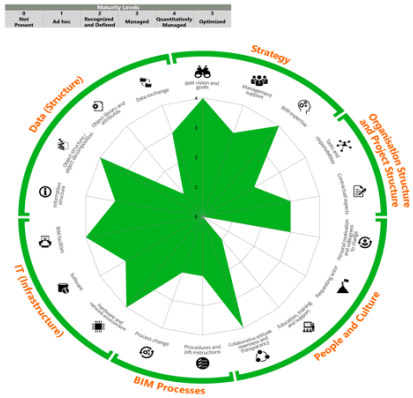


FIGURE 19- CONTRACTOR

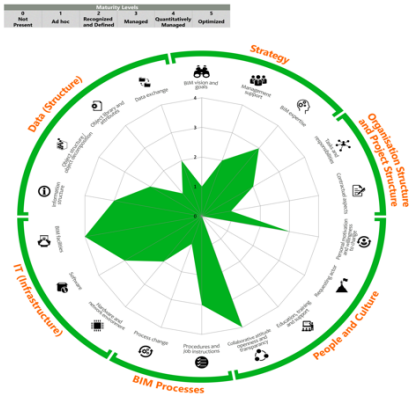


FIGURE 20- PROJECT LEADER

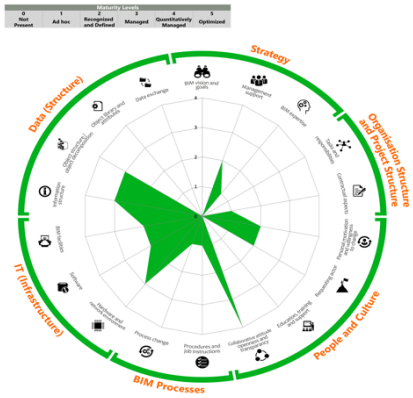


FIGURE 21- ARCHITECTURAL FIRM

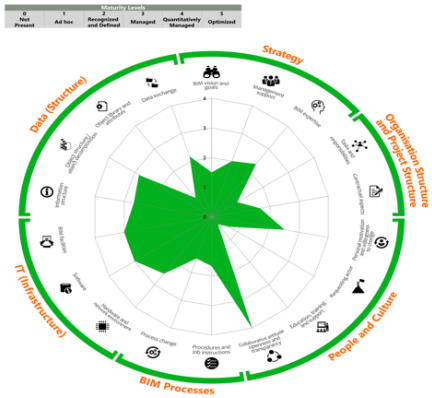


FIGURE 22- PROJECT OVERALL PROJECT C

RADAR CHARTS

As the radar diagrams show, there is enormous diversity in the radar diagrams of the different parties. The concrete supplier scores remarkably low compared to the other parties, and the architect also scores quite low. First of all, achieving a low maturity does not necessarily have to be negative, for these parties it fits into the relationship they have with certain parties. These parties are less actively included in the various aspects. Because the concrete supplier is less closely involved in the design process, they are less informed about certain aspects. The agreements that apply to their party are then only shared. A number of aspects are coordinated with all parties, such as the engineering firms or consultants, which are more part of the inner shell of the project than a supplier of concrete. This is the reason that the engineering consultancy firm, engineering firm for concrete, contractor and project leader are included more in the

whole BIM, specific agreements are made with them and not with others and therefore also estimate the project higher because they know more.

The cooperation and contact on this project are seen as positive according to all parties. This is noticed that the communication runs smoothly, and there is mutual understanding.
A lean moment was also planned every day, which promoted cooperation. The agreements are also clear insofar as they are shared. The cooperation is perceived as positive, which is promoted because they often work together on a project location.

PROJECT AS A WHOLE
By going through all criteria, it has been determined what the BIM maturity level of the project really is (Figure 23). This was done by studying the documentation etc., the complete data set has been considered for determining the maturity level on the project as a whole.

(1) Strategy
There is a "BIM plan van aanpak" with clear descriptions of goals and visions, these are as follows: Limiting the failure costs; Optimizing the implementation process at an early stage; Meet the requirements set by the client; Increasing the insight of the client, future users and construction partners into the design and construction process; and More efficient implementation process through digitization. So, the project scored level 3 on this aspect. Not all parties are aware and or not well informed and therefore score lower, the architectural firm and concrete supplier indicate that no vision or goals for BIM are formulated. The engineering firm for concrete, engineering consultancy firm and the project leader indicate it is not clear what the ultimate goal should be. Only the contractor scores the same on this aspect, it is clear to him. In this project there is sufficient management support which contributes to implementation and further development of BIM so, its level 2 for the project as a whole. Five parties scored the same and have the same perception on this aspect. The concrete supplier deviates extremely, and scored low on this aspect. This party indicates that no resources are released, the project is the same as for projects where no BIM is used and they do not notice the construction firm is extra committed to BIM. This impression is not obtained when examining / studying the documentation, and therefore the project as a whole scored level 2. In the "BIM plan van aanpak" it appears that a BIM expert has been assigned who give structured support for BIM guidance and it appears that this person has sufficient time for this task. This project scored therefor level 3 on the criteria BIM expertise. The engineering firm for concrete, engineering consultancy firm, project leader, and the contractor scored the same but the concrete supplier and architectural firm has a different perception on this aspect. They indicate there is no BIM expert on this project and therefor score low on this aspect.

(2) Organizational structure
The tasks and responsibilities regarding BIM are sufficiently formalized in job profiles and role descriptions in the "BIM plan van aanpak" so, its level 2. The project leader and the contractor scored the same on this aspect except for the engineering consultancy firm and engineering firm for concrete it is not clear for all off them. The concrete supplier and architectural firm indicate that tasks and responsibilities regarding BIM are not formalized, so these parties scored lower because they are not aware of this. BIM related agreements are laid down in the "BIM plan van aanpak", also an overview about what information is provided when and how is documented so, its level 4. All parties score lower

on this because they stated this is not included in contracts or protocols and indicate this is formalized with some of the parties.

(3) People and culture

On this project the majority is enthusiasm to work with BIM and there is an increasing willingness to change the way of working for the benefit of BIM so, its level 3. All parties have the same perception on this aspect and scored therefore the same except for one party which scored lower because, the concrete supplier indicates that he sees no resistance or motivation for BIM on this project, it is not really known exactly what BIM is, he can provide little information about this. In the "BIM plan van aanpak" describes a bim champion who functions as a driver of the implementation process by stimulating other so, its level 2. All parties scored low on this aspect because they don't know whether this person is present on this project. Training is also available for the parties on this project, which is also stated in the "BIM plan van aanpak" so, its level 3. All parties are not aware of this and therefore score low. The level on collaborative attitude and transparency is 4, because collaboration is part of the project strategy and mutual trust between partners is growing, openness and transparency is increasing. the parties all score the same on this and have the same perception of this as the project as a whole.

(4) Processes and procedures

Work instructions have been established for important uses of BIM these have been added to the "BIM plan van aanpak", for example work instructions for Naviswork and Revit so, its level 3. The architectural firm and concrete supplier scored lower on this aspect because they agreed procedures or work instructions are not documented, these parties were not informed about this. The extent to which BIM is a driving force for change and improvement of processes is highly dependent on individual skill and motivation so, its level 1 for this aspect on the project as a whole. Some parties score higher because they considers BIM to be a driving force for process improvement, because it is clear to everyone in which process phase the project is at that moment.

(5) IT (infrastructure)

Project wide, available hardware is able to run the advanced BIM software applications and the quality of the network environment allows cloud based working so, its level 4 for the project as a whole. There is one perception of a party which differs from this. The concrete supplier works from its own location, and therefore cannot give its opinion here and scored lower on the aspect hardware and network environment. The available software is appropriate for both design, engineering and construction activities so, its level 4 on the criteria software. All parties have the same perception on this aspect and scored the same. There is enough capacity of spaces that are well equipped to accommodate meetings and coordination sessions with BIM so, its level 4. Here too the parties have the same perception and score the same.

(6) Data (structure)

Project data are made accessible to other parties within the project by providing rights to read, add or change data, this project make use of BIM 360 and is used consistently, tink project and teams are also used for the working environment. This project scored level 3 on information structure and is in line with the scores of the parties except for the concrete supplier which does not use these systems and send the models via mail or we transfer and therefore score low on this aspect.

The object structure and decomposition are aligned with other parties on project level and documented in the "BIM plan van aanpak" so, its level 3. Here too the concrete supplier indicates that these are not present, as well as agreements for coding and scored low again on this aspect. Within this project different unaligned object libraries are used, there is no uniform approach and naming is inconsistent so, its level 1 on the criteria object libraries. All parties scored the same here.
The data exchange with other parties is well defined in the "BIM plan van aanpak" and supports working based on models of other parties so, its level 3 on this aspect. The supplier of concrete scores low on this aspect because the exchange of data is not via or from the building model but via email or we transfer.

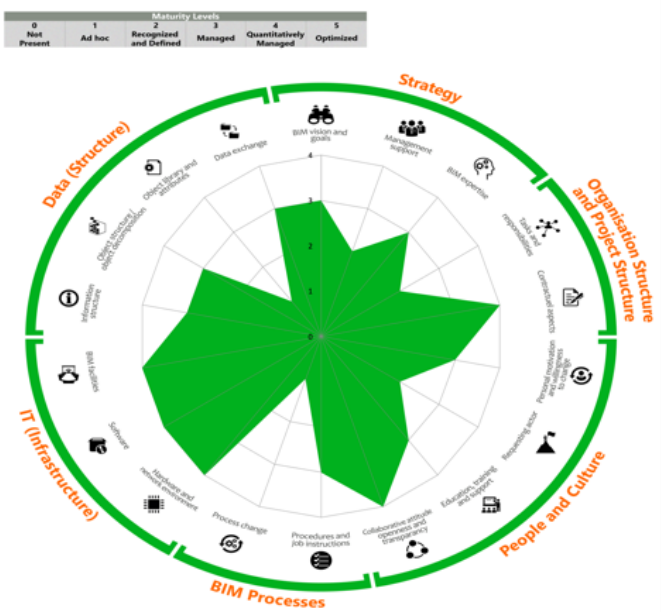
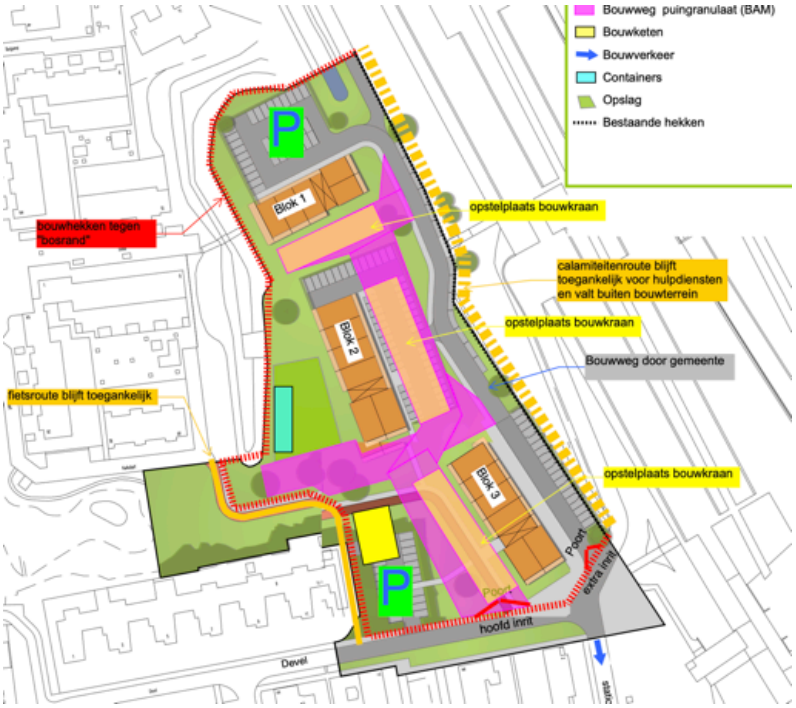


FIGURE 23- PROJECT C

3.4 Case 4 Project D

This project is located in just the south of Rotterdam, the Netherlands. The large construction company develops and realizes 82 apartments spread over three apartment complexes. The first apartment block consists of 23 social rental apartments, the second block of 30 owner-occupied apartments and the third block of 29 rental apartments for the private sector. The contractor started construction of the three residential blocks at the end of 2019 and will be finished medio 2020.
This project was designed around the end of 2009, and will be finished mid 2020. The project concerns a three-block apartment complex containing 82 apartments (see picture below). The interviews with the various parties were conducted during the executive phase.



For this case seven different dominant parties have been chosen to conduct an interview (Appendix D). These parties have been chosen by the construction company and vary in the field. The seven parties chosen are: Ventilating equipment manufacturer, electronics firm, plumber, concrete product supplier, contractor, concrete contractor and window supplier.
The results for the BIM maturity level per party for this project are depicted in Figures 24-30 and the overall result of the project in Figure 31. These show the scores in graphical manner on the 6 main criteria and the sub criteria on project level. Below the results of the parties will be discussed per criteria.

(1) Strategy

The parties score alternately on BIM vision and goals. The plumber scored high on this aspect, according to the plumber the BIM vision and goals have been defined in the BIM protocol and are aligned with important partners. The BIM goals are: compiling a coordination model / performance model, generating quantities, exchange models with construction partners/co-makers, using the model for the construction version (BIM360). The ventilating equipment manufacturer, electronics firm and concrete product supplier indicates a BIM vision has been defined, but there are no concrete goals associated with it. The contractor, concrete contractor and window supplier scored low on this aspect and indicates there are no vision or goals for BIM formulated. They score differently on this aspect because they either have not received the BIM protocol or they do not know whether it is described in the protocol. All

parties score equally on the support of the management. They are well supported by management and if they have problems they will be helped. The supplier of windows indicates that there is limited or unstructured support from the management and scored therefor low on this aspect. There is a clear consensus on the aspect of BIM expertise. They scored similar because no specific BIM expert has been assigned, but this role is partly fulfilled by the BIM coordinator. They indicate that there is someone who has a lot of experience with BIM and who knows everything, they can ask him everything, but there is no BIM expert. Because there is no BIM expert, all parties score low on this aspect.

(2) Organizational structure

The seven different parties score almost equal on the tasks and responsibilities. The ventilating equipment manufacturer, electronics firm, concrete product supplier, concrete contractor and window supplier scored low on this aspect because tasks and responsibilities regarding BIM are not formulized on project level. The plumber and contractor scored a bit higher on this aspect and indicates that tasks and responsibilities regarding BIM are partly or insufficiently formalized, it roughly states who has which task.

In terms of contractual aspects, two parties deviate in terms of BIM maturity. The concrete contractor and window supplier stated that BIM is not explicitly included in contracts, protocols or formalized in agreements. The ventilating equipment manufacturer, electronics firm, plumber, concrete product supplier, contractor state that BIM-related agreements are laid down in contracts/protocols, there is clarity about what information is provided when and how. The agreements are all formalized in the BIM protocol, it is clearly indicated which format and what information is shared, in which version of revit and agreements about file names. The BIM protocol has not been shared or has not been read by all parties as a result, it is not clear to all parties which agreements have been documented and therefore there is variation in maturity.

(3) People and culture

All parties scored almost equally on all four sub criteria, so a clear overall consensus on this aspect. No resistances are given by parties, everyone agreed that there is sufficient motivation to work with BIM. It has been imposed by the board of directors to work with BIM, which means you will have less resistance. The benefits are recognized by all parties, so they all score reasonably high on motivation and willingness to change. In this project no BIM champion is present, so all the parties score low on requesting actor except for the contractor which scored a bit higher on this aspect. He indicates that he is the one who fulfills this role, he functions as a driver of the implementation process and stimulate others. But he also agreed that extra capacity is needed to push harder for BIM. No education or specific training for BIM is available on this project, this will be done internally therefor, all parties score equally in terms of education, training and support. If there are specific ambiguities, this will be discussed with each other. This project is deliberately working to foster collaboration with other parties, there is more openness and transparency between the parties. All parties experience this equally and therefore score the same on collaborative attitude, openness and transparency.

(4) Processes and procedures

The parties score differently on the sub criteria, the most variation is on process change. The ventilating equipment manufacturer, electronics firm, plumber and concrete contractor scored equal on this aspect (relatively low). They indicate BIM processes are limited laid down in procedures and work instructions,

this project is seen as relatively simple, so the procedures and job instruction are indicated in outline and not specific.

The sub criteria process change is scored different by all the parties. The ventilating equipment manufacturer, electronics firm, window supplier and contractor indicate that BIM is a not driving force for processes but more for the elaboration and preparation itself, it is considered to be a tool for specific activities, but not lead to fundamental process change. The plumber, concrete product supplier and concrete contractor indicates BIM is a driving force for process improvement throughout the project. The parties consider BIM for different purposes and therefore score differently on this aspect.

(5) IT (infrastructure)

There is clear consensus on the aspect of IT, the seven parties scored equal on the three sub criteria. Because there is not a joint project location where the parties work together but individually work in their own office, all parties score low on hardware and BIM facilities. These two sub criteria focus on a collaborative work environment. They also score the same on the sub criteria software, because everyone is satisfied with the software and the cooperation with other parties, including the exchange of information, is well facilitated by the available software. Agreements have been made project-wide about which software is used and in which version.

(6) Data (structure)

The parties scored all high on information structure except for one party. The concrete contractor scored low on this aspect, instead of using a document management system, this discipline use email traffic. The other parties make use of SharePoint where project data made accessible to other parties within the project by providing rights to read, add or change data.

The plumber, contractor, concrete contractor and window supplier agreed there is no methodology used for the object structure/decomposition of a construction work hereby these parties scored equally low on object structure and decomposition. The ventilating equipment manufacturer, electronics firm and concrete product supplier scored higher on this aspect and indicate that the method for the object structure and decomposition is aligned with other parties on project level, this is all shared in the BIM protocol. For the object libraries and object attributes they scored equal because within the project different unaligned object libraries are used, there is no uniform approach and naming is inconsistent. In terms of data exchange there is also a clear consensus, the data exchange with other parties is well-defined and according to the project standard, exchange of BIM data take place via open standards, e.g. IFC. The exchange of data is via share point and are exchanged in IFC. Therefore, the parties scored all high on these criteria.

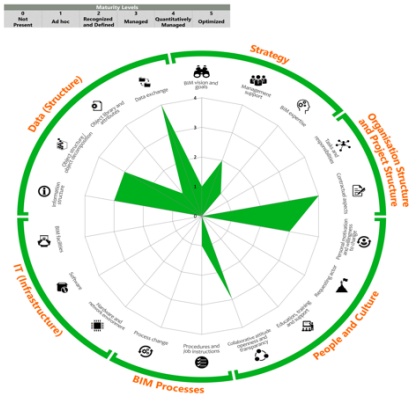


FIGURE 24- VENTILATING EQUIPMENT MANUFACTURER

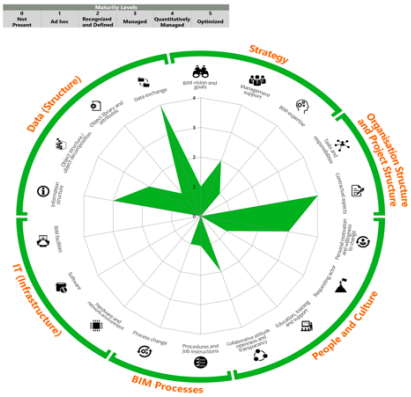


FIGURE 25- ELECTRONICS FIRM

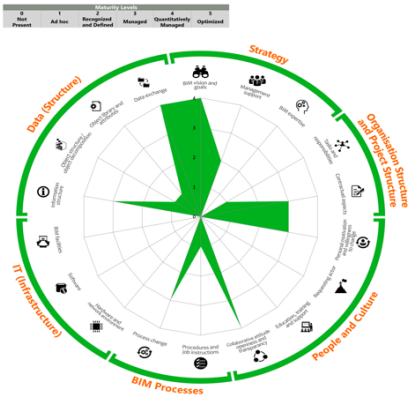


FIGURE 26- PLUMBER

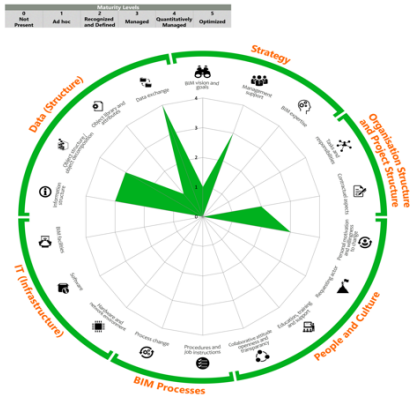


FIGURE 27- CONCRETE PRODUCT SUPPLIER

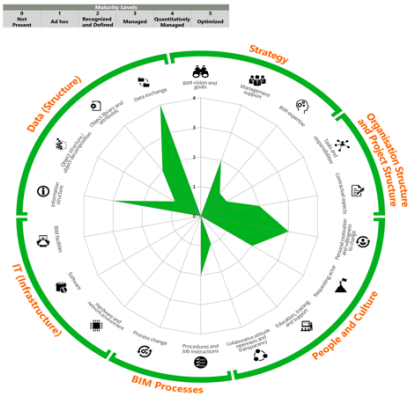


FIGURE 28- CONTRACTOR

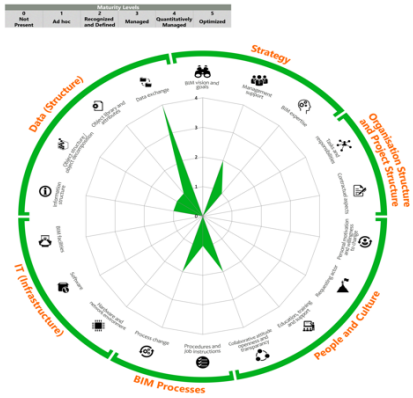


FIGURE 29- CONCRETE CONTRACTOR

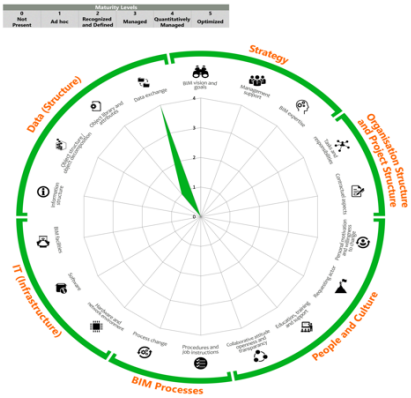


FIGURE 30- WINDOW SUPPLIER

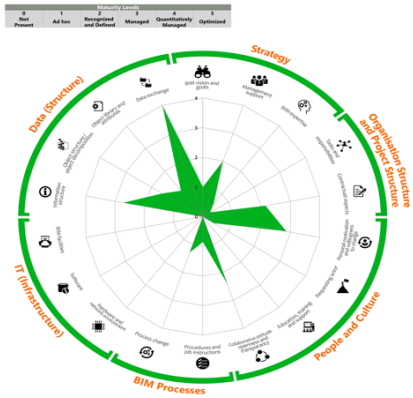


FIGURE 31- PROJECT OVERALL PROJECT D

RADAR CHARTS

As the radar diagrams shows, the maturity levels of the various parties on this project are very low. The concrete product supplier, concrete contractor and window supplier score relatively low compared to the other parties. These parties are less actively included in the various aspects, for example the BIM protocol and hard agreements are not shared with them. Because these suppliers are less closely involved in the design process, they are less informed about certain aspects. This is the reason that the ventilating equipment manufacturer, electronics firm, plumber and contractor estimate the project higher because they know more because they are included more in the whole BIM, specific agreements are made with them. The agreements that apply to their party are then only shared. All parties score low on the aspect IT infrastructure, because on this project there is not a joint project location.

Although the project has a relatively low maturity, the cooperation is experienced very positively.
This is noticed from the fact that when they call someone and answers, there is clarity and it is concrete. There is a suitable solution for every problem.

PROJECT AS A WHOLE

By going through all criteria, it has been determined what the BIM maturity level of the project really is (Figure 32). This was done by studying the documentation etc., the complete data set has been considered for determining the maturity level on the project as a whole.

(1) Strategy

Only the basic ideas of the BIM goals have been set out in the BIM protocol. It describes the following goals: Compiling a coordination Model / performance Model; Generating quantities; Exchange models with construction partners / co-makers; Using the model for the construction version (BIM360). Because only the basic ideas have been set out, the project scores level 2 on the criteria BIM vision and goals.
The plumber scored higher on this aspect, according to the plumber the BIM vision and goals have been defined in the BIM protocol and are aligned with important partners. Contradictory to this, all other parties indicate that there are no BIM goals formulated and scored lower on this aspect than the project as a whole. The project is well supported by the management which contributes to implementation and further development of BIM, so it is level 2 on management support. The perception of all parties is the same and therefore also have the same level on these criteria. The supplier of windows has a different perception and indicates that there is limited or unstructured support from the management and scored therefor low on this aspect. A BIM expert is described in the BIM protocol, but it emerges that he does not have enough time for this so, it is level 1 on BIM expertise. All parties have the same perception on this aspect and scored therefore the same on this aspect.

(2) Organizational structure

In the BIM protocol tasks and responsibilities regarding BIM are sufficiently formalized in role descriptions, so the level on these criteria is 2. All parties scored lower on this aspect because they all stated this is not or insufficiently formalized in the BIM protocol. The documentation therefore shows that this has been described, which results in a higher score on the project as a whole on these criteria.
In terms of contractual aspects, BIM related agreements are laid down in the BIM protocol there is clarity about what information is provided when and how so the level on this aspect is 4. The concrete contractor and window supplier have a different perception on this aspect and scored lower. They stated that there are no BIM related agreements. The documentation has also clearly shown that these agreements have been made, which shows that these two parties are not well informed.

(3) People and culture

There is a project wide motivation to work with BIM, no resistances are given so, the project as a whole scored level 3 on these criteria. Also, the perception of the parties is all the same and scored therefore also the same. In the BIM protocol is a person described who functions as a driver of the implementation process by stimulating others, so it is level 1 on this aspect. The contractor also indicates this and scored the same. There is a difference in perception of the other parties, they all indicate this person is not present and are not aware of this person. No education or specific training for BIM is available on this project, this will be done internally therefor, the project score level 0 in terms of education, training and

support. All parties scored the same on this aspect. This project is deliberately working to foster collaboration with other parties, there is more openness and transparency between the parties so, it is level 3. Here, too, all parties score the same on these criteria as what the project as a whole score.

(4) Processes and procedures

BIM processes are limited laid down in procedures or work instructions so the level on this aspect is 1. The ventilating equipment manufacturer, electronics firm, plumber and concrete contractor have the same perception and scored the same. The supplier of windows and concrete scored lower and indicate these are not documented. The extent to which BIM is a driving force for change and improvement is dependent on individual skill and motivation so, it is 1 on the project as a whole. The ventilating equipment manufacturer, electronics firm, window supplier and contractor scored lower and see BIM as a tool for specific activities. The plumber, concrete product supplier and concrete contractor scored higher and indicates BIM as a driving force for process improvement throughout the project.

(5) IT (infrastructure)

This project has no joint project location and therefore no joint hardware and network environment, this project as a whole scored level 0 on hardware and network environment and BIM facilities. All parties have also achieved this score on both aspects. The cooperation with other parties, including the exchange of information, is well facilitated by the available software, so its level 3 on software. All parties also indicate that in the aspect of software the cooperation with other parties, including the exchange of information, is well facilitated by the available software.

(6) Data (structure)

Project data are made accessible to other parties within the project by providing rights to read, add or change data, this project make use of SharePoint. This project scored level 3 on information structure and is in line with the scores of the parties except for the concrete contractor scored low on this aspect, instead of using a document management system, this discipline use email traffic. The object structure and decomposition are aligned with other parties on project level and documented in the BIM protocol so, its level 3. The ventilating equipment manufacturer, electronics firm and concrete product supplier has the same perception and scored also level 3. Here the plumber, contractor, concrete contractor and window supplier agreed there is no methodology used for the object structure/decomposition of a construction work hereby these parties scored equally lower on object structure and decomposition. Within this project different unaligned object libraries are used, there is no uniform approach and naming is inconsistent so, its level 1 on the criteria object libraries. All parties scored the same here. The data exchange with other parties is well defined in the BIM protocol and according to the project standard, exchange of BIM data take place via open standards, e.g. IFC., its level 4 on this aspect. The perception of the parties is also here the same as the project as a whole and scored therefore the same.

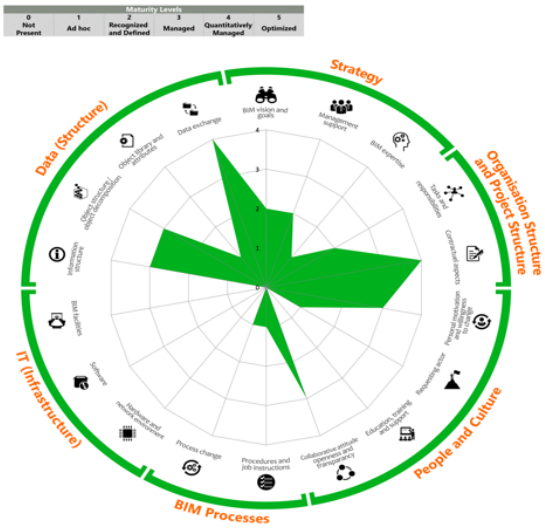


FIGURE 32- BARENDRECHT

3.5 CROSS CASE STUDY

In this Section, the cases are compared with each other and the focus is on identifying patterns or similarities / differences between the cases. These cases were first examined qualitatively by means of observations, semi-structured interviews and document analysis. The wide variety of qualitative data was then ordered by Qualitative Comparative Analysis (QCA) (Rihoux & Ragin, 2009) and analyzed by case comparison. The core dimensions for the case comparisons are; the phase of the project, the roles of the parties in the project, the type of project and project cooperation. The maturity level of the four projects as a whole is shown in Figures 33- 36.

TYPE OF PROJECT

First, the differences and similarities are examined by type of project. There is a variation in the type of project, both infrastructure projects and B&U projects are included. Two cases are infrastructure projects and the other two projects are B&U projects.

There is one project which scores relatively low compared to the other three projects, this project is a B&U project. Regardless of the fact that one of the cases scores relatively low at the maturity level, this is not due to the fact it is a different type of project. For the BIM use and coordination of the different dimensions, it is not due to whether it is an Infra project or B&U project, it depends on agreements. That distinction of type of project is no longer so relevant for BIM use and BIM maturity. All projects show that it is bound by the agreements that have been set up. Projects that have clearly defined these agreements from the start score significantly higher in most aspects. Sometimes agreements are made during the project and it is more ad hoc, which results in lower scores on many aspects.

In terms of cooperation between parties, there is actually a difference in the type of projects. The infrastructure projects involve more integrated cooperation on the project. It is often considered as one project organization and they are not seen as individual parties. On the infrastructure projects, everyone is closely involved in the process, both in the design process and in the execution phase. In the B&U projects, some parties are only involved in the project when they need them. Where the B&U projects work from their own organization, the infrastructure projects work on a joint project location, which also promotes cooperation.

PROJECT PHASE

There is a variation in the project phase, both design phase and executive phase are included. Three projects are interviewed during the executive phase and one during the design phase. The project that is still in the design phase scores relatively lower than the three projects in executive phase.

Whether the interviews took place during the design phase or the executive phase may influence the perception of the maturity of the project. If they are in the design phase and have just started the project, it is possible that not everything is known yet, while if the project is in the executive phase, they are already more implemented in the construction process of the project and as a result everything is further developed and more crystallized. It may be the case that the maturity level is dynamic rather than static, which means that the maturity level is still developing during the project. This could be the reason why the BIM maturity of the B&U project is therefore lower in the design phase.

Several interviews with different projects show that indeed during the process of the project, everything runs/work better and they know where to find each other. As the project progresses, the agreements are clear to everyone whereby the BIM use is stimulated and better applied.

ROLES OF THE PARTIES

Finally, the differences and similarities are examined by roles of parties. Interviews were held with representatives of organizations drawn from different subsectors: architectural firms; contractors; engineering firms; clients; mechanical, electrical, and plumbing (MEP) contractors; structure contractors; and suppliers.

When comparing the cases, there is a clear trend that there is variation in maturity in different roles. There are certain roles or parties that score more often higher than other parties. Contractors and engineers often score higher than parties further up the chain; suppliers and subcontractors. The lowest maturity score was found for the suppliers and architectural firms.

The interviews show that some parties are included to a limited extent in certain aspects, for example they receive a shortened "BIM plan van aanpak". The parties that belong more to the inner shell of the project, all aspects are fully coordinated with them, such as the engineering firms and consultants. Specific agreements have been made with them and not with other parties. These parties are included more in the BIM aspects and therefore estimate the project higher, because they know more.

The interviewed suppliers indeed indicated that BIM had largely been adopted because of requests from their clients (main contractor), and therefore scored lower because they only do what is necessary. When interpreting the outcomes of a BIM maturity analysis, one should not forget that a party does not need to be at the highest maturity level on all the BIM criteria in order to work or cooperate in a BIM project.

The most important dimensions to increase the BIM maturity are making clear agreements and formulizing them contractually, and especially clarity about aspects such as: strategy, goal, information platform, data exchange, what type of software, what information platform they use for DMS etc.

The projects that have established this since the first phase of the project score significantly higher in most aspects. When agreements are made during the project and are not documented or formulized, they score lower on many aspects. These agreements are then made between two parties and not project-wide, this creates ignorance and scores are lower.

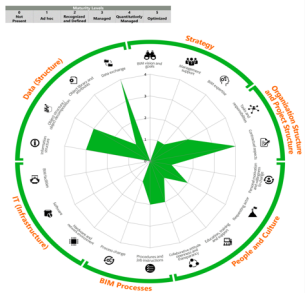


FIGURE 33- PROJECT OVERALL PROJECT A

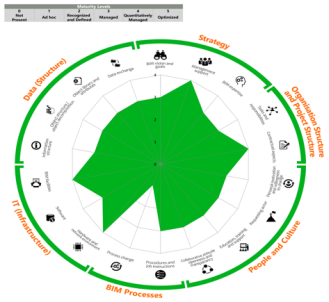


FIGURE 34- PROJECT OVERALL PROJECT B

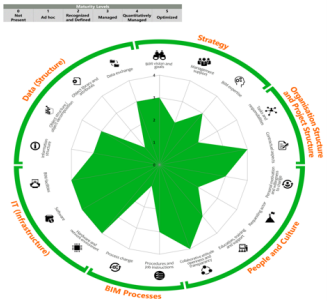


FIGURE 35- PROJECT OVERALL PROJECT C

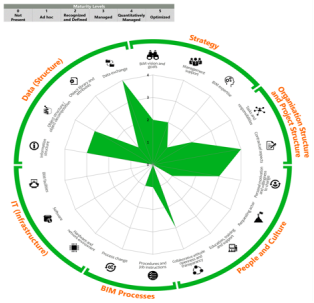


FIGURE 36- PROJECT OVERALL PROJECT D

COOPERATION

Table 2 illustrates an overview of the four different projects. It summarizes how the experiences have been in the field of BIM, cooperation, perception of parties and the problems and barriers involved in the project. Based on this, it will be examined whether this has had an impact on the maturity level of the project as a whole.

All projects clearly show that BIM is seen as an additional tool to support the design and construction activities. When the maturity is higher on projects, they indicate that BIM is also a working method that enables better cooperation between parties and disciplines and it is an IT solution to facilitate design and visualization processes, for the digital display of a building object.

The projects with a lower maturity level experience the cooperation as bad because it is unclear which agreements have been made. The parties are either insufficiently or not included in the agreements, which sometimes makes it unclear for the parties. As a result, the agreements are not kept because some parties are not aware of this. There is also a lot of resistance in projects with a lower maturity level which does not encourage cooperation.

When the project has a higher maturity level, the experiences of collaboration is better. This is because the parties have coordinated agreements with each other and are all aligned. This trend can also be continued in the problems that arise on the project. Projects with a higher maturity level experience fewer problems and the project runs smoothly, resulting in better cooperation. For projects with a lower maturity, more problems are experienced and the agreements are not clear.

Table 2 clearly shows, when the perceptions of the parties' match, the project has a higher maturity level and the cooperation on the project is better as well. The parties are all aligned, resulting in an integral whole. The consequences of differences in perceptions of BIM maturity between the parties are that they have poorer cooperation and experience more problems on the project.

TABLE 2 OVERVIEW CASES

	Case 1	Case 2	Case 3	Case 4
Consideration of BIM	BIM is considered in this project as to be an additional tool to support the design and construction activities.	BIM is considered in this project as to be; an additional tool to support the design and construction activities; an IT solution to facilitate design and visualization processes, for the digital display of a building object; a method for structured management of project data throughout the life cycle; a working method that enables better cooperation between parties and disciplines	BIM is considered in this project as to be a working method that enables better cooperation between parties and disciplines and to be an additional tool to support the design and construction activities.	BIM is considered in this project as to be a working method that enables better cooperation between parties and disciplines and to be an additional tool to support the design and construction activities. To a lesser extent it is considered to be an IT solution to facilitate design and visualization processes, for the digital display of a building object.
Experiences cooperation	The collaboration is perceived as bad, because it is a longer-term project. There is little cooperation from designers and not	The cooperation is experienced as very good. There is a lot of variation in the hired parties. The structure within the project is a plus, there are short lines between the	The contact and cooperation are good, communication is going well. There is a good feeling and there is understanding for each other. There is a good	The cooperation is partly experienced as good, the knowledge of certain parties can be improved. There are a lot of new people on the project,

	everyone keeps to the agreements.	cooperation. Everyone belongs to one company within the project and is not considered as individual companies.	response when comments are given. Every day there is a lean moment that promotes cooperation.	so complete answers are not given. Sometimes parties cannot start because other parties are not ready on time, or there are certain aspects that are not feasible.
Problems encountered	Problems are experienced with the engineer's stability because they are not mature enough to use BIM. As a result, errors are detected too late. There is also little cooperation from the designers because the project has already been completed for them. Not everyone adheres to the working method and the agreements. The project is not going well because they do not keep to the agreements because BIM was only implemented later in the project and not at the beginning.	Few problems have been identified in this project. It is indicated that freelancers are difficult to manage. And Subcontractors are sometimes still searching, which is why coordination is certainly necessary there. Sometimes something is wrong in the model which creates extra work and time.	Some parties are behind at maturity level, which does cause problems. A number of subcontractors still work very traditionally and do not uses BIM. The way of modeling and sharing and saving files then causes problems. Sometimes they have to do with outdated files because they are not put in the right location, which also makes mistakes. The consequences of this are that it contains so much information that it is unclear who is responsible for it. Checking the model is also experienced as difficult.	This project experiences variation in maturity, which sometimes causes problems. Some parties still work with 2D drawings and the others work with 3D drawings, which sometimes makes it difficult.
Perception parties on maturity level project	There is a lot of variation between the parties about how they experience BIM and how they score the project. There is a lot of variation in perception at the maturity level of the different criteria.	There is little to no variation between the parties on how BIM is perceived, and they also have the same perception on the maturity level of the different criteria.	There is little to no variation between the parties on how BIM is perceived, and they also have the same perception on the maturity level of the different criteria. One party differs slightly from the other parties in perception.	There is a bit of variation between the parties about how BIM is perceived, the perception at maturity level of the different criteria differs minimally.
Maturity level project as a whole	1	3	3	2

SCALED VALUES VERSUS PERCEPTION OF PARTIES

In previous Chapters, the results per case were described in both the parties' perception of the project and the scaled value on the project as a whole (by looking at the complete data set). The perception of the parties and the scaled values differ on some criteria in terms of maturity level.

Following the differences in perception of the parties and the scaled maturity level on the project as a whole, Table 3 provides an overview where the perceptions of the parties differ. The black crosses indicate that almost all parties have a different perception, where the gray crosses indicate that only one discipline deviates with its BIM level compared to the project as a whole.

When comparing the cases, there are a number of patterns where the differences are. First, the perceptions of the parties of all cases differ from the BIM vision and goals criteria compared to the

project as a whole. This variation is due to the fact that the BIM vision and goals have been formulated and documented, but not all parties are aware of this or have been informed and therefore score lower. This is reflected in all cases, causing that in all cases there is a difference in the score of the project as a whole and the perception of the parties on these criteria.

The table also shows that the perceptions of the parties of all cases differ from the tasks and responsibilities criteria compared to the project as a whole. The BIM maturity level of the project as a whole is scaled higher by all cases compared to the perceptions. This is because the parties either do not have sufficient insight or the protocol is not shared with them. It might be the case that they have not read the protocol properly and are therefore not aware of it.

The perceptions of the parties of all cases differ from the procedures and job description criteria compared to the project as a whole. The BIM maturity level of the project as a whole is scaled higher by all cases compared to the perceptions. This too is devoted to the same problem as mentioned above, either do not have sufficient insight or the protocol is not shared with them and therefore also scored lower on this criterion.

The criteria process also has a different score on the project as a whole compared to the perceptions of the parties on all cases. This because BIM is seen in a different way by everyone in terms of process change. In all cases, the parties differ in how they consider BIM. Sometimes BIM is considered to be a tool for specific activities and not lead to process change whereas other parties see BIM as a driving force for process improvement. Because there is a different view of this, everyone also scores differently than how the project as a whole is classified.

In three of the four cases, there are a number of criteria that are scored differently from the project as a whole. First, the perceptions of the parties of these cases differ from the management support criteria compared to the project as a whole. The deviation is not extreme because in two of the three cases there is only one party that deviates from the project as a whole. This deviation is due to the fact that these parties do not have sufficient insight into whether financial resources are being allocated to further develop BIM. For this reason, these parties scored lower on these criteria, because they did not have information about this.

The perceptions of the parties of these three cases differ from the contractual aspects criteria compared to the project as a whole. This variation is due to the fact that contractual aspects have been formulated and documented, but not all parties are aware of this or have been informed and therefore score lower. This is reflected in all the three cases, causing that in all cases there is a difference in the score of the project as a whole and the perception of the parties on these criteria.

The perceptions of the parties of all cases differ from the requesting actor criteria compared to the project as a whole. The BIM maturity level of the project as a whole is scaled higher by all cases compared to the perceptions. This too is devoted to the same problem as mentioned above, either do not have sufficient insight or the protocol is not shared with them and therefore also scored lower on this criterion. In the BIM protocol a person who functions as a driver of the implementation process by stimulating others is described, but all parties are not aware of this and score therefore lower. This also applies to the object structure criteria, this too has been described or supplied to the parties. Here again these

parties within these three cases indicate that this is not present on the project, but the documentation shows otherwise.

The perceptions of the parties of all cases differ from the information structure criteria compared to the project as a whole. The deviation is not extreme because in two of the three cases there is only one party that deviates from the project as a whole. This variation is due to the fact that not everyone uses the document management system but exchange data via email.

It can also be seen that in projects that generally already score low on the project, there are even more differences between the perception of the parties and the project as a whole than in a project that is already more mature. Here all agreements are clearly formulated and shared and the perceptions of the parties do not deviate from each other and neither on the project as a whole. This creates a well-coordinated project and the perceptions do not vary on the project.

TABLE 3 – OVERVIEW DIFFERENCES IN PERCEPTIONS OF THE PROJECT BIM MATURITY VS. THE PROJECT AS A WHOLE

	Case 1	Case 2	Case 3	Case 4
1. BIM vision and Goals	×	×	×	×
2. Management support	×		×	×
3. BIM expertise	×		×	
4. Tasks and responsibilities	×	×	×	×
5. Contractual aspects	×		×	×
6. Personal motivation and willingness to change				
7. Requesting actor/champion	×		×	×
8. Education, training and support	×		×	
9. Collaborative attitude, openness and transparency	×			
10. Procedures and job descriptions	×	×	×	×
11. Process change	×	×	×	×
12. Hardware and network environment				
13. Software				
14. BIM facilities				
15. Information structure	×		×	×
16. Object structure/ object decomposition	×		×	×
17. Object library and object attributes				
18. Data exchange			×	

It has repeatedly emerged that the parties are not aware of any agreements made, while these have actually been documented, which means that the project as a whole and the perception of the parties scored different on some criteria. To get a more integrated project, it is important to share all agreements with the parties. The most important dimensions to increase the maturity and creating an integral whole is making clear agreements and formulizing them contractually, and especially clarity about aspects such as: strategy, goal, information platform, data exchange, what type of software, what information platform they use for DMS etc.
The projects that have established this since the first phase of the project score significantly higher in most aspects, and all parties are more aware of it. When agreements are made during the project and are not documented or formulized, they score lower on many aspects and this creates variation in perception because they are not aware of some agreements.

4. DISCUSSION

This Chapter deals with steps 6 (shaping hypotheses) and 7 (enfolding literature) of the Eisenhardt framework as mentioned in Section 2.1.3 research framework. It treats the potential and contribution of this work in Section 4.1.

4.1 POTENTIAL AND INTERPRETATION

In this section, the results from the BIM maturity on project level will first be discussed. Hereafter, the role of type project, phase, party and collaboration even as the maturity model will be evaluated.

Maturity aspects

The BIM maturity of projects is evaluated on the basis of several criteria. Some of the most notable outcomes are then discussed. These outcomes can be used by projects in the construction industry to set priorities for improvement of the BIM maturity level on a project. When interpreting the findings, one should not forget that achieving a low maturity does not necessarily have to be negative.

Almost all of the projects scored highly on the data criterion. This implies that the project data are made accessible to other parties within the project by providing rights to read, add or change data. In addition, this criterion involves the object structure, object library as well as the data exchange between parties. All projects use a document management system to exchange data which promote data exchange and collaboration. The study of Sarmaniotis, Wickens, and Sigala (2014) similarly argued that the use of DMS stimulates and promotes cooperation between parties. This is also reflected in the projects, the projects that use a DMS system have a higher maturity and experience better mutually cooperation because everything is shared with each other and agreements have been made.

Second, in terms of organizational structure and project structure, the results show that parties have not given this significant attention. The project scored low because there is a limited formalization of tasks / responsibilities in contracts. There is still a lot to gain from developing contractual agreements and formalizing tasks/ responsibilities regarding BIM. Siebelink (2018) also indicate that these aspects have often lagged behind the rapid BIM development in other areas over recent years. A consequence is that BIM processes become highly dependent on individual competences, this may result in different BIM performance between projects or between internal departments. Froese (2010) also stated that the full potential of BIM can only be realized if the organizational structure, work practices, and project member skills are addressed. The importance of making contractual agreements is also recognized in the study of Hindmoor (1998), it allows parties to achieve understanding, which benefits all parties. Such rules are constitutive of a policy community, giving each party information about how others can be expected to act and so allowing a specific item of the project transacted and by whom (Hindmoor, 1998).

Almost all of the projects scored highly on the strategy criterion. This implies that the BIM vision and goals have been defined and the project is supported by the management. Regardless of whether the project scores high on these aspects, some of the individual parties score low on these criteria. This is due to the fact the parties do not know anything about it or they have not received it because it is a party which is less involved (for example a supplier). This has also emerged in previous studies, the suppliers were not considered strategic by the contractor and involved late in the project which resulted in ignorance (Papadonikolaki, Verbraeck, & Wamelink, 2017). For each project the visions and goals have

been set up, in many cases these were shared at the beginning of the project and not referred back during the project resulting in unknowingness. At a certain moment, people are not aware of the agreements that have been made, this can pose a risk for good BIM use. In this cases there is a lack of communication during the project which result in bad collaboration. Tulsky (2005) similarly argued that collaboration requires clear and consistent communication, poor communication can lead to misunderstandings and even errors in the project. This is also reflected in the projects where the parties are aware of this information, they score significantly higher in most aspects and experience better collaboration.

Almost all projects scored highly on the people and culture criterion. It implies that there is motivation to work with BIM and that there is a structured program for education and active guidance for employees. Except for one project and some parties there is given resistance, it is also not clear to a number of parties whether there is education or training. Here too, communication is lacking among the parties. Motivating the different parties is an important aspect in the success of a BIM project. Cao, Li, Wang, and Huang (2017) similarly argued that attitudes and motivation appear to be individual interest in learning BIM and incentive of using BIM.

If we look at the maturity aspects overall, there are clearly a number of connections between them.
First there is a relationship between the aspect data and contractual aspects. If contractual agreements have been made about exchanging the files (how, what and when), the project will score high on contractual aspects, and at the same time receive a high score on data, because it is clear to everyone what to expect and it is contractually established, everyone must adhere to it. Another correlation is between the aspect's IT and people and culture. A joint project location results in a higher maturity level on IT aspect and at the same time promote cooperation on the project resulting in a high score on people and culture. Projects with a joint project location focus on cooperation which resulted in more openness and transparency between parties. Another correlation is between strategy and the sub criteria tasks and responsibilities. When a project formalizes and documents many agreements, it generally scores high on both aspects. This is because clear agreements have been made about the vision and goals of the project and agreements have often been made about tasks and responsibilities. Projects with a low maturity often do not explicitly document these matters and discuss this verbally.

Type of project
In the cases examined here during the analysis of the cross-case study, no difference is seen between the type of project in relation to the maturity level. It appears that for the use of BIM and coordination of the different dimensions, in these four cases it is not due whether it is an infra project or B&U project, because no significant difference was found in maturity level. Shou, Wang, Wang, and Chong (2015) indicates that there is a difference in the use of BIM in infrastructure and construction, BIM uses in infrastructure projects lag several years behind building construction, but the implementation will probably grow in the future. The comparative analyses of Chong, Lopez, Wang, Wang, and Zhao (2016) show infrastructure and building projects had more or less the same BIM uses, the complex project characteristics and large capital investment is the main influence on the different BIM uses between buildings and infrastructure projects. On the basis of the four cases that were examined it emerges that there is no longer a substantial difference and is therefore not in line with the literature, it could be the case that this has leveled out over the years and no longer applies. Based on of the four cases, it cannot be concluded with statistical certainty whether this outcome is actually correct. In future research it can

be investigated whether there is actually still a difference in maturity between these different types of projects or this difference is no longer present.

There is actually a difference in collaboration, the infrastructure projects involve a more integrated cooperation on the project then a B&U project. The infrastructure projects work on a joint project location where a B&U project works from their own office. Cummings & Kiesler (2007) stated that a joint project location improves the communication and work environment. Geographical distance can slow group communication and consensus making, and a problem at one location may go unnoticed by the employees at the other parties (Cummings & Kiesler, 2007). The interviews conducted during the corona crisis showed that the interviewees looked at this differently. Due to the corona crisis, the parties were forced to work digitally from home, and under certain conditions they noticed that digital work can still be done remotely. So maybe because of this crisis it will go back to this situation and perhaps they will work from home in the future again.

Project phase

The level of maturity could depend on the project phase of the project. It may be the case that the maturity is still developing during the project. Because, during the design phase, things have not always clearly crystallized, the project team does not know each other very well yet, and they have not made sufficient detail agreements on certain things, which is reflected in the maturity on the project. This could be the reason why the BIM maturity level of the project in the design phase is lower than the projects in the executive phase and during the project the maturity can increase. The opposite is found in the paper by Eadie, Browne, Odeyinka, McKeown, and McNiff (2013) which measures BIM uses throughout the project lifecycle, confirming BIM is most often used in the early stages with progressively less use in the latter stages. In the study of Ashman (2004), it is indicated that as the project progresses, the IT use improves because people gain a greater understanding of the needs/requirements and also the accuracy of people will increase. This development can also be put into perspective to the development of the maturity of a project, and could be therefore the reason why the BIM maturity level of the project in the execution phase is higher.

Roles of parties

There are certain roles or parties that score more often higher than other parties. Contractors and engineers often score higher than parties further up the chain; suppliers and subcontractors. The lowest maturity score was found for the suppliers and clients. This implies that the level of maturity depends on the type of role of the party. This is supported in article (Siebelink et al., 2018), where the figure of the BIM maturity of subsectors shows that suppliers and clients score lower than the other parties on the different criterion. Contractors and engineers often score higher than parties further up the chain; suppliers and subcontractors. The parties which score lower are included to a limited extent in certain aspects, for example they receive a shortened BIM protocol. The parties that belong more to the inner shell of the project, all aspects are fully coordinated with them, such as the engineering firms and consultants. Specific agreements have been made with them and not with other parties. These parties are included more in the BIM aspects and therefore estimate the project higher, because they know more. Ideally, all project members should be involved early in the process and be informed of as many aspects as possible (Froese, 2010). The lowest maturity score was found for the suppliers and architectural firms. The architectural firms score relatively low in this study compared to the other parties, which is contradictory to the research of Siebelink et al. (2018). This is because in some projects these

parties offered a lot of resistance because they were in the initial phase of the project and stated that the project had already been completed for them and therefor they did not want to make any adjustments. It is also stated that it has no added value for them to work in BIM and work in their own software's.

Collaboration

The collaboration on projects with a lower maturity level is worse, it is unclear what agreements have been made within these projects. The parties are either insufficiently or not included in the agreements, which sometimes makes it unclear for the parties. The importance of making contractual agreements is also recognized in the study of Hindmoor (1998), it allows parties to achieve understanding, which benefits all parties. Such rules are constitutive of a policy community, giving each party information about how others can be expected to act and so allowing a specific item of the project transacted and by whom (Hindmoor, 1998). Contractual agreements are prerequisites to achieving integrated practices (Succar, 2009). Also, by making agreements about the information structure, less resistance would be given by parties. Agreements about collaboration processes and data- base-sharing skills are necessary to allow model-based collaboration (Succar, 2009). There is also a lot of resistance in projects with a lower maturity level which does not encourage cooperation. When the project has a higher maturity level, the experiences of collaboration is better. This is because the parties have coordinated agreements with each other and are all aligned. This is in line with Eadie et al. (2013) which shows that within Building Information Modelling (BIM) across the lifecycle of a project the stakeholder collaboration aspects related to its adoption produce the highest positive impact on the maturity of a project. This trend can also be continued in the problems that arise on the project. Projects with a higher maturity level experience fewer problems and the project runs smoothly, resulting in better cooperation. For projects with a lower maturity, more problems are experienced and the agreements are not clear. It is concluded that productivity is improved where BIM is used to enable easy sharing and integration of information and increasing convenient collaboration. (Li et al., 2014)

The results show that the perceptions of parties of all cases differ sometimes from criteria compared to the project as a whole. Most of the times this is because the agreements are not known by the parties or not shared or set up sufficiently resulting in ignorance. Similar findings in the literature reflect that stakeholders in BIM environments often do not maximize the benefits of BIM due to poor communication and non-sharing of information (Hjelseth, 2010).

When interpreting the outcomes of a BIM maturity analysis, one should not forget that a party does not need to be at the highest maturity level on all the BIM criteria in order to work or cooperate in a BIM project. (Siebelink et al., 2018)

Generalization results

TABLE 4 - RESULTS VS. LITERATURE

Dimension	Results	Literature
Data exchange	The projects that use a DMS system have a higher maturity and experience better mutually cooperation because everything is shared with each other and agreements have been made.	The use of DMS stimulates and promotes cooperation between parties (Sarmaniotis et al., 2014).
Organizational and project structure	There is still a lot to gain from developing contractual agreements and formalizing tasks and responsibilities regarding BIM.	It is indicated that aspects such as contractual agreements and tasks and responsibilities have often lagged behind the rapid BIM development in other areas over recent years.(Siebelink et al., 2018) The importance of making contractual agreements is also recognized in the study of Hindmoor (1998), it allows parties to achieve understanding, which benefits all parties.
Strategy	Some of the individual parties score low on these criteria. This is due to the fact the parties do not know anything about agreements or they have not received it because it is a party (supplier) which is less involved in the project. At a certain moment, people are not aware of the agreements that have been made, this can pose a risk for good BIM use. In these cases, there is a lack of communication during the project which result in bad collaboration.	The suppliers were not considered strategic by the contractor and involved late in the project which resulted in ignorance (Papadonikolaki et al., 2017). Tulsky (2005) similarly argued that collaboration requires clear and consistent communication, poor communication can lead to misunderstandings and even errors in the project.
People and culture	Motivating the different parties is an important aspect in the success of a BIM project. In the case studies there is given resistance, it is also not clear to a number of parties whether there is education and training. This is due to the fact that communication is lacking among/between the parties.	Cao et al. (2017) argued that attitudes and motivation appear to be individual interest in learning BIM and incentive of using BIM.
Type of project	In the cases examined here during the analysis of the cross-case study, no difference is seen between the type of project in relation to the maturity level.	Shou et al. (2015) indicates that there is a difference in the use of BIM in infrastructure and construction, BIM uses in infrastructure projects lag several years behind building construction, but the implementation will probably grow in the future.
Project phase	The level of maturity could depend on the project phase of the project. It may be the case that the maturity is still developing during the project.	In the study of Ashman (2004), it is indicated that as the project progresses, the IT use improves because people gain a greater understanding of the needs/requirements and also the accuracy of people will increase. This development can also be put into perspective to the development of the maturity of a project, and could be therefore the reason why the BIM maturity level of the project in the execution phase is higher.
Roles of parties	There are certain roles or parties that score more often higher than other parties. Contractors and engineers often	The figure of the BIM maturity of subsectors shows that suppliers and clients score lower than the other parties on the different criterion.

	score higher than parties further up the chain; suppliers and subcontractors.	Contractors and engineers often score higher than parties further up the chain; suppliers and subcontractors. (Siebelink et al., 2018),
Collaboration	The collaboration on projects with a lower maturity level is worse, it is unclear what agreements have been made within these projects. Making agreements is important for the collaboration between parties. When the project has a higher maturity level, the experiences of collaboration is better. This is because the parties have coordinated agreements with each other and are all aligned. Projects with a higher maturity level experience fewer problems and the project runs smoothly, resulting in better cooperation.	Making contractual agreements allows parties to achieve understanding, which benefits all parties (Hindmoor, 1998). Contractual agreements are prerequisites to achieving integrated practices (Succar, 2009). It is concluded that productivity is improved where BIM is used to enable easy sharing and integration of information and increasing convenient collaboration. (Li et al., 2014)

Table 4 provides an overview with the results of the case study and the literature found on these dimensions. In this part, the results of the case data are compared with what has been established in the literature in order to indicate the generalizability of the research. The first finding from the case study is that projects which use a DMS system have a higher maturity and experience better mutually cooperation. This result is consistent with the literature which shows that the use of a DMS system promotes cooperation between parties which is applicable to the entire construction industry (Sarmaniotis et al., 2014). The aspect that contractual agreements are important is also supported by broader literature. It is stated that contractual agreements are important and allows parties to achieve understanding, which benefits all parties (Hindmoor, 1998). Making contractual agreements is important for the entire construction industry as well as on other projects. Within the case study some parties (suppliers) did received less information about the project because they were less involved, similar literature has also argued that the suppliers were late involved which resulted in ignorance and unknowingness (Papadonikolaki et al., 2017). The case data showed that motivating the different parties is an important aspect in the success of a BIM project, which is consistent with the literature where it is argued that that attitudes and motivation appear to be individual interest in learning BIM and incentive of using BIM (Cao et al., 2017), these results does allow generalization to the entire construction industry where BIM is used.

The case data shows that there is no difference is between the type of project in relation to the maturity level. This is result is not consistent with the literature which shows that there is a difference between these two types of projects, BIM uses in infrastructure projects lag several years behind building construction. But it has also been indicated that this will probably grow in the future (Shou et al., 2015). On the basis of the four cases that were examined it emerges that there is no longer a substantial difference and is therefore not in line with the literature, it could be the case that this has leveled out over the years and no longer applies.

According to the case data, the level of maturity could depend on the project phase of the project. It may be the case that the maturity is still developing during the project. This result is generalized by the fact that it is stated in the literature that the use of IT improves as the project progresses, because people gain a greater understanding of the needs/requirements and also the accuracy of people will increase

(Ashman, 2004). This development can also be put into perspective of the development of the maturity of a project and does allow generalization to all projects.

The case data also emerges that contractors and engineers often score higher than parties further up the chain; suppliers and subcontractors. These findings have also been observed in equivalent research (Siebelink et al., 2018) which ensures the generalization of this research.

Finally, it is concluded that projects with a higher maturity level, the experiences of collaboration are better. This is because the parties have coordinated agreements with each other and are all aligned. These outcomes are in line with the literature where is concluded that productivity is improved where BIM is used to enable easy sharing and integration of information and increasing convenient collaboration (Li et al., 2014). The results of the cooperation aspect apply to all projects, making this result more generalizable.

BIM maturity tool

The BIM maturity tool of Siebelink (2018), comprising the maturity model and the interview format, were now applied at project level. During the interview, the interviewees were questioned on six main criteria (strategy, organizational structure, people and culture, processes and procedures, IT (infrastructure) and data (structure)). A similar model on project level is the Virtual Design & construction (VDC) scorecard (Kam, Senaratna, McKinney, Xiao, & Song, 2013) which assesses the maturity of the implementation of a project across 4 Areas. The 4 Scorecard Areas are Planning, Adoption, Technology, and Performance. The Planning Area covers the creation of objectives and standards as well as the availability of technological and fiscal resources that will promote the projects' business goals. The quantitative and qualitative success in achieving these objectives is measured in the Performance Area. The Adoption Area assesses the organizational and procedural aspects of social methods for adopting technology while the Technology Area assesses the product, organization, and process models implemented. This model compared to the BIM maturity tool of Siebelink (2018) contains the same sub-criteria but is divided into four criteria instead of six. The designation of these sub-criteria is also different, but contains the same results. The sub-criteria of the maturity model have more in-depth aspects than the VDC model, such as the object structure or object libraries. Also 7 out of 8 categories are for assessing technical aspects of a project, without covering social collaboration. Which are included in the BIM maturity model, this is included in the criteria people and culture. It is important to have this collaboration aspect in the model because through true collaboration, interdependency, and mutual support amongst team members, and work toward common team goals emerges in many BIM-based projects, allowing highly innovative building solutions rather than just efficient and similar results as in traditional approaches (Grilo & Jardim-Goncalves, 2010). From other project assessments it is concluded that the identification of the goals and objectives for learning, understanding of how these are addressed on the project is important (Petkov & Petkova, 2006). Also the evaluation of leadership and project management is important in a project assessment(Brown, Bull, & Pendlebury, 2013). These aspects are also both included in the BIM maturity model. As stated earlier, it is important to include the collaborative aspects in determining the maturity of a project. In the maturity model attention is be paid to the trust related aspects of openness and transparency between parties in respect to BIM, which is not included in the VDC scorecard. The contractual aspects are also included in the maturity model and not in the VDC scorecard, this is also important to include because contractual arrangements will improve productivity and project coordination (Porwal & Hewage, 2013). So, it can be concluded that

the chosen model was the right model to use compared to the other models that are available in the literature.

When conducting the interviews, all parties were very supportive and took enough time for us to answer all questions. Also, no real obstacles were experienced during and after the interviews. The only thing that was perceived as troublesome at the beginning is that the interviewee had already given information on a question that was discussed later, which was sometimes difficult, but as the interviews progressed, this also went better. Overall, the interviewees believed that all relevant aspects of BIM were included in the interview. It can be concluded from this that the content of the maturity model and the accompanying interview questions are sufficient to represent the meaning of BIM.

While processing the interviews and the analysis of the results, the project phases emerged. However, this aspect is not reflected in the interview format. This aspect could complement the format, because it can be made clear whether the maturity of a project also changes as the project progresses.

5. CONCLUSION & RECOMMENDATIONS

This final Chapter is dedicated to the conclusions drawn from this study and several recommendations for subsequent research. This Chapter deals with step 8 (reaching closure) of the Eisenhardt framework as mentioned in Section 2.1.3 research framework. In the conclusion in Section 5.1, the research questions were answered and it was examined whether the objective of the research was met. Section 5.2 presents the recommendations, which provides advice on what can be further explored on the projects. As in every research, several limitations of the methodology and overall study were detected and these form together with recommendations for further research the subject of Section 5.3

5.1 CONCLUSION

By answering the three research questions, the objective from Section 1.2 has been completed. The research aim was:

> *The aim of the research is to gain insight into the differences between the parties' perception of the BIM maturity of the project as a whole on the collaboration on this project.*

The research was guided by the following research questions:

- What is the current BIM maturity level on the project by the perception of the parties?
- What is the overall assessment of the maturity level of the project as a whole?
- What are possible consequences of difference perceptions of the BIM project maturity for the BIM cooperation on project level?

Table 5-8 provides an overview of the perceptions of the participants of the maturity levels per project. This contains all aspects of the maturity model and it is indicated whether the interviewee had a high (+) or low (-) perception of a certain aspect. The results of the interviews conducted showed that the current BIM maturity level on the project differ in some cases by the perceptions of the parties. Some parties are closely connected to the project and do receive certain documentation, which results in a higher perception at the BIM level. Meantime, other parties are less involved in the project which resulted in unknowingness because they have not received information about certain aspects. From the case data, most of the differences in perception between the parties were observed in the following aspects. First there is a lot of variation in perception on the aspect BIM processes, it is not clear to all parties whether procedures or work instructions have been formalized within a project. Also, the perceptions of the parties about how BIM is considered differ extremely. BIM is considered to be a tool for specific activities or a driving force for process improvement throughout the project. Second, there is a lot of variation in perception on the aspect strategy. For some parties it is clear whether any BIM visions and goals have been formalized where some other parties didn't know anything about this formalization, which results in a difference in perception. Finally, there is a lot of variation on the aspect organizational and project structure. This aspect is about formalizing tasks and responsibilities and contractual agreements, here too, not all parties are always informed about these agreements and are ignorant of these aspects, which results in a difference in perception. When the perceptions of the parties' match, the project has a higher maturity level and the cooperation on the project is better as well. The parties are all aligned, resulting in an integral whole. The consequences of differences in perceptions of BIM maturity between the parties are that they have poorer cooperation and experience more problems on the project. Another possible consequence of differences in maturity level is it can pose a risk for good BIM use.

TABLE 5 PERCEPTION PARTICIPANTS

Barendrecht	P1	P2	P3	P4	P5	P6	P7
Strategy	-	+/-	-	-	-	-	-
Organisation project structure	-	+/-	+/-	-	-	-	-
People and culture	+/-	+/-	+/-	+/-	-	-	+/-
BIM processes	-	+/-	-	-	-	-	-
IT	-	-	-	-	-	-	-
Data	+/-	+/-	+/-	+	+	+/-	-

TABLE 6 PERCEPTION PARTICIPANTS

Project A	P1	P2	P3	P4
Strategy	+	-	-	-
Organisation project structure	+	-	-	-
People and culture	-	+/-	-	-
BIM processes	+	-	-	-
IT	-	-	-	-
Data	+	+/-	+/-	+/-

TABLE 7 PERCEPTION PARTICIPANTS

Project B	P1	P2	P3	P4	P5
Strategy	+	+	+	+	+
Organisation project structure	+	+	+	+	+/-
People and culture	+	+	+	+	+
BIM processes	+/-	+/-	+	+	+/-
IT	+	+	+	+	+
Data	+	+	+	+	+

TABLE 8 PERCEPTION PARTICIPANTS

Project C	P1	P2	P3	P4	P5	P6
Strategy	-	+	+	+	+	-
Organisation project structure	-	+/-	+/-	+	+/-	-
People and culture	+/-	+	+/-	+/-	+/-	+/-
BIM processes	-	+/-	+	+	+	-
IT	+/-	+	+	+	+	+
Data	-	+	+	+	+	+

The overall assessment of the maturity of the project as a whole is illustrated in Figure 37- 40. The projects as a whole scored all relatively high on the data criterion which implies that the project data are made accessible to other parties within the projects by providing rights to read, add or change data. In terms of organizational structure and project structure, the results show that projects have not given this significant attention. The project scored low because there is a limited formalization of tasks / responsibilities in contracts. Almost all of the projects scored highly on the strategy criterion. This implies that the BIM vision and goals have been defined and the project is supported by the management.

Almost all projects scored highly on the people and culture criterion. It implies that there is motivation to work with BIM and that there is a structured program for education and active guidance for employees. When comparing the dimensions of the radar charts, a number of relationships have been identified. There is a strong correlation between IT and people and culture. When a project has no project location, the IT aspect is scored low, resulting in a low score on people and culture. The relationship between these two aspects is when there is no project location, there is less focus on cooperation, which resulted in less openness and transparency between parties. Another correlation is between the aspect strategy and the sub criteria tasks and responsibilities. Achieving a low score on the criteria strategy means that no vision and goals have been formalized or any agreements have been made about support from management or a BIM expert. For projects where this has not been formalized, the score of tasks and responsibilities is also low because it has not been laid down. In general, the agreements have not been laid down or formalized well for these projects, which means that they therefore score low on these aspects. There is also a relationship between the aspect Data and contractual aspects. If contractual agreements have been made about exchanging the files (how, what and when), the project will score

high on contractual aspects, but at the same time receive a high score on data, because it is clear to everyone what to expect.

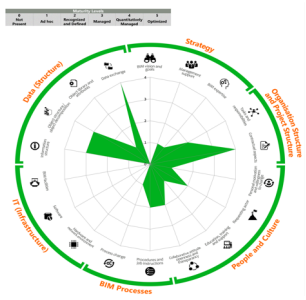


FIGURE 37- PROJECT OVERALL PROJECT A

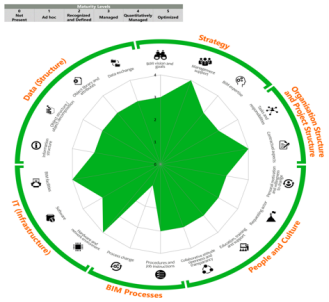


FIGURE 38- PROJECT OVERALL PROJECT B

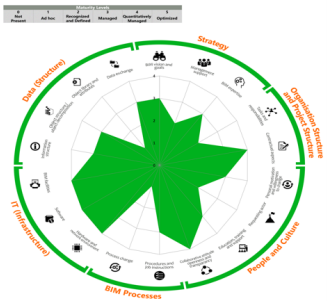


FIGURE 39- PROJECT OVERALL PROJECT C

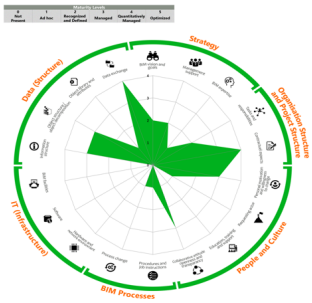


FIGURE 40- PROJECT OVERALL PROJECT D

There are some differences in the maturity level of the project as a whole in comparison with the perception of the parties. The project as a whole scored relatively higher on maturity level on some aspects. First the project scored higher on BIM vision and goals criteria, this variation is due to the fact that the BIM vision and goals have been formulated and documented but not all parties are aware of this. Second, the BIM maturity level of the project as a whole is scaled higher on the tasks and responsibilities criteria in comparison with the perception of the parties. This is due to the fact the parties either do not have sufficient insight in the documentation or it is not shared with them. Third, the project as a whole scored also higher on the procedures and job description criteria for the same reason. Finally, all projects scored higher on the criteria processes, the perceptions on how BIM is considered different by all parties which resulted in differences in maturity level. By some projects there are also differences recognized by one party of a project in other aspects, but this has not been experienced by all projects and parties. Here some projects scored higher on the following aspects; contractual, requesting actor, information structure. This variation is because there are parties which are less involved and not aware of everything and therefore score lower.

The projects which generally score low on the project results in more differences between the perception of the project and the project as a whole. Projects which are more mature have clearly formulated all agreements and all parties are aware of this which resulted in less deviation between the maturity of the project and the perception of parties. So, the results show that the perceptions of parties of all cases differ sometimes from criteria compared to the project as a whole. Most of the times this is because the agreements are not known by the parties or not shared or set up sufficiently resulting in ignorance. The projects that have established these agreements since the first phase of the project score significantly higher in most aspects, and all parties are more aware of it. When agreements are made during the

project and are not documented or formulized, they score lower on many aspects and this creates variation in perception because they are not aware of some agreements.

It turned out that projects with a lower maturity level, the cooperation is experienced as bad because it is unclear which agreements have been made. The parties are either insufficiently or not included in the agreements, which sometimes makes it unclear for the parties. As a result, the agreements are not kept because some parties are not aware of this. There is also a lot of resistance in projects with a lower maturity level which does not encourage cooperation. It also turned out that the projects which has a higher maturity level, the experiences of collaboration are better. This is because the parties have coordinated agreements with each other and are all aligned. Projects with a higher maturity level experience fewer problems and the project runs smoothly, resulting in better cooperation. For projects with a lower maturity, more problems are experienced and the agreements are not clear. When the perceptions of the parties' match, the project has a higher maturity level and the cooperation on the project is better as well. The parties are all aligned, resulting in an integral whole. The consequences of differences in perceptions of BIM maturity between the parties are that they have poorer cooperation and experience more problems on the project. Another possible consequence of differences in maturity level is it can pose a risk for good BIM use. When some people/parties are not aware of the agreements that have been made it will result in unknowingness about certain aspects resulting in a difference in maturity level. Also, the lack of communication during a project will result in bad collaboration and differences in maturity level. The consequence of bad collaboration is misunderstandings and even errors in the project.

The results finally showed that no difference is seen between the type of project in relation to the maturity level. It also appears that the level of maturity could depend on the project phase of the project and the maturity could still developing during the project. Finally, it appears that certain roles or parties score more often higher than other parties. These results are discussed in detail in Section 4.1 Potential and interpretation.

5.2 Practical Recommendations

Here several recommendations which may help to improve the BIM maturity on project level are presented, which are specifically aimed at the large construction company and affiliated parties.

To increase the BIM maturity level on each project they can improve on different aspects. The results show that the BIM vision and goals have been formulated for all projects, but are not clear to all parties. In projects where the vision and goals have been defined and are well formalized, higher scores are achieved at the maturity level. By clearly formulating the vision and goals, it is clear to each party what is expected. So, by creating a BIM protocol and defining BIM vision and goals, the maturity of a project will increase. It is important to share this with all the parties; this vision and goals becomes clear for everyone. Also ensuring that all parties read this document, clarity about goals will be created for every party in the projects. The projects that have established this since the first phase of the project score significantly higher in most aspects, and all parties are more aware of it. Also, by actively monitor the BIM vision and goals, will increase the maturity of a project.

The management support criteria can affect the maturity level. When sufficient support is given, the implementation process can be improved. By allocating sufficient budgets by management, the project can further develop BIM and implement new BIM uses. So, the support of the management can be improved by allocating resources to further develop BIM and to implement new BIM uses for example a five-year plan. This is also stated by Jamal, Mohammad, Hashim, Mohamed, and Ramli (2019) continuous supports from the project's external as well as internal environment are significant to increase the BIM maturity. Importantly there is a need to have a clear plan for implementation and support for organization to fully leverage the advantages of BIM

By paying more attention to implementing the use of BIM by giving BIM experts appropriate and dedicated time, huge improvements can be created. The BIM experts could focus more on checking the models on a project, some parties indicate that they need this. So, by assigning a BIM expert with sufficient time, this person can focus on the implementation process and motivate people to increase the maturity level.

Formalizing tasks and responsibilities can take projects to a higher level, which creates clarity. In all cases tasks and responsibilities regarding BIM are formalized but not everyone is aware of it. it would be an improvement if these tasks and responsibilities are clearly described and sent to all parties, everyone is informed and it would be clear for everyone. To get this part on a project to a higher level, the BIM related tasks and responsibilities should be regularly evaluated, so they remain tuned to the changing context.

This also applies to hard agreements because it is not clear for all parties' agreements have been made, there is still resistance. By sharing these agreements with all parties, it can be prevented that parties still send the models by email, there will be less resistant. It also creates clarity for everyone about when models are exchanged. By creating clarity through agreements, the motivation within this project can increase and the resistance can decrease. Also, by continuously updating the contractual agreements based on changing BIM use, BIM perspectives or changing legal terms will improve the maturity on this part.

Motivation could be low due to insufficient knowledge and training, so this can be increased by offering training and organizing education to facilitate BIM use. A BIM champion who functions as a driver of the implementation process by steering and stimulating others will ensure that less resistance is given.
Also, focusing on motivating the older generation by giving them more training to work with BIM, will increase the maturity. Informing the parties of the available education and training on a project will increase the use thereof, which gives an increase of the maturity level.

The results show that it is not clear whether there are work instructions and/or procedures where this is clear for others. So, by establishing work instructions and procedures for important uses of BIM and sharing it with all parties, it would be clear for everyone. In order to take the procedures and work instructions to a higher level, it must be check whether everyone adheres to this regardless of whether there is time pressure. By sharing process changes will have a positive influence on both internal and external process, intensive cooperation with other parties and disciplines supports process optimization.

The IT infrastructure includes the hardware and network environment that support smooth use of the software as well as the sharing of data. The quality of the network environment determines the extent to which project disciplines can work in an integrated way and in real time can be improved. Another component for improvement is the BIM facilities, such as having a joint project location with spaces where the models can be visualized. These facilities enable interactive coordination sessions with project partners, for example to detect clashes. This will promote cooperation between the parties. The maturity level of project with a joint project location scored relatively higher then projects without a joint project location. A project with a joint project location can be taken to a higher level by expanding the project location on facilities also the interior of the smart screens could have been better equipped. Future needs for BIM could be mapped regularly to keep the used software aligned with these needs. The needs of BIM-related utilities could be actively monitored to identify necessary changes to facilities and to be able to change them in time.

By making agreements about the information structure, less resistance would be given by parties. By using a shared and aligned object library the maturity will increase and less mistakes will be made. Also focusing on continuously keeping object libraries up to date with additional data from other projects and checking and monitoring the quality and consistency of exchanged data will improve the Maturity level on a project.

For all projects, all parties scored high on data exchange meaning that data exchange with other parties is well defined. There are sometimes parties which does not adhere this, this can be prevented by making clear agreements about data exchange as mentioned above. For a more coherent whole, the use of the DMS by all parties is important and not using email for data exchange.

5.3 Limitations & Recommendations for further research

In this section several limitations of the study are presented, based on the results of this study even as the limitations and discussion, directions for further research are proposed.

The first limitation in this study is the lacking of statistical evidence, in a case study there is only a limited dataset on which the conclusion of the study can be based. The limitation is therefore that conclusions cannot with statistical certainty been drawn based on the case study. In this study we are looking for theoretical generalization. Therefore, the first general recommendation for this study is to increase the statistical evidence. To support the results of this research, additional research must be done on the same topic. Hereby, it makes it possible to look from a broader data set whether the same type of results is found.

Many people are involved in a project, some have implemented BIM well and others have not. For this research, people were consciously chosen for the interviews that have a BIM perspective. This can give the research a discolored picture because there are also people who are not completely in to BIM and who may have a different view BIM. So, based on this limitation, it would be useful to further explore the BIM maturity level on project level and look to the effects of other types of people or people who have less to do with BIM. A related research topic would be to analyze to what extent the findings here on the BIM maturity, at project level in this field, are in line with other project roles and what are the effects of this?

It is also a limitation that the interviews were conducted at some point during the project, and not over a longer period of time. In one project, the interviews were conducted during the design phase and others during the executive phase. This is not a problem for the research questions of this research, but if the project has passed over time at different times and investigated how the project is developed, better conclusions can be drawn. It can also show whether the maturity of a project may be dynamic, this can be investigated by visiting the projects at different times over a longer period of time. So thirdly, it would be appropriated to further investigate whether the maturity of a project is dynamic or not, by visiting the projects at different times over a longer period of time. A related research topic would be to investigate whether the BIM maturity level is dynamic at project level?

Finally, the results show no difference is seen between the type of project in relation to the maturity level. It appears that for the use of BIM and coordination of the different dimensions, in these four cases it is not due whether it is an infra project or B&U project, because no significant difference was found in maturity level. It could be the case that this has leveled out over the years and it may no longer exist in practice between those types of projects. This finding should be confirmed through additional studies as this finding differs from what has been found in the literature. So, it would be relevant to analyze whether an increase in BIM maturity corresponds with certain project type, or there is no difference in project type. A related research topic would be to explore whether there is a difference in maturity between an infrastructure project or B&U project.

REFERENCES

Alliance, N. (2012). National BIM Standard-United States Version 2. *USA: National Institute of Building Sciences buildingSMART allianc*.

Ashman, R. (2004). Project estimation: a simple use-case-based model. *IT professional, 6*(4), 40-44.

Boeykens, S., De Somer, P., Klein, R., & Saey, R. (2013). Experiencing BIM Collaboration in Education.

Brown, G. A., Bull, J., & Pendlebury, M. (2013). *Assessing student learning in higher education*: Routledge.

Cao, D., Li, H., Wang, G., & Huang, T. (2017). Identifying and contextualising the motivations for BIM implementation in construction projects: An empirical study in China. *International journal of project management, 35*(4), 658-669.

Chong, H. Y., Lopez, R., Wang, J., Wang, X., & Zhao, Z. (2016). Comparative analysis on the adoption and use of BIM in road infrastructure projects. *Journal of Management in Engineering, 32*(6), 05016021.

Cummings, J. N., & Kiesler, S. (2007). Coordination costs and project outcomes in multi-university collaborations. *Research policy, 36*(10), 1620-1634.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction, 36*, 145-151.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532-550.

Froese, T. M. (2010). The impact of emerging information technology on project management for construction. *Automation in Construction, 19*(5), 531-538.

Grilo, A., & Jardim-Goncalves, R. (2010). Value proposition on interoperability of BIM and collaborative working environments. *Automation in Construction, 19*(5), 522-530.

Hindmoor, A. (1998). The importance of being trusted: transaction costs and policy network theory. *Public Administration, 76*(1), 25-43.

Hjelseth, E. (2010). Exchange of relevant information in BIM objects defined by the role-and life-cycle information model. *Architectural engineering and design management, 6*(4), 279-287.

Jamal, K. A. A., Mohammad, M. F., Hashim, N., Mohamed, M. R., & Ramli, M. A. (2019). Challenges of Building Information Modelling (BIM) from the

Malaysian Architect's Perspective. doi:https://doi.org/10.1051/matecconf/2019l2018266266003

Joblot, L., Paviot, T., Deneux, D., & Lamouri, S. (2019). Building Information Maturity Model specific to the renovation sector. *Automation in Construction, 101*, 140-159.

Kam, C., Senaratna, D., McKinney, B., Xiao, Y., & Song, M. (2013). The VDC scorecard: Formulation and validation. *Center for Integrated Facility Engineering: Stanford University*.

Kassem, M., Succar, B., & Dawood, N. (2013, 2013). *A proposed approach to comparing the BIM maturity of countries*.

Kushwaha, V. (2016). Contribution of building information modeling (BIM) to solve problems in architecture, engineering and construction (AEC) industry and addressing barriers to implementation of BIM. *Int. Res. J. Eng. Technol, 3*(1), 100-105.

Li, J., Wang, Y., Wang, X., Luo, H., Kang, S.-C., Wang, J., . . . Jiao, Y. (2014). Benefits of building information modelling in the project lifecycle: construction projects in Asia. *International Journal of Advanced Robotic Systems, 11*(8), 124.

Papadonikolaki, E., Verbraeck, A., & Wamelink, H. (2017). Formal and informal relations within BIM-enabled supply chain partnerships. *Construction management and economics, 35*(8-9), 531-552.

Petkov, D., & Petkova, O. (2006). Development of scoring rubrics for IS projects as an assessment tool. *Issues in Informing Science & Information Technology, 3*.

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction, 31*, 204-214.

program, C. i. c. r. (2013). planning guide for facility owners. In (pp. 79). PA; Pennsylvania State Univ.: State College.

Sarmaniotis, C., Wickens, E., & Sigala, M. (2014). Evaluating the performance of destination marketing systems (DMS): stakeholder perspective. *Marketing Intelligence & Planning*.

Shou, W., Wang, J., Wang, X., & Chong, H. Y. (2015). A comparative review of building information modelling implementation in building and infrastructure industries. *Archives of computational methods in engineering, 22*(2), 291-308.

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), 05018007.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction, 18*(3), 357-375.

Succar, B. (2010). *The five components of BIM performance measurement*.

Tulsky, J. A. (2005). Beyond advance directives: importance of communication skills at the end of life. *Jama, 294*(3), 359-365.

van Berlo, L., Dijkmans, T., Hendriks, H., Spekkink, D., & Pel, W. (2012). *BIM quickscan: Benchmark of BIM performance in the Netherlands*.

Wolf, G. (2018). Optimalisatie van BIM modellen tov verschillende wensen van opdrachtgevers.

Wu, C., Xu, B., Mao, C., & Li, X. (2017). Overview of BIM maturity measurement tools. *Journal of Information Technology in Construction (ITcon), 22*(3), 34-62.

Yang, J.-B., & Chou, H.-Y. (2019). Subjective benefit evaluation model for immature BIM-enabled stakeholders. *Automation in Construction, 106*, 102908.